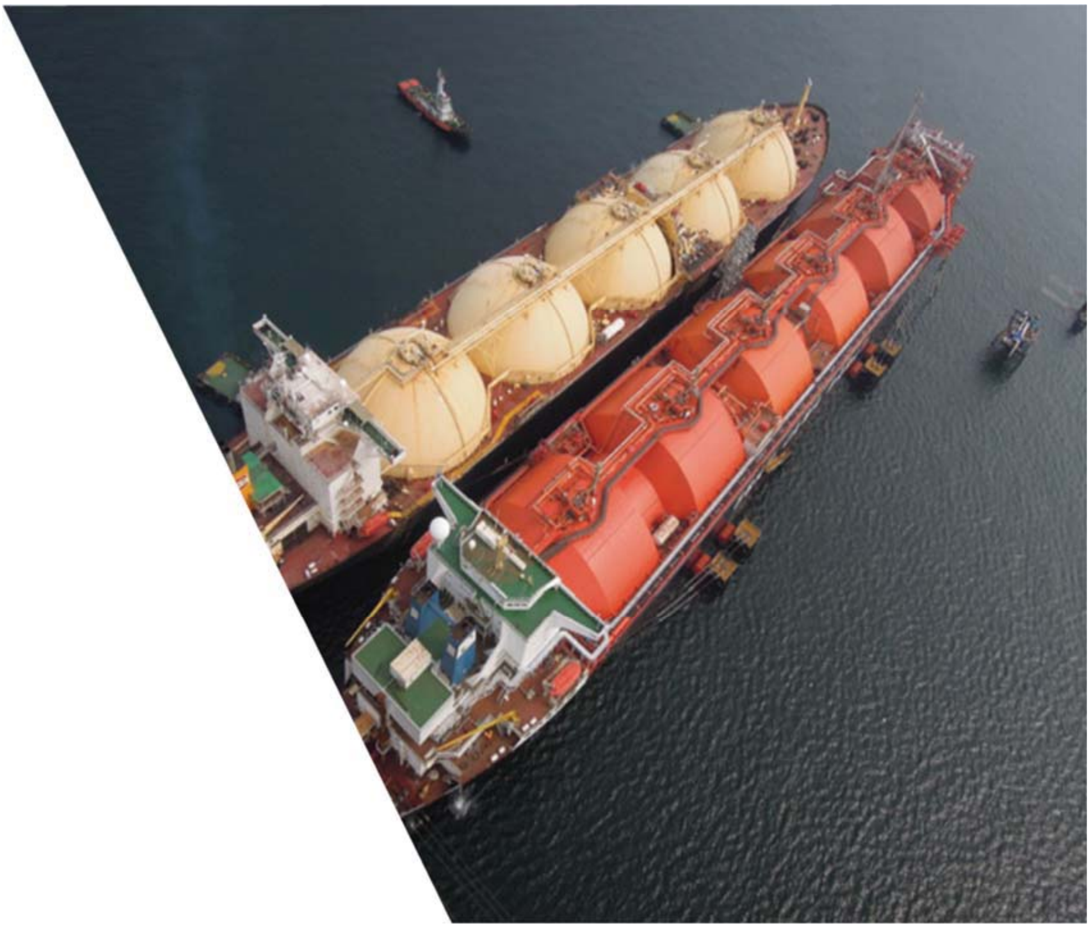
Appendix D
Hazard and risk

WorleyParsons
resources & energy

AUSTRALIAN INDUSTRIAL ENERGY

Port Kembla Gas Project

Preliminary Hazard Analysis



Document No 401010-01496-SR-REP-0002

31 October 2018

Blue Tower
Level 31 12 Creek Street
Brisbane QLD 4000
Australia
T: +61 7 3239 7400

www.worleyparsons.com

EcoNomics

Disclaimer

This report has been prepared on behalf of and for the exclusive use of Australian Industrial Energy, and is subject to and issued in accordance with the agreement between Australian Industrial Energy and WorleyParsons. WorleyParsons accepts no liability or responsibility whatsoever for it in respect of any use of or reliance upon this report by any third party. Copying this report without the permission of Australian Industrial Energy or WorleyParsons is not permitted.

PROJECT 401010-01496-SR-REP-0002 – Port Kembla Gas Project

Rev	Description	Original	Review	WorleyParsons Approval	Date	Customer Approval	Date
00	Issued for Use	A Boschma	A Fergusson	F Losty	31-Oct-18		

Contents

Appendices

1. EXECUTIVE SUMMARY

1.1 Project Background

Australian Industrial Energy (AIE) proposes to develop the Port Kembla Gas Terminal (the project). The project involves the development of a liquefied natural gas (LNG) import terminal at Port Kembla, south of Wollongong in NSW. The project will be the first of its kind in NSW and provides a simple, flexible solution to the state's gas supply challenges.

NSW currently imports more than 95% of the natural gas it uses, with the majority of supplies coming from Victoria and South Australia. In recent years, gas supplies to the Australia east coast market have tightened, resulting in increased prices for both industrial and domestic users. Several recent economic studies have predicted significant future gas shortfalls for NSW by 2022.

The project provides an immediate solution to address predicted shortages and is expected to result in considerable economic benefits for both the Illawarra region and NSW.

The project will have capacity to deliver 100 petajoules of natural gas, equivalent to more than 70% of NSW's gas needs and provide between 10 to 12 days of natural gas storage in case of interstate supply disruption. LNG will be sourced from worldwide suppliers and transported by LNG carriers to the Port Kembla Gas Terminal. The LNG will then be re-gasified for input into the NSW gas transmission network.

Key objectives of the project are to:

- Introduce a new source of competitively priced gas to meet predicted supply shortfalls and help put downward pressure on prices;
- Provide gas security to NSW with ability to supply more than 70% of the State's gas needs;
- Provide long term contracts to industrial users and ability to meet 100% of the State's industrial demand (manufacturers, power stations, hospitals, small businesses etc.);
- Help support the 300,000 jobs across NSW, and the 15,000 jobs in the Illawarra region, which rely on the competitive, reliable supply of natural gas; and
- Support the diversification and future growth of Port Kembla consistent with the NSW Ports 30 Year Master Plan.

1.2 Objectives

The objectives of this report are to address the Hazard and Risk requirements of the Secretary's Environmental Assessment Requirements (SEARs) issued 10 August 2018.The SEARs outlined key issues which need to be addressed in the Environmental Impact Statement (EIS). These key issues and reference to the relevant sections of this document are listed in Table 1-1 below.

Table 1-1: SEARs Key Hazard and Risk Issues

Requirements	PHA Section
▪ A comprehensive Quantitative Risk Assessment (QRA), covering all aspects of the project which may impose public risks, to be prepared consistent with Hazardous Industry Planning Advisory Paper No. 6 – Guidelines of Hazard Analysis (DPE, 2011). This QRA must include:	Section 4 summarises the risk assessment methodology used in line with HIPAP 6 [2].
▪ Identification of all potential hazards and associated control measures for all aspects of the project, including but not limited to entry of LNG carriers into port, mooring, refilling of FSRU, regassification, and transfer of LNG into gas network distribution tie in point, and other external threats (such as propagation risks from other facilities and vessel movements and cargoes and impacts from adverse sea conditions on the FSRU);	Section 5 includes the hazard identification activities associated with the project scope. The project Hazard Register is contained in Appendix B.
▪ A quantitative risk assessment to estimate the risks from activities of LNG Carrier and/or FSRU operation, with reference to applicable International and/or Australian Standards and Industry Best Practice. The risk assessment must consider the worst-case scenarios from all identified potential hazards that may result in off-site impact. It must also consider:	Section 6 and Section 7 document the basis for the quantitative risk assessment.
▫ The potential risk exposure to all shipping terminal activities at the port, including cruise shipping; and	Section 8 identifies the risk levels considered per HIPAP 4 [1], with the following Section 9 assessing the results in comparison to the risk criteria.
▫ The potential propagation risks to and from neighbouring industrial facilities, such as the steelworks, onshore approved bulk liquid storage facilities and other berth activities (such as loading/unloading of dangerous goods at nearby berths);	Section 8 identifies the propagation risk levels considered per HIPAP 4 [1], with the following Section 9 assessing the results in comparison to the risk criteria.
▪ A quantitative pipeline risk assessment to estimate the risks from the pipeline to the surrounding land uses, with reference to Australian Standards AS2885 Pipelines – Gas and Liquid Petroleum - Operation and Maintenance;	The pipeline is included in the quantitative risk assessment model as per Section 6 and Section 7. The pipeline is designed to AS2885 as discussed in Section 3.5.3.
▪ Demonstration that the risks from the project comply with the criteria set out in Hazardous Industry Planning Advisory Paper (HIPAP) No. 4 – Risk Criteria for Land Use Safety Planning (DoP, 2011);	Section 6 and Section 8 identifies the criteria per HIPAP 4 [1], including radiant heat levels, overpressure levels and risk levels. Section 9 assesses the results in comparison to the risk criteria.
▪ An assessment of the adequacy of existing firefighting systems on shore and within the harbour (e.g. fire tugs) through a preliminary Fire Safety Study; and	Section 3.7 discusses the fire protection systems that will be implemented.
▪ Proposed on-going maintenance and safety management of the project inclusive of associated pipeline infrastructure.	Section 3.6 discusses the safety management system that will be implemented.

1.3 Findings

The results of the risk modelling conducted in this Preliminary Hazard Analysis (PHA) are assessed against the HIPAP 4 criteria in Table 1-2 and Table 1-3 below.

Table 1-2: Risk Results Summary

HIPAP 4 Criteria (pa)	Land Use	Criteria Met
5E-07	Sensitive land use; e.g. hospitals, schools, child-care facilities, old age housing	Yes
1E-06	Residential area; including hotels, motels, tourist resorts	Yes – Cruise ships will berth outside the 1E-06 contour and will only be exposed to higher than 1E-06 risk whilst entering / leaving the Inner Harbour, i.e. exposure is low.
5E-06	Commercial development; including retails centres, offices and entertainment centres	Yes
1E-05	Active open space; including sporting complexes	No – Limited risk exposure to people on the private Seawall Road. The private road is only open during daylight hours, unless closed due to other port operational requirements. As a result, large numbers of people do not use this road regularly or gather in this area.
5E-05	Industrial	Yes – Risk contour is largely within the proposed facility boundary.

Figure 1-1 shows the risk contours for the project.

Table 1-3: Propagation and Injury Risk Results Summary

Frequency (pa)	HIPAP 4 Criteria	Criteria Met
5E-05	Damage and propagation – 23kW/m^2	Yes (Refer to Figure 1-2)
5E-05	Damage and propagation – 14kPa	Yes (Refer to Figure 1-3)
5E-05	Injury – 4.7kW/m^2	Yes (Refer to Figure 1-2)
5E-05	Injury – 7kPa	Yes (Refer to Figure 1-3)

The overall findings from the risk modelling were the following:

- The main contributor to the risk profile was the FSRU. In particular, the jet fires, flash fires and pool fires dictated the extent of the risk contours, while explosions made negligible impact.
- As the LNGC is only in the Harbour for a one day period every two weeks, and it has less process equipment and therefore less potential leak sources as the FSRU, its addition to the overall risk contours was significantly less than the FSRU.

- High pressure natural gas release consequence distances extended the greatest distance, and therefore are a significant contributor to the extent of the risk contours, more so than the low pressure LNG.

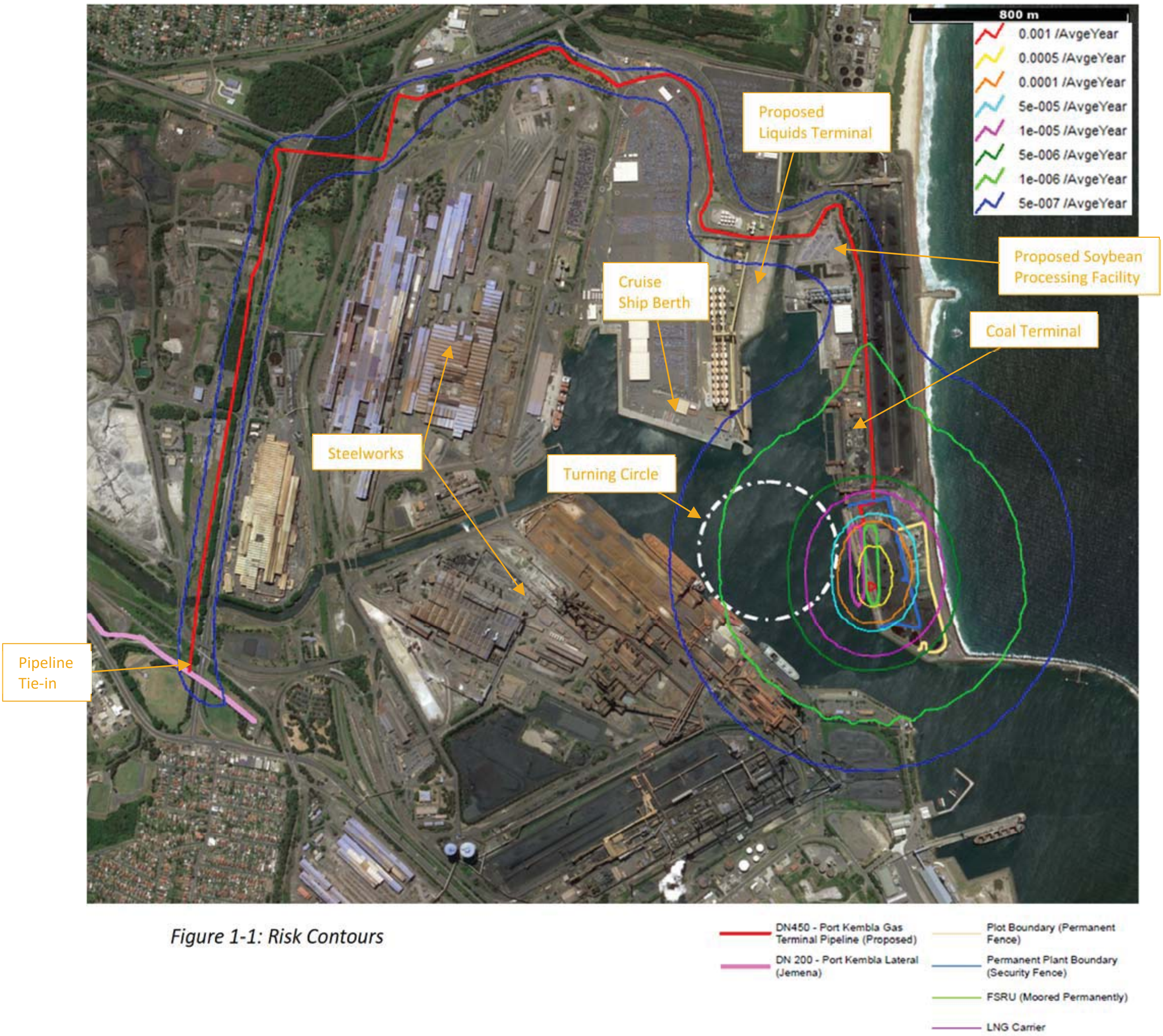


Figure 1-1: Risk Contours

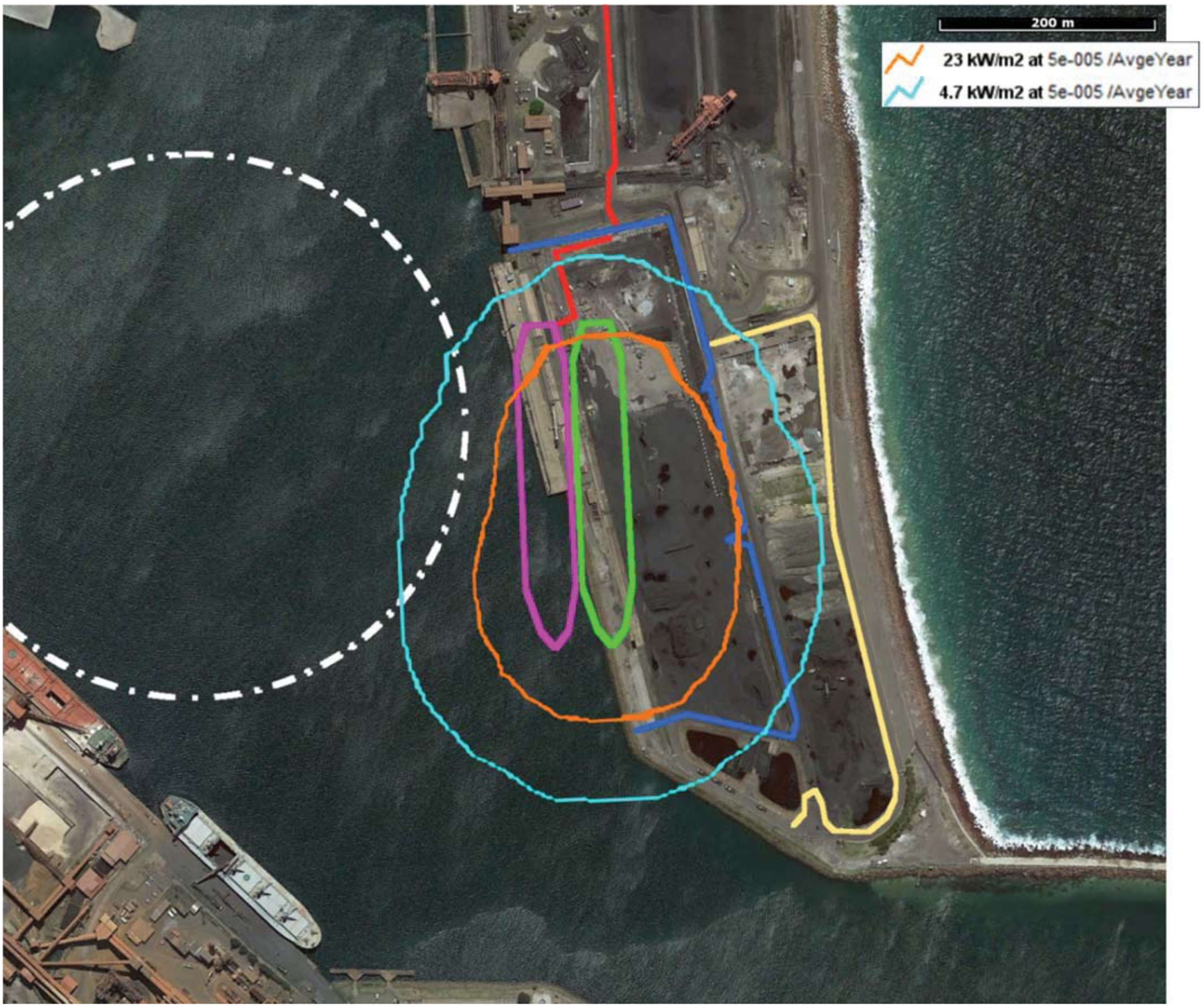


Figure 1-2: Propagation and Injury Risk due to Heat Radiation

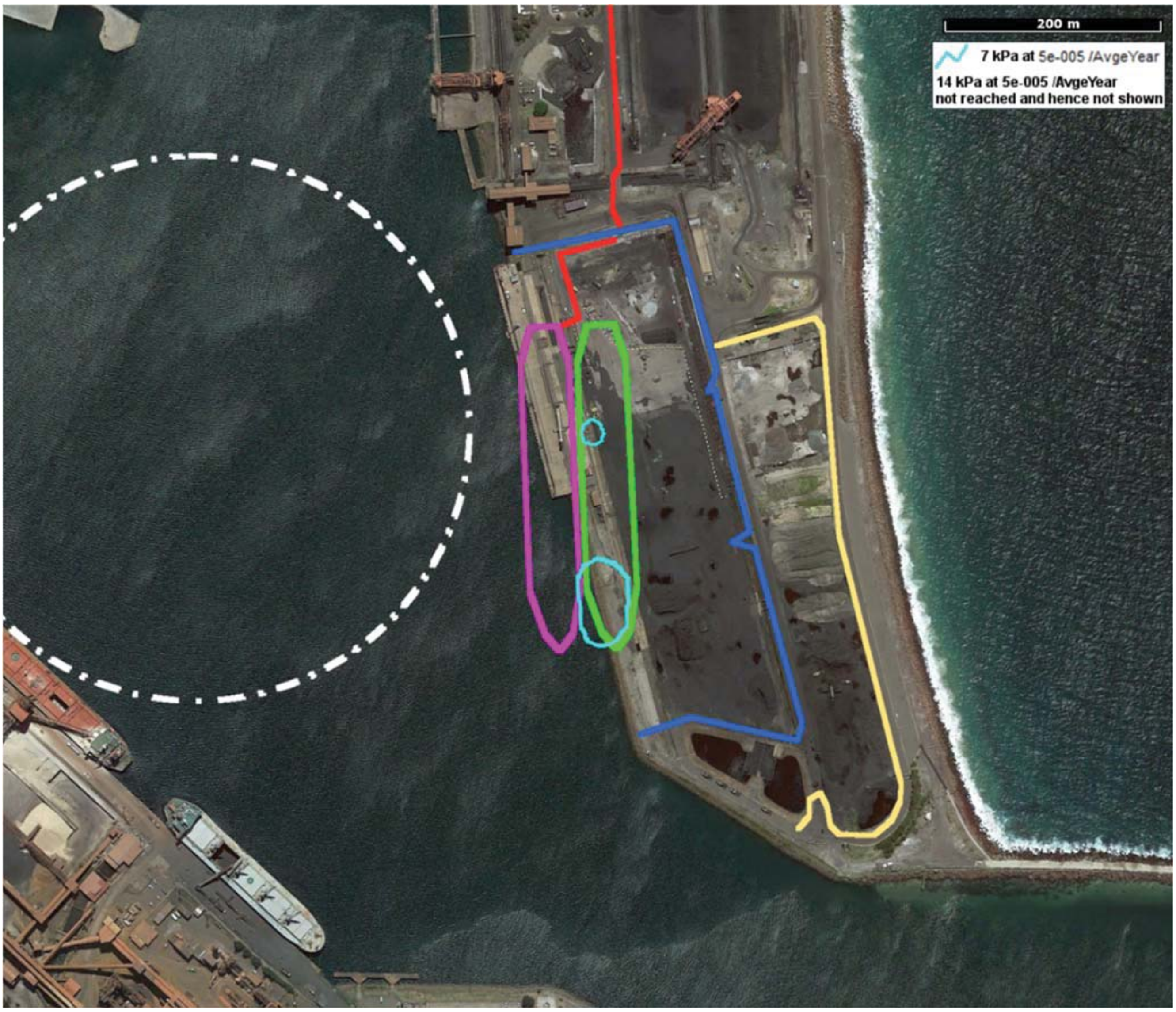


Figure 1-3: Propagation and Injury Risk due to Explosion Overpressure

2. INTRODUCTION

2.1 Project Background

Australian Industrial Energy (AIE) proposes to develop the Port Kembla Gas Terminal (the project). The project involves the development of a liquefied natural gas (LNG) import terminal at Port Kembla, south of Wollongong in NSW. The project will be the first of its kind in NSW and provides a simple, flexible solution to the state's gas supply challenges.

NSW currently imports more than 95% of the natural gas it uses, with the majority of supplies coming from Victoria and South Australia. In recent years, gas supplies to the Australia east coast market have tightened, resulting in increased prices for both industrial and domestic users. Several recent economic studies have predicted significant future gas shortfalls for NSW by 2022.

The project provides an immediate solution to address predicted shortages and is expected to result in considerable economic benefits for both the Illawarra region and NSW.

The project will have capacity to deliver 100 petajoules of natural gas, equivalent to more than 70% of NSW's gas needs and provide between 10 to 12 days of natural gas storage in case of interstate supply disruption. LNG will be sourced from worldwide suppliers and transported by LNG Carriers (LNGCs) to the Port Kembla Gas Terminal. LNGCs are expected to be required every two weeks for 24 to 36 hours to supply LNG. The LNG will then be re-gasified for input into the NSW gas transmission network.

Key objectives of the project are to:

- Introduce a new source of competitively priced gas to meet predicted supply shortfalls and help put downward pressure on prices
- Provide gas security to NSW with ability to supply more than 70% of the State's gas needs
- Provide long term contracts to industrial users and ability to meet 100% of the State's industrial demand (manufacturers, power stations, hospitals, small businesses etc.)
- Help support the 300,000 jobs across NSW, and the 15,000 jobs in the Illawarra region, which rely on the competitive, reliable supply of natural gas
- Support the diversification and future growth of Port Kembla consistent with the NSW Ports 30 Year Master Plan.

2.2 Objectives

The objectives of this report are to address the Hazard and Risk requirements of the Secretary's Environmental Assessment Requirements (SEARs) issued 10 August 2018. The SEARs outlined key issues which need to be addressed in the Environmental Impact Statement (EIS). These key issues and reference to the relevant sections of this document are listed in Table 2-1 below.

Table 2-1: SEARS Key Issues

Requirements	PHA Section
■ A comprehensive Quantitative Risk Assessment (QRA), covering all aspects of the project which may impose public risks, to be prepared consistent with Hazardous Industry Planning Advisory Paper No. 6 – Guidelines of Hazard Analysis (DPE, 2011). This QRA must include:	Section 4 summarises the risk assessment methodology used in line with HIPAP 6 [2].
▪ Identification of all potential hazards and associated control measures for all aspects of the project, including but not limited to entry of LNG carriers into port, mooring, refilling of FSRU, regassification, and transfer of LNG into gas network distribution tie in point, and other external threats (such as propagation risks from other facilities and vessel movements and cargoes and impacts from adverse sea conditions on the FSRU);	Section 5 includes the hazard identification activities associated with the project scope. The project Hazard Register is contained in Appendix B.
▪ A quantitative risk assessment to estimate the risks from activities of LNG Carrier and/or FSRU operation, with reference to applicable International and/or Australian Standards and Industry Best Practice. The risk assessment must consider the worst-case scenarios from all identified potential hazards that may result in off-site impact. It must also consider:	Section 6 and Section 7 document the basis for the quantitative risk assessment.
▫ The potential risk exposure to all shipping terminal activities at the port, including cruise shipping; and	Section 8 identifies the risk levels considered per HIPAP 4 [1], with the following Section 9 assessing the results in comparison to the risk criteria.
▫ The potential propagation risks to and from neighbouring industrial facilities, such as the steelworks, onshore approved bulk liquid storage facilities and other berth activities (such as loading/unloading of dangerous goods at nearby berths);	Section 8 identifies the propagation risk levels considered per HIPAP 4 [1], with the following Section 9 assessing the results in comparison to the risk criteria.
▪ A quantitative pipeline risk assessment to estimate the risks from the pipeline to the surrounding land uses, with reference to Australian Standards AS2885 Pipelines – Gas and Liquid Petroleum - Operation and Maintenance;	The pipeline is included in the quantitative risk assessment model as per Section 6 and Section 7. The pipeline is designed to AS 2885 as discussed in Section 3.5.3.
▪ Demonstration that the risks from the project comply with the criteria set out in Hazardous Industry Planning Advisory Paper (HIPAP) No. 4 – Risk Criteria for Land Use Safety Planning (DoP, 2011);	Section 6 and Section 8 identifies the criteria per HIPAP 4 [1], including radiant heat levels, overpressure levels and risk levels. Section 9 assesses the results in comparison to the risk criteria.
▪ An assessment of the adequacy of existing firefighting systems on shore and within the harbour (e.g. fire tugs) through a preliminary Fire Safety Study; and	Section 3.7 discusses the fire protection systems that will be implemented.
▪ Proposed on-going maintenance and safety management of the project inclusive of associated pipeline infrastructure.	Section 3.6 discusses the safety management system that will be implemented.

2.2.2 Scope

The scope of this document includes the LNG Carriers (LNGCs), Floating Storage Regasification Unit (FSRU), wharf facility and gas pipeline.

2.3 Acronyms

The abbreviations utilised in this project are listed below.

Abbreviation	Definition
AIE	Australian Industrial Energy
AS	Australian Standard
BOG	Boil Off Gas
BOM	Bureau of Meteorology
CMMS	Computerised Maintenance Management System
CMPT	Centre for Marine and Petroleum Technology
DNVGL	Det Norske Veritas Germanischer Lloyd
EGIG	European Gas Pipeline Incident Data Group
EGP	Eastern Gas Pipeline
EIS	Environmental Impact Statement
ESD	Emergency Shut Down
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
HCRD	Hydrocarbon Release Database
HD	High Duty
HHV	Higher Heating Value
HIPAP	Hazardous Industry Planning Advisory Paper
IG	Infragravity
ISGOTT	International Safety Guide for Oil Tankers and Terminals
LD	Low Duty

Abbreviation	Definition
LFL	Lower Flammable Limit
LNG	Liquefied Natural Gas
LNGC	Liquefied Natural Gas Carrier
MAOP	Maximum Allowable Operating Pressure
MLA	Marine Loading Arm
NG	Natural Gas
NSW	New South Wales
OGP	International Association of Oil and Gas Producers
OSHA	Occupational Safety and Health Administration
P&ID	Piping and Instrumentation Diagram
PJ	Petajoule
PHA	Preliminary Hazard Analysis
PKCT	Port Kembla Coal Terminal
PKGT	Port Kembla Gas Terminal
QRA	Quantitative Risk Assessment
SEAR	Secretary's Environmental Assessment Requirement
SMS	Safety Management System
SOP	Safe Operating Practice
UKHSE	United Kingdom Health and Safety Executive
UKOOA	United Kingdom Offshore Operators Association
UKOPA	United Kingdom Onshore Pipeline Operators Association
UPS	Uninterruptable Power Supply
VCE	Vapour Cloud Explosion

3. DESCRIPTION OF SITE AND SURROUNDING ENVIRONMENT

3.1 Project Overview

The project incorporates four key components proposed to be located within industrial land at Port Kembla, which include:

- LNG carrier vessels — there are hundreds of these in operation worldwide transporting LNG from production facilities all around the world to demand centres.
- Floating storage and regasification unit (FSRU) — an ocean-going vessel which would be moored at berth 101 in Port Kembla. There are around 30 such vessels currently in operation around the world.
- Berth and wharf facilities — including landside offloading facilities to transfer natural gas from the FSRU into a natural gas pipeline located onshore.
- Gas pipeline — a class 900 carbon steel high-pressure pipeline connection from the berth to the existing gas transmission network.

At present it is envisaged that an LNG shipment will be required every 2 to 3 weeks to provide for an annual supply of up to 100 petajoules (PJ) of gas. Supply could be increased further to around 140 to 150 PJ per annum through a slight increase in LNG delivery schedules and pipeline upgrades.

It is expected to take about 10 to 12 months to complete construction and other works in order commence operations, it is possible to have first gas by the end of Quarter 1 in 2020.

The estimated capital investment for the development is between $200 and $250 million.

3.2 Location and Surrounding Land Use

Consultations with Port Kembla Coal Terminal (PKCT) during the Feasibility Phase identified that Berth 101 located in the East side of the Port Kembla Inner Harbour as an option to moor the East Coast Gas FSRU (). The berth 101 site is located between the existing PKCT coal berth (B102) to the north, and "The Cut" shipping channel to the south.

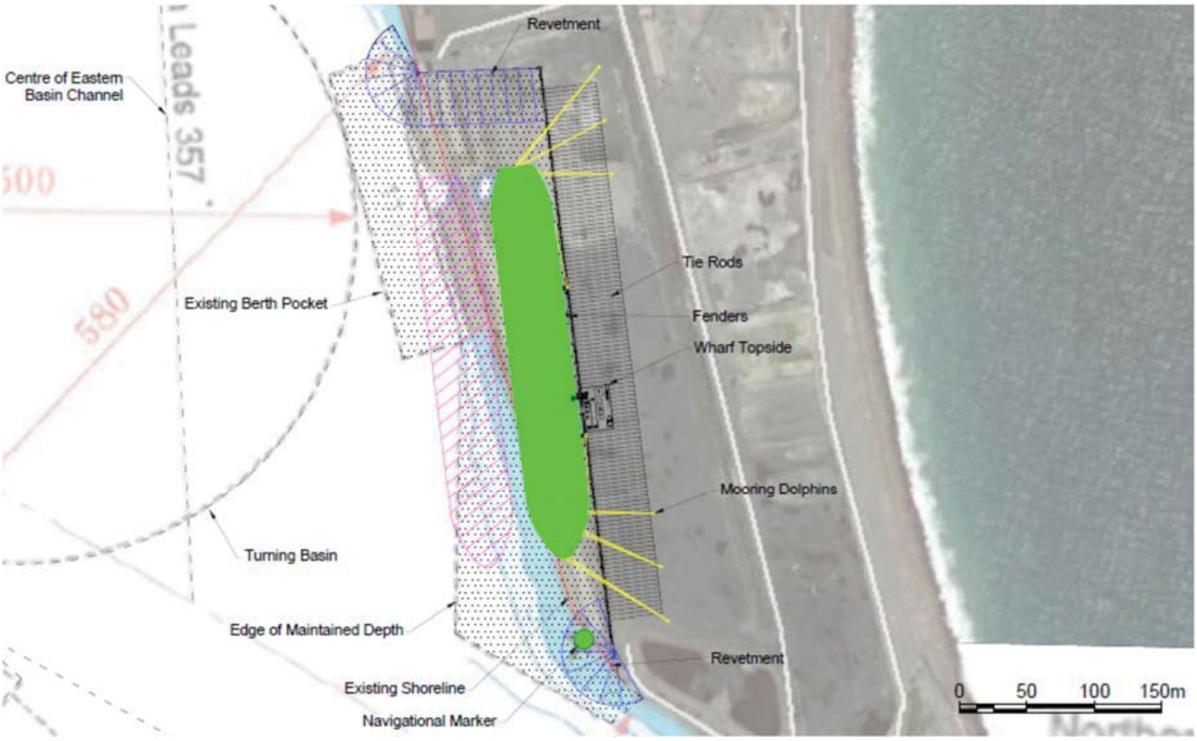


Figure 3-1. Site Location, Port Kembla Berth 101, East Inner Harbour

Berth 101 has recently been used as an offloading wharf for materials handling equipment required for the coal terminal, but does not have any regular use. The land adjoining Berth 101 is currently leased to PKCT from the Land Owner, but is rarely used.

Excavation and dredging will be required in order to establish the berth and wharf facilities to support the side-by-side configuration of the FSRU and LNG carriers without limiting the existing navigability of the Inner Harbour.

The surrounding land use is primarily categorised as industrial. There are no significant commercial spaces that routinely have large number of people present. The road to the east of berth 101 is under the control of NSW Ports and public access is currently permitted during daylight hours unless the road is closed due to operational requirements, such as coal ship deliveries. Public access to the Port Kembla Inner harbour is not permitted and is under the control of the Port Authority of NSW. The closest residential areas are approximately 2km to the north and south of the berth 101 site.

Refer to Figure 3-2 for a map identifying the sensitive receptors in the surrounding area to the Port Kembla harbour.

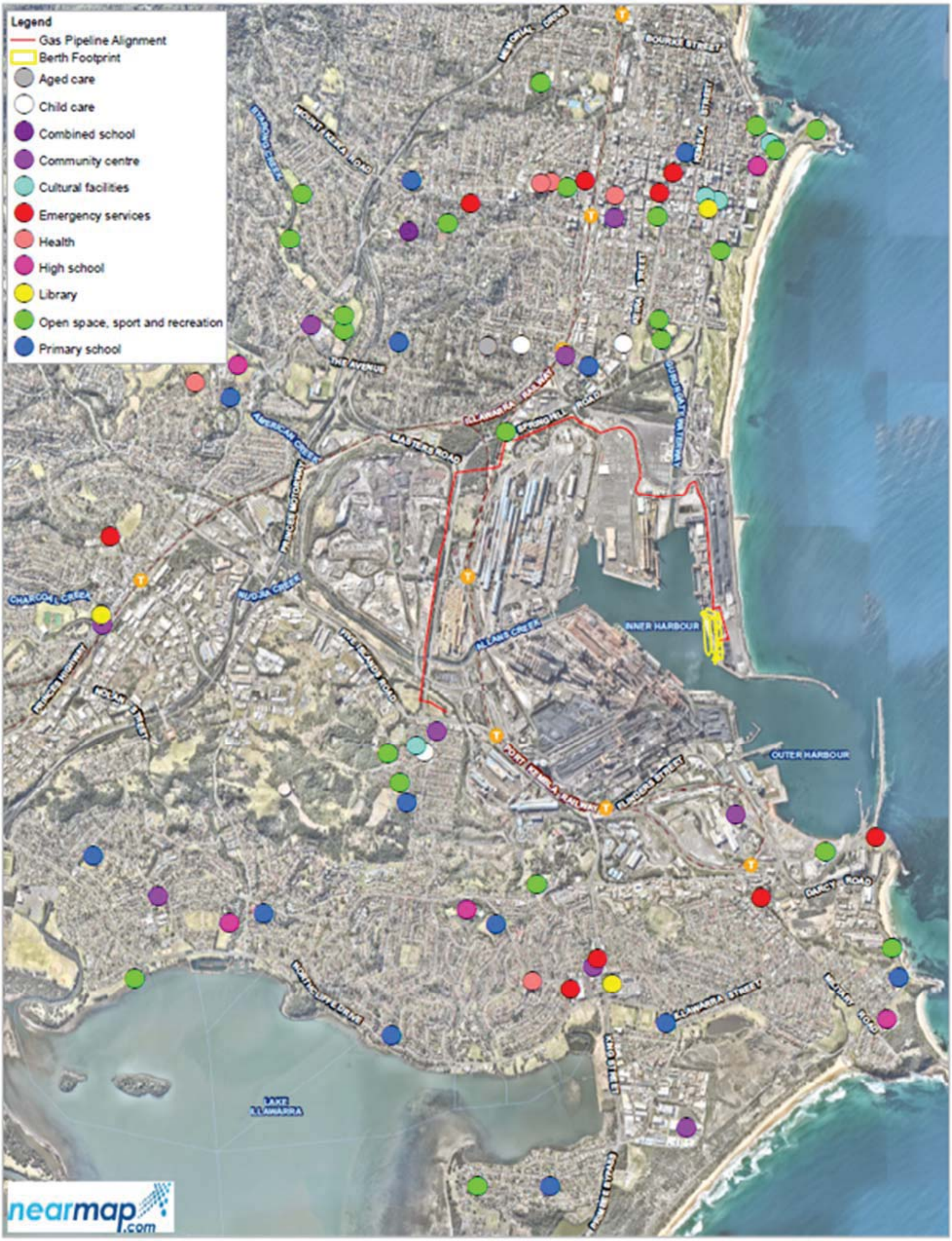


Figure 3-2: Sensitive Receptors

Proposed developments located within the Inner Harbour include a bulk liquids terminal and a Soybean Processing and Biodiesel Facility located near berth 103 and berth 104.

There is also a cruise ship terminal (berth 106) within the Inner Harbour, approximately 550m from the FSRU, which is used 2 to 5 times a year.

Port Kembla Inner Harbour has numerous other berths and associated industrial facilities as identified in Figure 3-3.

Figure 3-3: Port Kembla

3.3 Operational Workforce

Operation of the project is planned to commence in 2020. Once operational the project would operate 24 hours per day and 7 days per week supplying up to 100 petajoules of gas each year.

The project is expected to employ an operational workforce of between 40 – 50. A significant proportion of the operational workforce would be employed on the FSRU, and would only be at the berth and wharf facilities or carrying out other operational tasks such as inspection of the gas pipeline as required. The minimum number of personnel expected at site at any time is 15.

3.4 Operational Traffic

It is expected that a LNG carrier would arrive at the FSRU once every two to three weeks dependent upon operational demand. The LNG carrier would typically remain at the berth for around 24 to 36 hours to allow transfer of gas to the FSRU prior to departing. During arrival and departure, the LNG carriers would be accompanied by pilot tug boats. The LNG carriers are expected to be able to travel to and from the FSRU within the existing marine traffic and access arrangements at Port Kembla, with some minor changes to operating practices for the duration a LNG carrier is present. LNG carriers and other vessels associated with the project will be required to comply with the port navigation protocols in place at Port Kembla.

During operation LNG carriers operated by external suppliers will regularly visit Port Kembla with LNG shipments. They will pull alongside the FSRU, tether to the FSRU and then transfer their load to the FSRU. While the capacity of LNG carriers can vary, it is most likely that the LNG supplier to the project will seek to match the LNG carrier capacity to the FSRU capacity as closely as possible, in order to ensure a full transfer of cargo. As such, the LNG carriers are most likely to have a capacity of around 170,000 cubic metres, with a length of approximately 294 metres and breadth of 46 meters. With a total annual capacity of around 100 PJs per annum, this would typically equate to 24 LNG carrier deliveries per annum.

3.5 Process Overview

3.5.1 Floating Storage Regasification Unit (FSRU)

The FSRU is an ocean-going vessel approximately 294 metres in length and about 46 metres in breadth. It has a total capacity of about 170,000 cubic meters or equivalent to about 4 PJs of gas. This in turn is equivalent to about 10 – 12 days of natural gas supply for the whole of NSW.

The FSRU is a double-hulled vessel with a cargo area which consists of four cargo tanks suitable for carrying LNG at low temperatures (about -160°C) and at atmospheric pressure. There are also two high pressure manifolds located on the vessel that are required to export the natural gas produced via the regasification process into the pipeline.

The FSRU, for the term of the project and subject to any maintenance requirements or Port Authority directions, would be moored at the berth and wharf facilities.

The vessels will be obtained and operated under long-term charter by Hoegh LNG, the world's largest and most experienced owner and operator of FSRU's globally. All Hoegh LNG vessels are designed to comply with comprehensive international safety regulations and standards.

The purpose of the FSRU is to receive LNG from regularly scheduled LNG carriers visiting Port Kembla. These vessels will be operated by the suppliers of LNG contracted to the project. A global tender is currently underway to select the most competitive sources of reliable scheduled supply. It is anticipated that up to 24 LNG carriers would visit Port Kembla in any one year during project operations.

These LNG carriers will tether alongside the FSRU for 24–36 hours while they transfer their LNG cargo, still under atmospheric pressure, into the cargo holds of the FSRU. Once the transfer is completed the LNG carriers will leave the port subject to suitable navigational conditions.

The FSRU has four key functional elements being: facilities to receive LNG from LNG carriers; facilities to store LNG; facilities to convert LNG to high pressure gas; and then send it into the gas pipeline.

Purpose built cryogenic flexible hoses will be used to transfer LNG from visiting LNG carriers to the FSRU. It is expected that the FSRU itself will have five hoses which will include four for receiving LNG and one for maintaining a balance of vapour gas between ships.

The vessel cargo tanks are designed with a primary and secondary barrier to protect the cargo tanks and mitigate loss of containment. Cargo tanks which store the LNG in the FSRU are purpose built. The Cargo Containment System (CCS) is a GTT Mark III membrane type which consists of a primary barrier and a complete secondary barrier, further supported by insulation and intervening spaces. These cargo tanks are designed to achieve two outcomes:

- to insulate and contain LNG cargo at cryogenic temperatures (-160°C); and
- to prevent leakages and isolate the cargo from the hull structure.

The vessel hull structure is a double hull construction which also provides mechanical protection of the cargo tanks.

Boil-off gas (BOG) management facilities are also in place to capture any trace amounts of vaporised gas that is generated from LNG in the storage tanks. This BOG is used to fuel the on-board generators for the operation of pumps and other equipment used on-board.

The regasification unit located on board the FSRU is typically located toward the bow or centre of the vessel. The regasification module contains all necessary pumps, motors, heat exchangers, instrumentation, control and emergency shutdown systems to ensure the operation of the unit can occur. The regasification unit involves LNG being pumped up from the cargo tanks into a suction drum. The LNG is then pumped through a series of heat exchanges, which utilise seawater as a source of natural heat differential to warm up the LNG. Once in a gaseous form, the gas is exported, under pressure, through the marine loading arms to the wharf facility.

3.5.1.1 FSRU Safeguarding

The FSRU has a variety of safeguarding systems to prevent or mitigate a loss of containment event. These include:

- Fire and gas detection;
- Process control ESD system;
- Emergency disconnection system for ship to ship or ship to shore transfer;
- Blowdown system;
- Fire protection system (active and passive); and
- High Integrity Pressure Protection System (HIPPS).

Primary means of escape from the FSRU is provided via fixed gangway and secondary means of escape is via lifeboats.

3.5.1.2 FSRU Classification

The FSRU is classed by DNVGL and therefore has been designed in accordance with DNVGL standards, built and tested under the survey of DNVGL and will be regularly surveyed by DNVGL whilst the FSRU is at Port Kembla. The classification scope includes:

- Regasification plant and safety systems;
- Availability of main functions (i.e. stability, watertight integrity, ballasting, power generation, propulsion, etc.) and the safety of installations supporting the main functions;
- Structural strength and integrity of essential parts of the FSRU hull and its appendages; and
- Safety of machinery, systems and equipment supporting non-main functions that constitute possible hazards to personnel and unit.

Specific safety systems related to the regasification plant and covered by the classification scope include pressure relief and venting system, process shutdown (PSD) system, emergency shutdown (ESD) system, blowdown/depressuring system, High Integrity Pressure Protection System (HIPPS), and heating systems for vaporizers. Fire and gas detection and alarm systems, fire protection and extinction also form part of the FSRU classification scope.

For the purposes of this assessment the modelling was based around the general arrangement of a Hoegh FSRU with the regasification module at the bow of the ship per Figure 3-4.

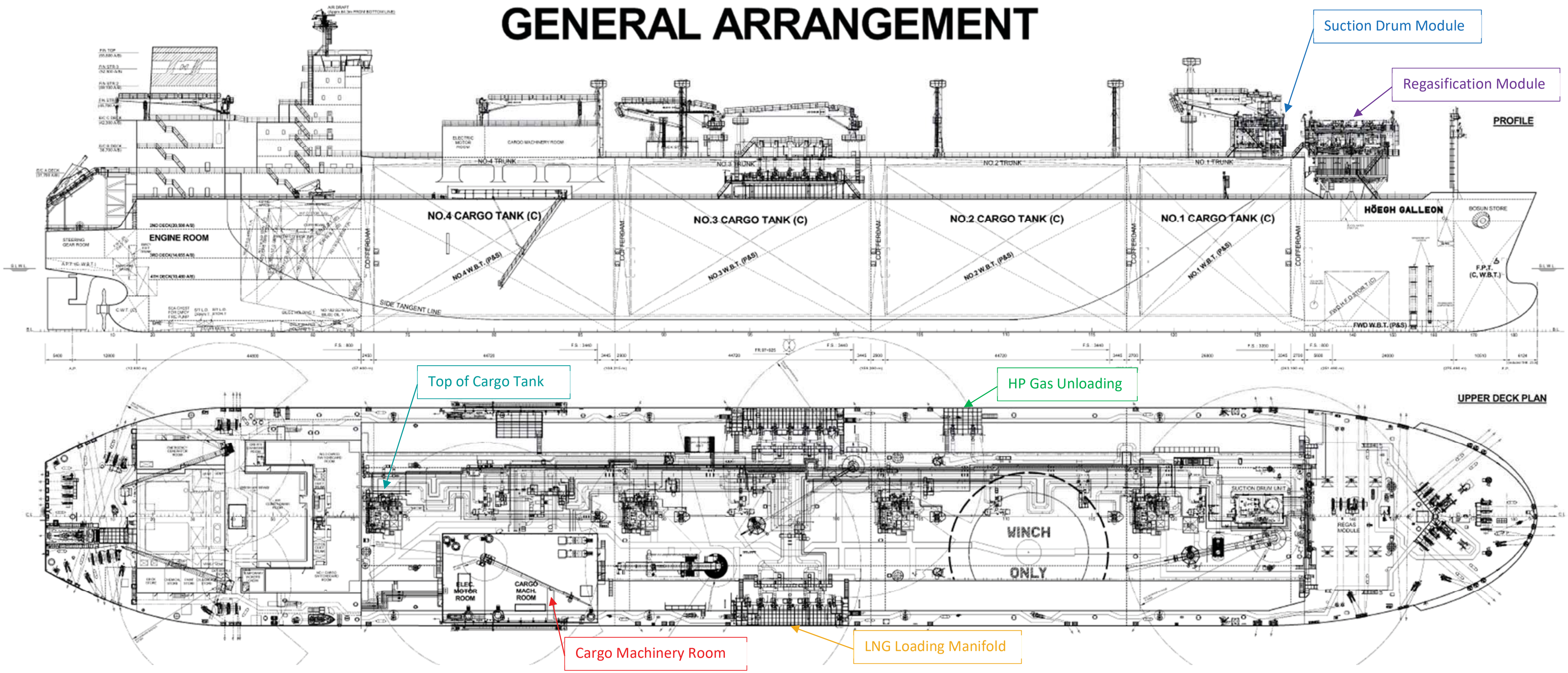


Figure 3-4: FSRU General Arrangement

3.5.2 Wharf Topside Facility

Berth and wharf facilities are proposed to be situated at Berth 101 within the Inner Harbour of Port Kembla. The berth and wharf facilities will incorporate a quay wall configuration to provide the necessary space for the FSRU and LNG carriers to be configured side-by-side without limiting the existing navigability of the Inner Harbour.

A range of topside facilities will be established at the wharf. These facilities will include mooring infrastructure for the FSRU, gas transfer infrastructure including offloading arms, and gas pipeline tie-in and maintenance infrastructure.

A range of ancillary facilities would also be situated at the wharf including access roads, fencing and other security, lighting, telecommunications, electricity, water, sewerage and other utilities.

A general arrangement of the berth is shown in Figure 3-5.

3.5.2.1 Wharf Safeguarding

The Wharf are has a number of safeguarding systems to prevent or mitigate a loss of containment event. These include:

- Fire and gas detection;
- Process control ESD system;
- Emergency disconnection system for ship to shore transfer;
- Blowdown system; and
- Fire protection systems (active and passive).

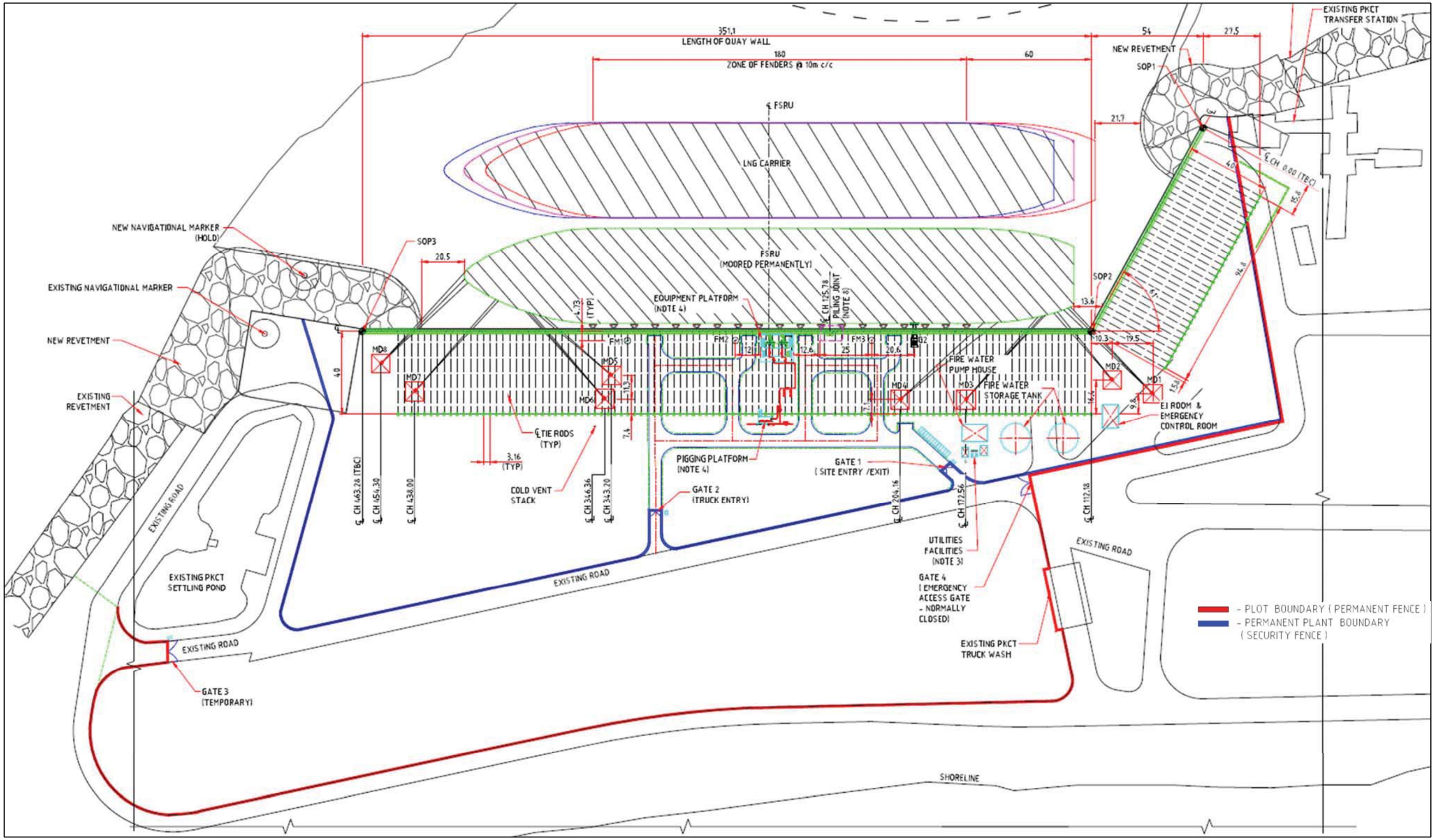


Figure 3-5: Berth 101 General Arrangement

3.5.3 Gas Pipeline

A short gas pipeline would connect the FSRU to the tie-in point at Cringila, which in turn is connected to the Eastern Gas Pipeline (EGP). The gas pipeline would be a DN400 carbon steel pipeline about 6 kilometres in length, with a Maximum Allowable Operating Pressure (MAOP) of 14.895 MPag and wall thickness of 12.7mm. The DN400 gas pipeline would be designed to comply with all current environmental and safety requirements including those required under Australian Standard (AS) 2885 [12]. The pipeline would be operated and maintained in line with AS 2885.3 [13].

The alignment of the gas pipeline has been selected to minimise disruption to public access, port operations and avoid areas of environmental and cultural sensitivity. The project application area for the purpose of the EIS includes a 16-metre corridor (8 metres either side of the pipeline centre line) where there are no limitations such as road, rail, power lines or other constraints. This construction right of way will allow for temporary working areas and micro-siting within the proposed corridor. The final easement width for the pipeline (outside of the road reserve areas) will be 6 metres (3 metres either side of the pipeline centre line).

The proposed pipeline route is shown in Figure 3-6.

Figure 3-6: PKGT Pipeline

3.6 Safety Management System

A Safety Management System is a systematic approach to managing safety. The project will develop a comprehensive Safety Management System (SMS) based on local standards and industry best practice for facilities handling LNG. An accepted framework for a SMS consists of specific elements which address the identification and control of hazards which pose a threat to:

- personnel onsite and offsite; and
- the environment onshore and within the Inner Harbour.

Typical SMS elements include:

- Leadership
- Risk Management
- Planning

- People and Capability
- Communication, Consultation and Documentation
- Facility Design and Construction
- Operations and Maintenance
- Working with Contractors and Suppliers
- Emergency and Security Management
- Management of Change
- Performance Measurement and Monitoring
- Incident Management and Learning
- Governance
- Management review

The management system will define how the facility manages all aspects of personnel and process safety from the identification of hazards to the maintenance and testing of safety critical barriers, which either prevent or mitigate releases of inventory and emergency response to events from within or external to the facility or pipeline. The SMS will interface with a Computerised Maintenance Management System (CMMS) which will be utilised to manage facility maintenance of both safety critical and non-safety critical equipment.

3.7 Fire Protection

The FSRU will have a range of firefighting and protection systems including a fire and gas detection systems, emergency shutdown (ESD) systems which initiate isolation and depressing of process inventories, fire suppression systems, inerting systems and fire water systems (primarily to prevent escalation through thermal radiation exposure or metal embrittlement). The on-board fire detection and protection systems will be subject to DNVGL classification requirements.

The existing berth fire water system is not considered to be sufficient for a berth handling LNG or NG. Therefore, the berth area will be provided with a new fire water system to provide additional firefighting capacity (over and above the fire water system on the FSRU) in accordance with AS 3846 The Handling and Transport of Dangerous Cargoes in Port Areas [14] and The International Safety Guide for Oil Tankers and Terminals (ISGOTT) [15]. This berth fire water system provides fire water coverage of the FRSU cargo tanks from the berth. In addition to the fire water system on the berth, fire and gas detection will be provided to detect a gas release or fire from the marine loading arms or berth piping. On confirmed detection the berth piping will be isolated and depressured to a local cold vent.

The firefighting capacity of existing Port Kembla Fire Fighting Tugs (FFT) is currently under review. This assessment will be completed against the requirements of AS 3846 [14] which recommends two class A FFTs are required.

A Fire Safety Study will be completed after final selection of the FRSU.

4. METHODOLOGY

The methodology for hazard and risk assessment is well established internationally and within Australia. This assessment has been carried out in accordance with the NSW HIPAP6 guidelines for hazard and risk assessments [2] which describes the methodology to be used in hazard and risk assessment in NSW as outlined in Figure 4-1.

Where a facility produces or handles and stores significant quantities of flammable or toxic materials Quantitative Risk Assessment (QRA) is typically used to determine onsite and offsite risk. For oil or gas pipeline assets within Australia the methodology is defined in AS2885.1 Pipelines – Gas and Liquid Petroleum Design and Construction [12]. This methodology is largely qualitative. However, given the location of the pipeline and neighbouring facilities QRA has also been applied to the pipeline in accordance with the SEARs requirements.

The PHA methodology includes the following steps:

1. Identification of Hazards (Section 5) – Review of possible accidents and the associated impacts that may occur based on previous accident experience or judgement where necessary.
2. Consequences and Impact Analysis (Section 6) – Define the characteristic of the identified possible accidents, and the facility thresholds for each consequence type (i.e. thermal radiation, flash fire, blast overpressure etc.).
3. Frequency Analysis (Section 7) – Define the probability of the identified possible consequences.
4. Risk Analysis (Section 8 and Section 9) – Define the acceptable risk levels and compare against the determined Location Specific Individual Risk contours.

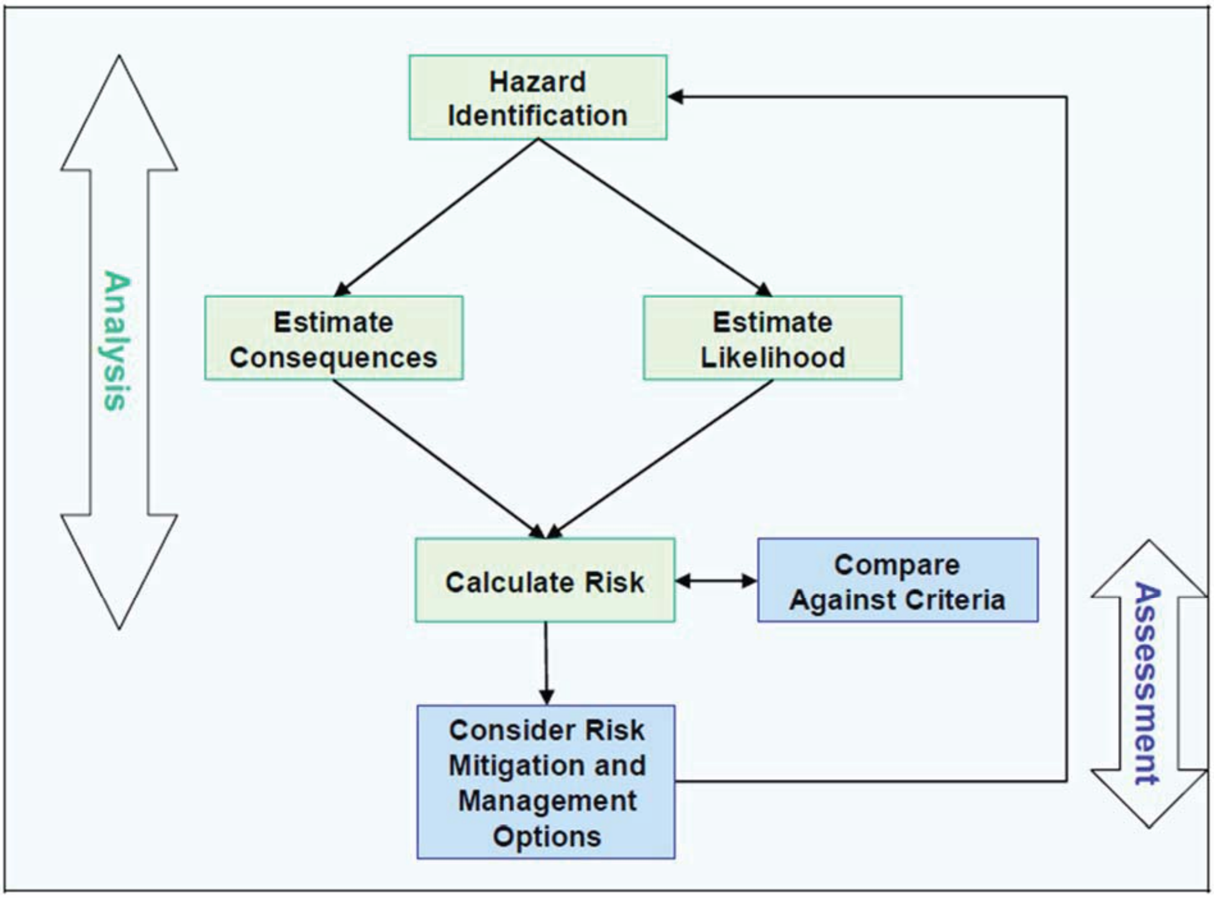


Figure 4-1: Hazard Analysis Methodology [2]

5. HAZARD IDENTIFICATION

5.1 Hazardous Inventories

5.1.1 Process Liquid and Gas

LNG is known to be a clean source of methane with very few contaminants. The following LNG compositions presented in Table 5-1 have been calculated from the leanest and richest Higher Heating Values (HHV) of 950 and 1200 BTU/SCF based on a range of LNG sources from potential suppliers. It is confirmed that the composition of all the identified sources fall within the HHV and Wobbe index range considered by the composition below.

Table 5-1: LNG Composition [3]

Component	Lean LNG [mol%]	Rich LNG [mol%]
Methane	93.59	81.48
Ethane	0.07	12.64
Propane	-	4.53
i-Butane	-	0.39
n-Butane	-	0.61
Pentane	-	0.02
Nitrogen	6.34	0.34

The contaminants presented in Table 5-1 are below the Occupational Safety and Health Administration (OSHA) permissible exposure limit (based on a time weighted average of 8 hours). As such toxicity modelling is not included in this assessment.

If LNG or natural gas (NG) is released to the atmosphere, then a flammable gas cloud would form having the potential to cause fire and/or explosion. Therefore, releases of LNG or NG leading to flash fire, jet fire and /or Vapour Cloud Explosion (VCE) are further assessed in this study. If LNG spills to the ground or into the water, with ignition a pool fire could occur, which is therefore also assessed in this study. The consequences of a loss of containment are discussed further in Section 5.5.

5.1.2 Glycol

Glycol is combustible but can pose a fire hazard at elevated temperatures especially above its flash point, and can pose a fire hazard if it contacts a very hot surface. The flash point of the Glycol is expected to range from 115 ~ 200°C depending on type. FSRU regasification Glycol processes are expected to be well below the flash point. Glycol is therefore not considered further.

5.1.3 Diesel

Diesel is combustible and has a flash point above 61°C with auto-ignition temperature at 250°C. It is classed as C1 combustible liquids as per AS1940 (i.e. a combustible liquid that has a flash point of 150°C or less, i.e. >60°C, ≤150°C) [17]. Diesel is expected to be stored onshore as fuel for the fire water pumps and will be at ambient pressure and temperature, well below its flash point and is not considered to be flammable, and therefore not further considered.

5.1.4 Hazardous Material Storage

The identified hazardous inventories will be stored at the facility in various quantities as summarised in Table 5-2.

Table 5-2: Hazardous Materials Storage

Hazardous Material	Dangerous Goods Class	HAZCHEM Code	UN Code	Maximum Storage Quantity
Natural Gas	2.1	2SE	1971 (as methane)	Nil in storage
LNG	2.1	2WE	1972	FSRU cargoes (170,000m^3)

5.2 Hazard Identification

Two hazard identification (HAZID) studies have been completed to date and a hazard and operability (HAZOP) has been completed on the current Front End Engineering Design (FEED). The FEED HAZID and HAZOP studies [16] were conducted 9th to 11th October 2018 and were attended by representative from Hoegh, AIE and WorleyParsons.

The objective of 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 methodology of a HAZID review is as follows:

- Identify all potential hazardous events and their significance to safe operations;
- Identify the potential impact/s on personnel, the asset, or the environment;
- Identify existing safeguards (also termed barriers); and
- 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.

The output from the HAZID Study, the Hazard Register is provided in Appendix B. From the HAZID studies the following loss of containment events have been identified:

1. Loss of containment of LNG from the FSRU and LNGC; and

2. Loss of containment of NG from the FSRU, Marine Unloading Arms (MLA), berth piping and pipeline.

The studies considered interactions between existing operations within the Inner Harbour and the LNGC and FSRU, Ship to Ship Transfer (LNGC to FSRU) of LNG, regasification of LNG and send out of NG. Known design and operational safeguards against the identified hazardous scenarios are listed in the minutes provided in Appendix B.

An AS2885.1 Safety Management Study was completed 8th October and included identification of threats to the pipeline and proposed pipeline design and operational mitigations.

5.3 Ship Collision

Berth 101 is located to the east of the existing Inner Harbour turning circle which as the name suggest is used to turn vessels either entering or leaving the harbour. To validate the terminal design navigation simulations were conducted. The aims of the simulations were to determine if safe passage of an LNG vessel was possible and to assess the interaction of the proposed berth layout and FSRU on other shipping movements in the Inner Harbour. The Vessel navigation simulations were held at the Australian Maritime College Centre for Maritime Simulations, Launceston, during the week of the 13th of August 2018 and were attended by representatives from Hoegh, AIE, WorleyParsons, NSW Port Authority, NSW Ports, Svitzer Tugs [22].

The main outcomes from the simulations are listed below:

- LNG vessels can enter and depart the port and berth within the current weather limitations, however the wind conditions may need to be reduced for contingency until the pilots are familiarised with the LNGC manoeuvring;
- A fourth ocean-going tug is required as an escort for LNGC operations;
- Two pilots are required for arrival and departure of the LNGC until the pilots are familiarised with the LNGC manoeuvring;
- The berth pocket has been moved north and rotated to align parallel with Berth 102;
- The stern of the 52m beam LNGC moved to a 40m offset from the turning basin;
- The berth pocket length may be reduced; and
- Navigational lead light repositioned for better visibility, with the final position to be confirmed.

The 40m offset referred to above is an exclusion zone which will be observed by tug operators and pilots involved in vessel movements within the Inner Harbour. This exclusion zone is greater than the 25m stipulated in AS 3846 The Handling and Transport of Dangerous Cargoes in Port Areas [14].

5.4 Adverse Sea Conditions

The Outer Harbour of Port Kembla is exposed to swell wave action from the north, and infragravity (IG) wave occurrences, also known as seiche waves. The long period waves that cause the seiching in Port Kembla occur from offshore waves and storms. Typically, the IG waves in the outer harbour can be predicted, but at times unexpected severe weather occurs. These events can result in mooring lines breaking and therefore may require vessels to be evacuated at short notice from their berths for an average of 12 times per year, and up to 4 days at a time.

The FSRU is located in the Inner Harbour which, while well protected, also experiences seiching. The FSRU is expected to remain moored during such events and the mooring system will be designed to ensure it can accommodate the IG waves. The simulation of seiching and mooring analysis which will inform the design is currently ongoing. Nevertheless, the FSRU will maintain the required maritime crew levels required to enable the vessel to be moved out to sea if required by the Port Authority.

5.5 Credible Hazard Consequences

5.5.1 Process Liquid / Gas

Release of hydrocarbons can potentially lead to fire and explosion scenarios and constitute major hazards. Leaks can occur due to failures of pipe work systems (in particular small bore piping), flanges, valves and failure of vessels. Immediate or delayed ignition can occur from hot work activity, naked flames, static electricity, hot surfaces, hot gases or faulty equipment and sparking.

5.5.2 Flash Fire or Vapour Cloud Explosion

Flash fire or VCE may arise if released vapour fails to disperse (through confinement or still-air conditions) and an ignition source is present.

Flash fires will occur when obstruction in the area is low and significant flame velocities are not generated, with the principal hazard exposure to high levels of radiant heat. Injury / fatality are likely for people located within the impact zone of the flash fire. However, as durations are short, equipment damage is not typically a concern. The burn zone is typically the boundary of flammable limit of the cloud.

VCEs occur due to rapid combustion of flammable gas which generates pressure effects due to the acceleration of the flame front by congestion or confinement. For deflagration type explosions, the severity of the explosion depends on the material of combustion and the degree of confinement and congestion. Explosions have the potential to lead to injury / fatality and significant equipment damage.

5.5.3 Jet Fire

Jet fires are highly directional sonic momentum driven releases, and have high flame temperatures, because air-fuel mixing is efficient.

The high temperatures and radiant heat pose a hazard for surrounding equipment and personnel. Where there is direct flame impingement or elevated levels of radiant heat, significant convective heat transfer may occur, potentially resulting in injury / fatality and failure of structural members or equipment resulting in possible further escalation. Radiant heat can also affect the ability of personnel to escape from or through an area on the facility.

5.5.4 Pool Fire

A pool fire may occur if there is a spill of LNG on the ground or into the harbour and is ignited. Where the spill is unbunded or in the water, the pool can spread to a significant diameter. The diameter continues to increase until the burn rate matches the liquid supply rate. Similar to jet fires, pool fires pose a hazard to personnel and surrounding equipment, however radiant heat levels are lower and pool fires take longer to fail structural members and equipment.

5.5.5 Rapid Phase Transition

Loss of containment of LNG in water can result in rapid phase transition. The rise in temperature of the LNG results in the very rapid generation of vapour as the cold LNG absorbs heat from the underlying spill surface. The rapid formation of vapour creates localised overpressure also described as physical explosion as no chemical reaction or combustion occurs. The consequences of rapid phase transitions can be severe, but are highly localised within or in the immediate vicinity of the spill area [20].

A significant leak from an LNG transfer hose has the potential to result in rapid phase transition. However, the localised overpressure is not considered severe enough to cause damage to the vessel cargo tanks resulting in further loss of containment and escalation.

6. CONSEQUENCE ANALYSIS

The following section describes the assumptions, inputs and scenario development for the flammable gas cloud, fire and explosion risk modelling. The consequence modelling results are contained in Appendix C.

6.1 Risk Modelling Software

DNV GL PHAST Risk (also known as SAFETI) version 6.7 was used to model the possible identified consequences from releases of hazardous inventories by using a wide range of models for discharge and dispersion as well as flammable and explosive effects.

6.1.1 Model Assumptions

The following assumptions were made for the modelling carried out with PHAST Risk.

- 'Vessel or Pipe Source' model with Leak Scenario Type used.
- Risk calculation is based on initial fire impact characteristics (i.e. immediately post ignition) at 1.5m above ground.
- Due to the modelling software limitations with regards to modelling discharges angled downwards, 'Horizontal Impingement' was used for all vertical downward leaks.
- The standalone Multi Energy Explosion with 3D Obstructed Region models was used for explosion modelling.
- The 'Long Pipeline' scenario type was used for the pipeline rupture case.
- All other parameters were set to default unless specified within this report.

6.2 Leak Characteristics

The leak sizes presented in Table 6-1 were modelled.

Table 6-1: Leak Size

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

The above leak sizes are considered to be representative of releases from typical leak sizes. Small release sizes are characteristic of pinhole leaks and seepage and medium release sizes representative of gasket failure, valve leaks and failed instrument connections. Large releases are representative of high energy impacts such as catastrophic failure and ruptures primarily from mechanical defects. Full bore rupture represents the worst case release scenario.

The pipeline leak sizes were based on data available from a different source of leak frequencies as discussed in Section 7.2. As such the leak sizes modelled for the pipeline are as summarised in Table 6-2.

Table 6-2: Leak Size – Pipeline

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

6.3 Leak Direction and Elevation

Three different release orientations were modelled and the applied directional probabilities are as follows:

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

The exceptions to this are a leak due to a ship collision, which is all assumed to be in a horizontal direction, and a leak from the pipeline, which is as follows:

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

All releases from the process on the FSRU were modelled at an elevation of 14m, releases from the ship collision were assumed to be at 7m, releases from the ground facilities were modelled at an elevation of 1m, and releases from the buried pipeline at an elevation of 0m.

6.4 Shutdown and Isolation

The full bore rupture cases are considered to be the largest bore piping within each system. The consequence distances are large if the release model is continued at the initial discharge rate with unlimited inventory. The release rate therefore is limited to the maximum production flow rate as upon rupture the system is assumed to be isolated (where the rupture occurs in a facility) via gas detection and ESD, and thus pressure will drop significantly in a short timeframe (seconds) as the inventory is limited and the pressure loss through the rupture point is significant. For all other leak sizes, less than full bore rupture, the model takes no credit for isolation and flow limitation and is therefore conservative.

The only exception with the full bore cases is the pipeline from the wharf facility to the metering station. A rupture of the pipeline would have the entire pipeline inventory behind it, and would not be as readily detected and isolated as a leak / rupture at the FSRU. The pipeline full bore rupture was modelled in line with AS 2885 [12], with the quasi-steady state flow 30 seconds after the initiating event used for the model calculation.

6.5 Environmental Conditions

Environmental conditions were sourced from the Port Kembla Signal Station climate statistics reported by the Australian Government Bureau of Meteorology (BOM). The weather parameters summarised in Table 6-3 were used as the basis for the consequence modelling.

Table 6-3: Weather Parameters

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

The probability of the wind blowing in a certain direction and up to a certain speed was also taken from the BOM statistics available. These probabilities are summarised in Table 6-4.

Table 6-4: Weather Probability Distribution

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

The associated wind roses from BOM used to determine the wind speed distribution are included in Appendix A.

6.6 Fluid Compositions

The rich LNG composition specified in Table 5-1 was selected to be used for the modelling [3]. This will conservatively produce the greater consequence impact distance results than the lean LNG composition.

6.7 Operating Conditions

The main consequences identified for this facility were fire (flash fire and jet fire) and explosion. The scenarios identified were broken down by operating conditions. This was done for simplification purposes as part of the Fire and Explosion Analysis (FEA) to minimise the number of cases that had to be modelled and areas with small difference in pressure or temperature were grouped together with the more conservative operating conditions selected. The groups of operating conditions and associated facility areas are summarised in Table 6-5.

Table 6-5: Consequence Modelling Operating Conditions

Scenario ID	Scenario	Pressure (kPag)	Temperature (°C)
1	BOG from Tanks to Header and Cargo Machinery Room	0	-160
2	BOG from HD Compressors for return to shore during LNG loading / unloading	100	-120
3	LNG from Tank to Regasification Module	550	-160
4	BOG from Low Duty (LD) Compressors for fuel gas or to BOG cooler for reliquefication	550	60
5	LNG from Regasification Booster Pumps	12,000	-160
6	NG from Regasification Module to Wharf and Pipeline	12,000	10

6.8 Explosions

On the FSRU the following areas above deck were identified as congested / enclosed areas with the potential for a VCE:

- Piping directly above each LNG cargo tank;
- Cargo machinery room;
- Suction drum module; and
- Regasification module (top and bottom half).

Fire or explosion events below deck, such as events with engine and utility rooms, have not been considered as they are not considered to impact offsite risk beyond the FRSU.

The other areas of the FSRU are not considered congested enough to cause a VCE. The wharf facility is considered an open facility with low levels of congestion and no areas with the potential for VCE were identified.

6.8.1 Blast Strength

Table 6-6 presents the ignition energy, obstruction and parallel plane confinement for the identified areas, and selects and appropriate blast strength for each area based on guidance provided in the Yellow Book [7].

Table 6-6: Blast Strength Index

Area	Ignition Strength	Obstruction	Parallel Plane Confinement	Blast Strength
LNG Cargo Tank 1-4 Piping	Low	High	Yes – Partial	6
Cargo Machinery Room	High	High	Yes	8
Suction Drum Module	Low	High	Yes – Partial	6
Regasification Module – Bottom Half	Low	High	Yes	6
Regasification Module – Top Half	Low	High	Yes – Partial	7

Figure 6-1 shows the theoretical peak overpressure which can be achieved for each blast strength number. The figure shows that in order to get a peak overpressure > 7 kPa (the level of overpressure likely to cause injuries from flying debris for personnel per Section 6.12) a blast strength of at least 4 is required [7], which all of the VCEs from the identified areas are above.

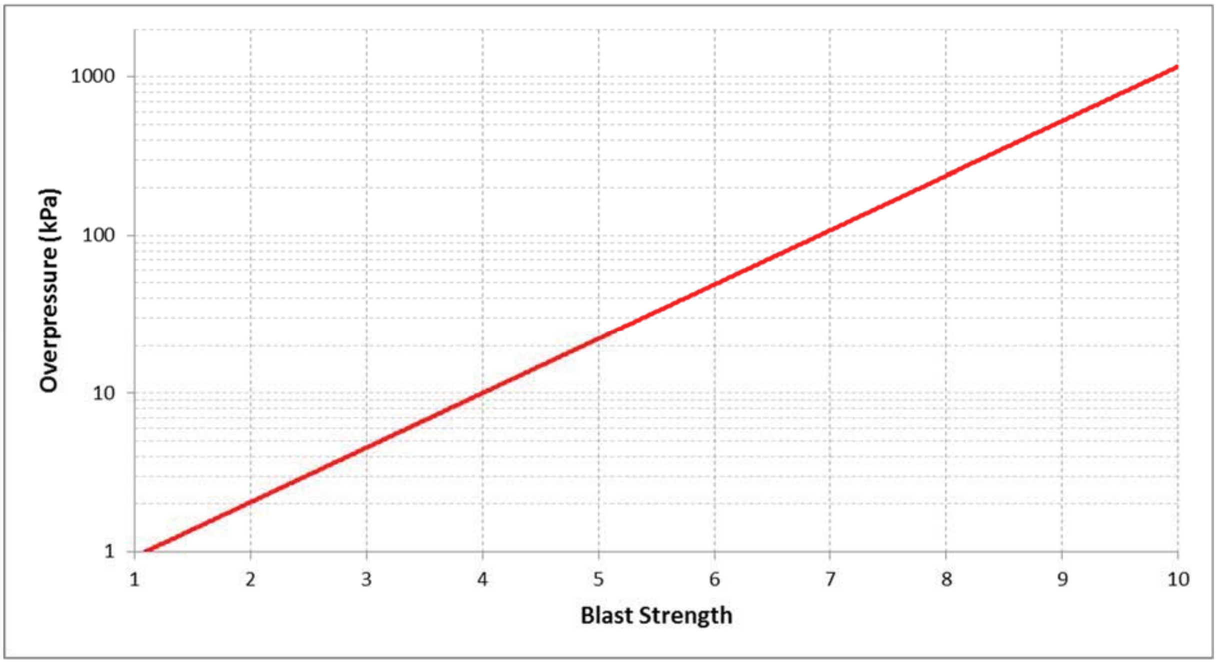


Figure 6-1: Theoretical Peak Overpressure [7]

6.8.2 Stoichiometric Flammable Mass

Table 6-7 presents the potential worst case stoichiometric flammable masses for the potential VCE areas identified. The volumes of the congested / confined volumes are estimated from the FSRU general arrangement drawing (refer to Figure 3-4).

Table 6-7: Flammable Mass

Area	Total Volume (m^3) NOTE 1	Equipment Volume (m^3) NOTE 2	Gas Volume (m^3)	Gas Density at NTP	Flammable Stoichiometric Factor	Flammable Mass (kg)
LNG Cargo Tank 1-4 Piping	83.8	12.6	71.2	0.816	0.095	5.5
Cargo Machinery Room	2484	373	2112			164
Suction Drum Module	331	50	282			22
Regasification Module – Bottom Half	1512	227	1285			100
Regasification Module – Top Half	3115	467	2648			205

Note 1: Length, width and height estimated from FSRU general arrangement drawing (Figure 3-4).

Note 2: 15% of the total volume is assumed to be equipment.

6.9 Scenario Identification

Table 6-8 lists the areas where there the potential hazardous consequences which have been identified could potentially occur. These are the scenarios which were included in the risk analysis modelling.

Table 6-8: Identified Scenarios

Location	Area / Event	Potential Consequence
FSRU & LNGC	Ship Collision	■ Flash Fire ■ Pool Fire
LNGC to FSRU	LNG Transfer Hoses	■ Jet Fire ■ Flash Fire ■ Pool Fire
FSRU & LNGC	LNG Loading Manifold	■ Jet Fire ■ Flash Fire ■ Pool Fire
FSRU & LNGC	Cargo Tank 1 – 4	■ Jet Fire ■ Flash Fire ■ Pool Fire ■ Explosion

Location	Area / Event	Potential Consequence
FSRU & LNGC	Cargo Machinery Room	■ Explosion
FSRU & LNGC	Headers	■ Jet Fire ■ Flash Fire ■ Pool Fire
FSRU	Suction Drum Module	■ Jet Fire ■ Flash Fire ■ Pool Fire ■ Explosion
FSRU	Regasification Module	■ Jet Fire ■ Flash Fire ■ Pool Fire ■ Explosion
FSRU	HP Gas Unloading Manifold	■ Jet Fire ■ Flash Fire
FSRU to Wharf	Marine Loading Arms	■ Jet Fire ■ Flash Fire
Wharf	Wharf Facility (from MLAs to Pig Launcher)	■ Jet Fire ■ Flash Fire
Pipeline	Buried Pipeline (from Wharf Facility to Metering Station)	■ Jet Fire ■ Flash Fire

6.10 Impact Criteria – Radiant Heat

Radiant heat can impact both personnel (injury or fatality) and equipment (damage and escalation) at the facility. The radiant heat levels specified in Table 6-9 are based on HIPAP no 4 [1].

Table 6-9: Radiant Heat Consequences [1]

Radiation (kW/m^2)	Effect – People	Effect – Equipment
2.1	■ Minimum level to cause pain after 1 minute	■ Nil
4.7	■ Pain in 15-20 seconds ■ Injury after 30 seconds exposure (second degree burns minimum)	■ Nil
12.6	■ Significant chance of fatality with extended exposure ■ High chance of injury	■ Temperature of wood rises to point where it can be ignited by a naked flame after long exposure ■ Thin steel with insulation on non-fire side may reach thermal stress level high enough to cause structural failure

Radiation (kW/m^2)	Effect – People	Effect – Equipment
23	■ Likely fatality with extended exposure ■ Chance of fatality with instantaneous exposure	■ Spontaneous ignition of wood after long exposure ■ Unprotected steel reaches thermal stress temperature causing failure ■ Pressure vessels need to relieve or failure occurs
35	■ Significant chance of fatality	■ Cellulosic material will pilot ignite within one minute exposure

6.11 Impact Criteria – Flash Fire

Flash fire impact is based on the ignition of a dispersed gas cloud at the Lower Flammability Limit (LFL).

Table 6-10: Flash Fire Consequences

Criteria	Impact on Personnel	Impairment Criteria
Lower Flammability Limit (LFL)	Potentially fatal for people in the ignited flammable cloud path	Immediate fatality: 100% fatality if in the open; 0% fatality if in a building (i.e. shielded)

6.12 Impact Criteria – Explosion Overpressure

The overpressure impact criteria are based on HIPAP no 4 [1] as summarised in Table 6-11.

Table 6-11: Explosion Overpressure Consequences [1]

Overpressure (kPa)	Effect – People	Effect – Equipment
3.5	■ No fatality ■ Very low probability of injury	■ 90% glass breakage
7	■ No fatality ■ 10% probability of injury	■ Repairable damage to internal partitions and joinery
14		■ House uninhabitable and badly cracked
21	■ 20% chance of fatality to a person in a building	■ Reinforced structures distort ■ Storage tanks fail
35	■ 50% chance of fatality for person in a building ■ 15% chance of fatality for person in the open ■ Threshold for eardrum damage	■ House uninhabitable ■ Wagons and plant items overturned
70	■ 100% chance of fatality for a person in a building and out in the open ■ Threshold for lung damage	■ Complete demolition of houses

7. FREQUENCY ANALYSIS

The frequency of an event is the number of occurrences of the event in specific time period; typical one year or p.a. The estimation of event frequency relies upon historical equipment failure data and the use of Event Trees to define the pathways to the event consequence. Appendix D includes equipment failure frequency data from Hydrocarbon Release Database (HCRD) maintained by the United Kingdom Health and Safety Executive (UKHSE) [6] used in this study. The following sections provide further detail of the inputs to the frequency analysis and discussion of the frequency of specific failure events and loss of containment scenarios.

Figure 7-1 presents the event tree for all hydrocarbon events as a basis for this QRA.

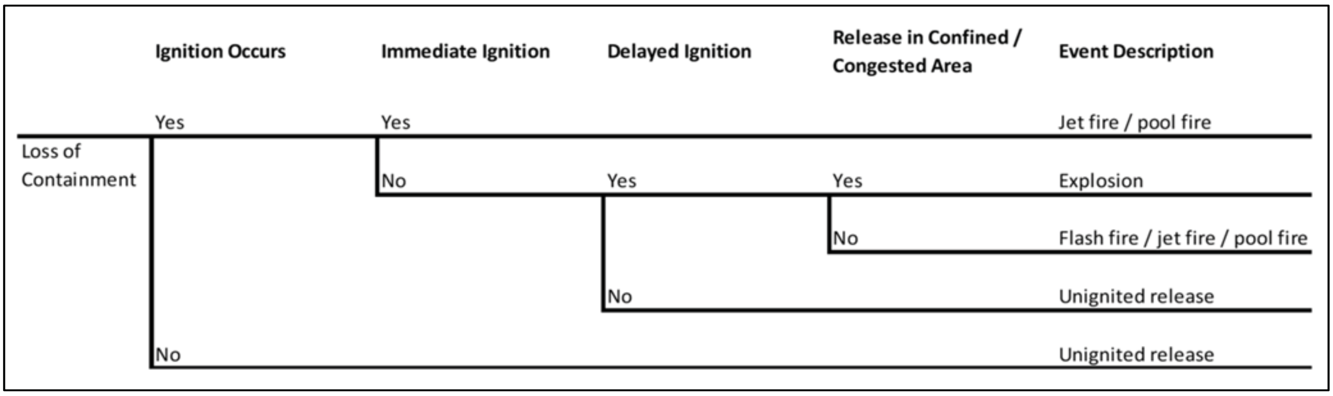


Figure 7-1: QRA Event Tree

7.1 Ignition Probability

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

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

There are a range of correlations available for applying an ignition probability to a release, and most are based on the release rate and state. The ignition probabilities utilised in this QRA are based on the United Kingdom Offshore Operators Association (UKOOA) ignition correlations [4] which take into account the factors above as well as the nature of the surrounding area with respect to potential ignition sources.

The ignition probability determined using the UKOOA ignition correlations for a Large Plant Gas LPG was split between immediate and delayed ignition based on Cox, Lees and Ang [5] as per Table 7-1.

Table 7-1: Probability of Immediate versus Delayed Ignition

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

The consequences of hydrocarbon fire events are as follows:

- Immediately ignited gas releases result in jet fires.
- Delayed ignition gas releases are modelled as flash fires or explosions (depending on the level of confinement and congestion surrounding the release).

7.2 Parts Count and Leak Frequencies

7.2.1 FSRU, LNGC and Wharf Facility

A parts count was undertaken using the Revision A Issued for Review Piping and Instrumentation Diagrams (P&IDs) for the wharf side and the proposed vendor's P&ID for the FSRU.

For each equipment item identified (vessels, valves, flanges, instrumentation, piping, etc.), the failure rate data from the HCRD maintained by the UKHSE [6] was applied.

A number of assumptions were made to the parts count and leak frequencies calculated as follows:

- An additional 15% contingency was applied to all parts count in the frequency assessment to account for future minor changes to the P&IDs and design modifications.
- As no detailed general arrangement drawings were available for the FSRU showing the piping directly above tanks or in the cargo machinery room, suction drum module or regasification module, another 20% margin was applied to the parts count to account for the frequency contribution from piping.
- The regasification module was adjusted in the model so that only 2 of the 3 regasification trains will be in operation at any time, as 2 trains are adequate for the throughput of LNG required during operation.
- Jet fires and flash fires within the cargo machinery room are assumed to remain within the room and therefore not contribute to offsite risk.
- As no detail is currently available regarding the piping and equipment on the specific LNGCs likely to be associated with this project, they are assumed to have a similar arrangement to the FSRU, but without the suction drum and regasification module.
- A LNGC was assumed to be in the harbour to load LNG onto the FSRU for 1 day every 2 weeks.

A summary of the leak frequencies calculated is attached in Appendix D. While the highest leak frequency is typically associated with the smaller leak sizes, these also contribute the least to offsite risk due to their reduced consequence distances.

7.2.2 Marine Loading Arms

As the HCRD [6] did not contain information regarding MLAs specifically, the leak frequency data for these was taken from the Purple Book [8]. The calculation of this leak frequency is based on the number of times the MLAs are connected, which for the FSRU to wharf was assumed to be once per year.

7.2.3 Ship Collision

A ship collision with either the FSRU or LNGC is considered to only lead to a puncture when the speed and weight of the colliding vessel is great enough to puncture the LNGC or FSRU double hull and the cargo tank. Current vessel entries and exits from the Inner Harbour are 1680 per year and this number is expected to increase to 2380 by 2030. The heaviest vessels in the harbour are Cape Size vessels with a dry weight of approximately 205,000 tonnes. The speed of these vessels entering and leaving the Inner Harbour is typically 2.5 knots. Roll on Roll off car carrying vessels have a dry weight mass of 35,000 tonnes and entry and exit speeds of 6-7 knots.

Based on the guidance developed by Sandia National Laboratories for U.S. Department of Energy to quantify potential threats to an LNG ship [10], the estimated minimum kinetic energy required to puncture a LNG tank within a double hulled tanker is approximately 10^8 Nm. The heaviest vessel weighing 205,000 tonnes travelling at 2.5 knots would generate a kinetic energy of 1.7×10^8 Nm and 2.3×10^8 Nm for the car carrier vessel. Therefore, there exist a potential for ship collision leading to puncture of the FSRU or LNGC if all the kinetic energy is transferred (e.g. 90° impact).

The expected ship collision scenario between two ships, is that the collided ships would remain joined for several hours, if signification penetration of one ship occurs the puncture size available for the release of LNG is expected to produce an effective hole size of no more than 1 m^2 for an LNG spill [10].

For this QRA, the ship collision risk assessment was conducted in the above context together with ship collision calculation method specified in the CMPT (A Guide to QRA for Offshore Installations) [9] with the following inputs:

- 50% of all ships entering and exiting the harbour are conservatively assumed to have sufficient kinetic energy to puncture a LNG tank within the FSRU or LNGC.
- All ship collisions are conservatively assumed to be at 90° to the FSRU or LNGC resulting in maximum kinetic energy transfer.
- Effective leak size (diameter) from a puncture on a LNG tank is 1.128 m (i.e. 1 m^2 hole) leak.
- 5% chance that the passage planning was carried out unsuccessfully.
- 5% chance that tugboat fails to change the course of the moving vessel.
- 0.76% chance that harbour master fails to alert moving vessel(s) including tugboat to avoid a collision [9].
- The shipping lane is beyond the 40m exclusion zone i.e. 40m from the LNGC when present.

7.2.4 Pipeline

For the pipeline the data available from the United Kingdom Onshore Pipeline Operators Association (UKOPA) [18] and International Association of Oil and Gas Producers (OGP) [19] are applicable. Table 7-2 summarises the information available for the pipeline from the two sources.

Table 7-2: Pipeline Release Data

Reference	Applicability	Release Rate for Onshore Gas Pipeline (per 1000km of pipe)	Hole Size Distribution
UKOPA [18	Predominantly onshore natural gas pipelines, but also includes other pipelines such as ethylene, ethane and crude. (UK data from 1962 – 2010)	0.234 (1962 – 2010) 0.079 (1990 – 2010)	Based on historical data: ■ Small (<20mm) = 78% ■ Medium (20–80mm) = 16% ■ Large (>80mm) = 2% ■ Full Rupture = 4%
OGP [19	Onshore gas pipeline data set (data based on the European Gas Pipeline Incident Data Group (EGIG))	0.17 (5 – 10mm thick pipe) 0.081 (10 – 15mm thick pipe)	Recommended for Risk Assessments: ■ Small (<20mm) = 50% ■ Medium (20–80mm) = 18% ■ Large (>80mm) = 18% ■ Full Rupture = 14%

In general, total release rates for onshore gas pipelines are approximately 0.2 events per 1,000 km of pipe. Differences in the data arise when looking at the hole size distribution. UKOPA data shows a significant amount of releases recorded at the lower end of the hole size spectrum with 78% of releases occurring for small hole sizes. The OGP data is based on the EGIG report and provides a hole size distribution which it recommends utilising as part of a risk assessment.

The OGP [19] data has been utilised for this risk assessment for a number of reasons:

- Wall thickness rather than pipeline diameter has been found to be the most significant factor in determining pipeline failure rates; and
- Hole size distribution is more conservative than what has been reported for in the UKOPA data (greater frequency of full rupture).

For the Port Kembla Gas Terminal (PKGT) pipeline the release frequency of 0.081 per 1000km per year will be used as the pipeline has a wall thickness of 12.7mm.

8. RISK CRITERIA

The risk criteria assessed against in this report are based on HIPAP No 4 Risk Criteria for Land Use Planning [1]. These criteria are presented in Table 8-1 below.

Table 8-1: Fatality Risk Criteria

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

8.1 Propagation Risk

Heat radiation levels of 23kW/m^2 and explosion overpressure levels of 14kPa are considered sufficient to cause damage at neighbouring industrial operations to the extent where further hazardous incidents can potentially occur [1].

In order to ensure the risk of property damage at neighbouring installations the frequency of these impact levels occurring shall not exceed a risk of 50 in a million per year (5E-05 per annum).

8.2 Injury Risk

Heat radiation levels of 4.7kW/m^2 and explosion over pressure levels of 7kPa [1] are considered sufficient to cause injury to the public. As such the frequency of these impact levels shall not exceed 50 in a million per year (5E-05 per annum) at residential and sensitive areas.

9. RISK RESULTS

The overall findings from the risk modelling were that the main contributor to risk was from jet fires and flash fires on the FSRU. The impact distance from explosion events remain close to the vessel therefore these events do not significantly contribute to the risk contours beyond the facility.

As the LNGC is only in the Harbour for a one day period every two weeks, and it did not have as much process equipment and potential leak sources as the FSRU, its addition to the overall risk contours was significantly less than the FSRU.

The consequence distances from high pressure gas are the largest, and therefore these releases are a significant contributor to the risk contours, more so than the low pressure LNG.

9.1 Individual Fatality Risk

Figure 9-1 and Figure 9-2 show the individual fatality risk contours generated from the modelling conducted. When assessed against the HIPAP No 4 criteria, the following conclusions can be made:

- The 5E-05 risk contour for industrial land use extends beyond the security fence although remains mostly within the permanent boundary fence. While the risk does not reach the coal terminal it does approach the coal terminal truck wash station along the permanent boundary fence (Refer to Figure 3-5 for the general arrangement showing more detail on the berth layout).
- The 1E-05 risk contour for active open space extends beyond the wharf fenceline across the road to the shore, as well as approximately halfway across the harbour near the front end of the FSRU. The end of the road that is encroached upon is controlled by NSW ports and is only open during daylight hours unless closed due to port operations such as coal loading / unloading; as such large groups of people are not expected to be present in this area. Vessels entering or exiting the harbour may pass through the outer edge of the risk contour for a short duration.
- The 5E-06 risk contour remains within the harbour in the area directly around the berth, away from commercial developments.
- The 1E-06 risk contour for residential areas extends across to the western side of the harbour from the berth. This area is mostly industrial land. The contour does not reach the cruise ship terminal at berth 106. Cruise ships entering and exiting the harbour will pass through this risk contour but exposure will be low, i.e. people on board a cruise ship will be exposed whilst entering or leaving the Inner Harbour.
- The 5E-07 risk contour for sensitive land use remains on industrial land and active open space around the berth. This contour also follows the path of the pipeline to the metering station, occasionally reaching nearby roads. No hospitals, schools, etc. are impacted by this contour. The cruise ship terminal at berth 106 is outside this risk contour.

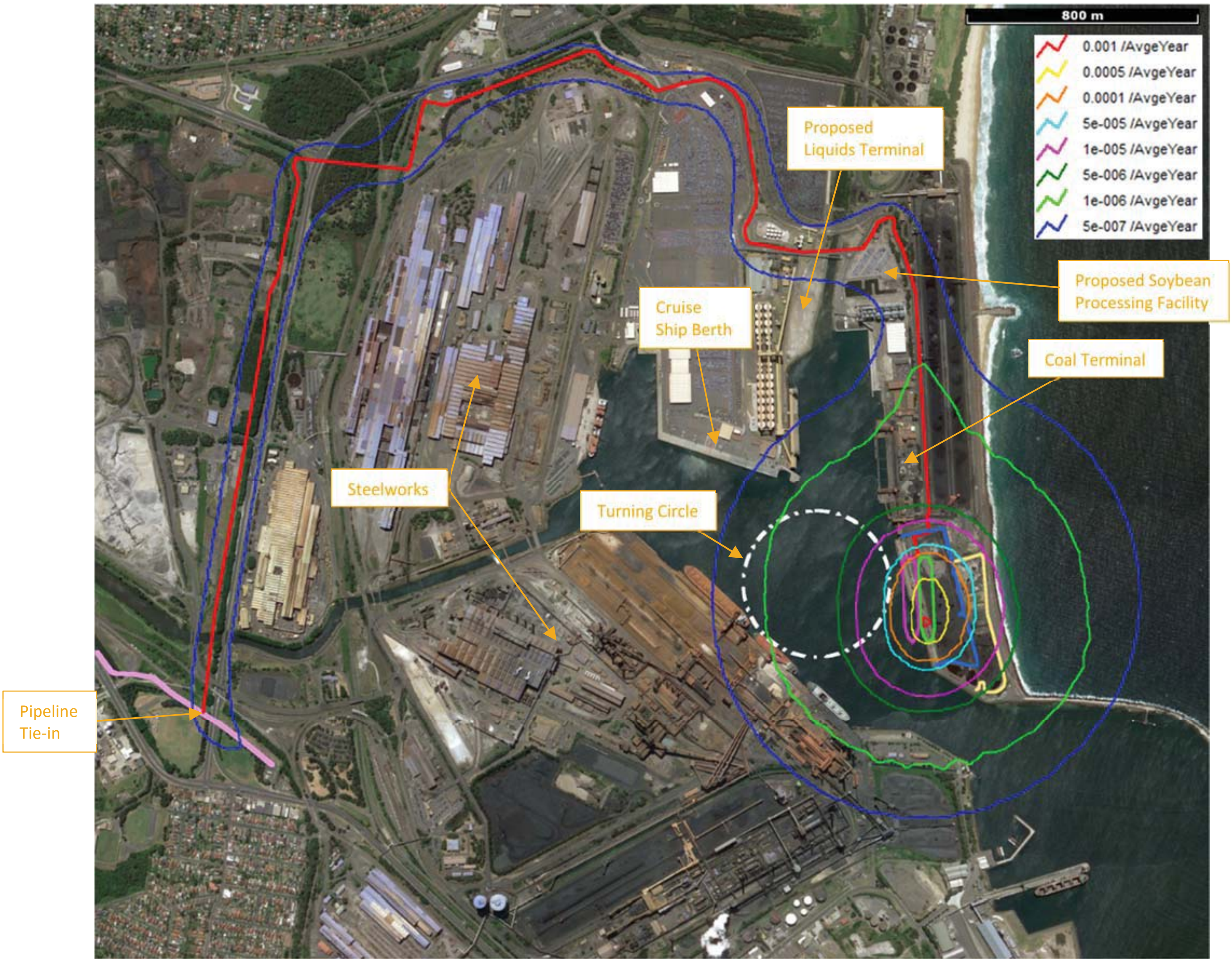


Figure 9-1: Risk Contours

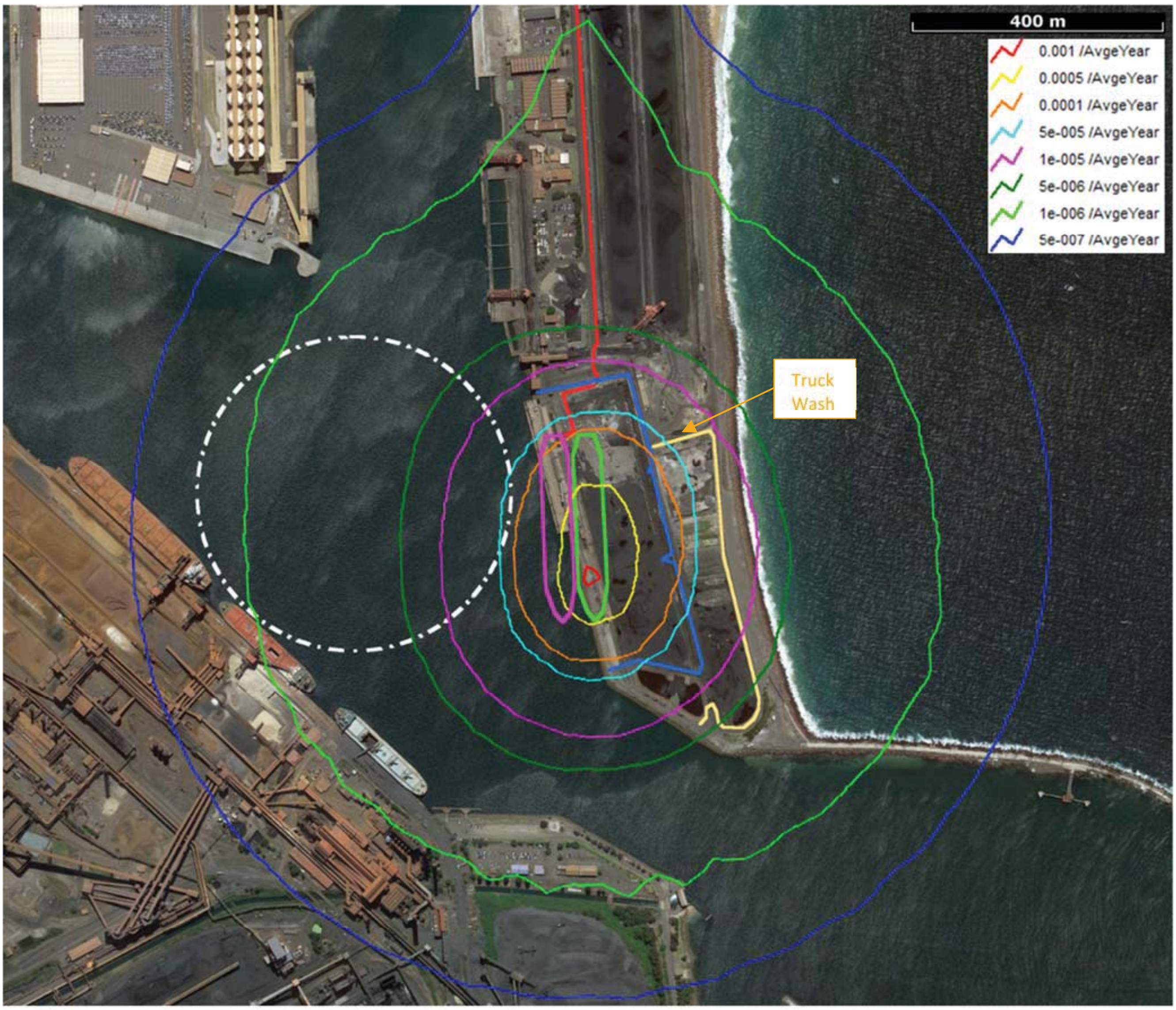


Figure 9-2: Risk Contours (Berth 101)

9.2 Propagation and Injury Risk

Damage and propagation risk due to heat radiation levels in excess of 23kW/m^2 and explosion overpressure levels greater than 14kPa were assessed for the Port Kembla site to determine whether there was a potential for the site to present a risk of escalation at neighbouring facilities. Additionally, injury risk due to heat radiation levels in excess of 4.7kW/m^2 and explosion overpressure levels greater than 7kPa were assessed. This assessment considered the entire project scope including the LNGC, FSRU, wharf facility and pipeline.

Figure 9-3 shows the 5E-05 frequency of heat radiation levels of 4.7kW/m^2 which have the potential to cause injury extend marginally outside of the fence line. No sensitive or residential areas are within this area.

The 5E-05 frequency of heat radiation levels of 23kW/m^2 which have the potential to cause damage and escalation at neighbouring facilities remains entirely within the fenceline and do not impact the nearby onshore industrial facilities.

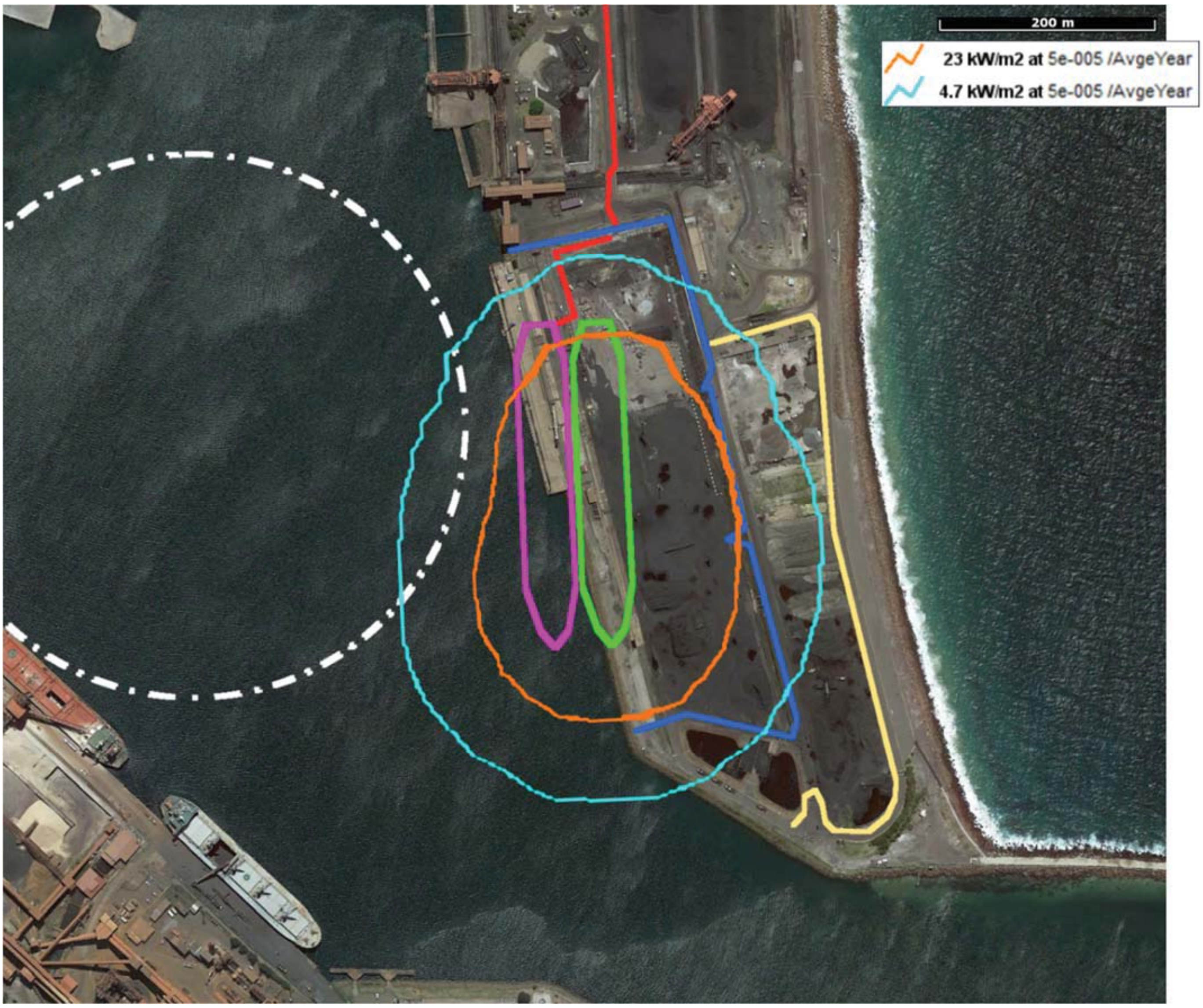


Figure 9-3: Propagation and Injury Risk due to Heat Radiation

Figure 9-4 shows the 5E-05 frequency of explosion overpressure levels of 7kPa which has the potential to cause injury remains on the FSRU, in the vicinity of the regasification module. It does not impact any sensitive or residential areas.

The 5E-05 frequency contour for explosion overpressure levels of 14kPa is not reached. There is no risk of damage or propagation at the surrounding industrial facilities due to explosion at the berth.

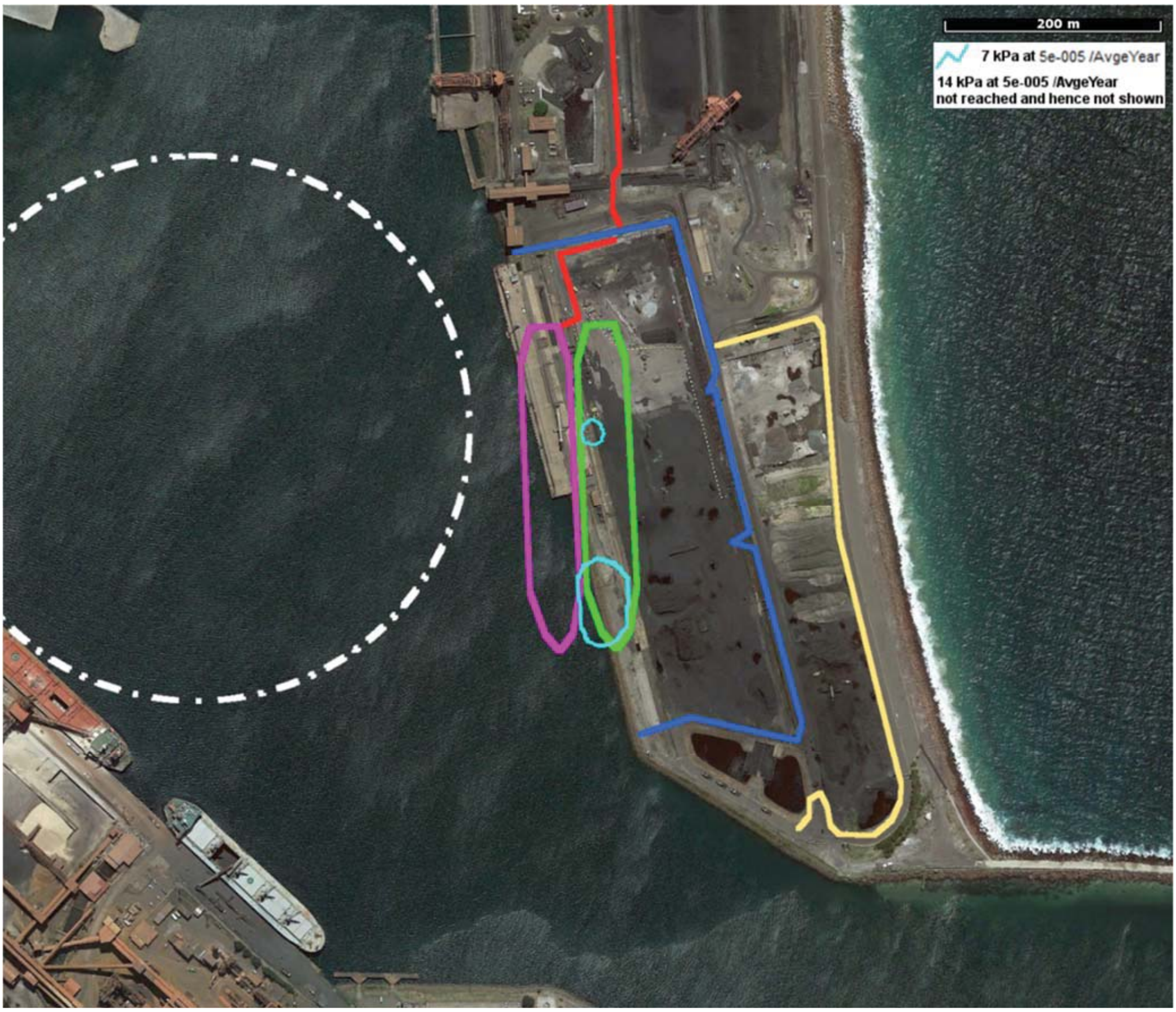


Figure 9-4: Propagation and Injury Risk due to Explosion Overpressure

9.2.2 Propagation Risk from Adjacent Facilities

A bulk liquids handling terminal owned by TQ Holdings Australia is proposed to be located to the North of the FSRU berth within Port Kembla harbour at berth 104. The PHA conducted for this facility shows neither the lowest individual fatality risk contour of 5E-07 for sensitive land use nor the propagation risk contour of 5E-05 reach the LNGC, FSRU or wharf facility [11].

A Soybean Processing and Biodiesel Production Facility is proposed to be located proposed at berth 103, also to the North of the FSRU berth 101. The facility risk assessment available for this facility concluded there were no offsite risks as consequence modelling did not exceed threshold values that would lead to damage or injury [21].

The current proposed pipeline route takes it close to the proposed liquids terminal and soybean processing facility. However the risk from this buried pipeline is within the 5E-07 contour along that section, well below the industrial risk criteria of 5E-05. Note that the pipeline in these sections will be buried to a minimum depth of 1.5m and is there not considered to be threatened by a fire vent at either the biodiesel or the bulk liquids facilities.

There is no publicly available risk model for the steelworks, therefore our assessment is based on the propagation and LSIR contours from the proposed LNG Terminal. These risk contours indicate a low level of risk at the steelworks from an event at the LNG Terminal.

9.3 Societal Risk

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

A quantitative assessment of societal risk was not carried out as the plotted LSIR contours indicated the associated societal risk in areas of population would be similarly low.

10. CONCLUSION

The results of the risk modelling conducted in this PHA are assessed against the HIPAP 4 criteria in Table 10-1 and Table 10-2 below.

Table 10-1: Risk Results Summary

HIPAP 4 Criteria (pa)	Land Use	Criteria Met
5E-07	Sensitive land use; e.g. hospitals, schools, child-care facilities, old age housing	Yes
1E-06	Residential area; including hotels, motels, tourist resorts	Yes – Cruise ships will berth outside the 1E-06 contour and will only be exposed to higher than 1E-06 risk whilst entering / leaving the Inner Harbour, i.e. exposure is low.
5E-06	Commercial development; including retails centres, offices and entertainment centres	Yes
1E-05	Active open space; including sporting complexes	No – Limited risk exposure to people on the private Seawall Road. The private road is only open during daylight hours, unless closed due to other port operational requirements. As a result, large numbers of people do not use this road regularly.
5E-05	Industrial	Yes – Risk contour is largely within the proposed facility boundary.

Table 10-2: Propagation and Injury Risk Results Summary

Frequency (pa)	HIPAP 4 Criteria	Criteria Met
5E-05	Damage and propagation – 23kW/m^2	Yes
5E-05	Damage and propagation – 14kPa	Yes
5E-05	Injury – 4.7kW/m^2	Yes
5E-05	Injury – 7kPa	Yes

11. REFERENCES

1. Hazardous Industry Planning Advisory Paper No 4 – Risk Criteria for Land Use Safety Planning, January 2011
2. Hazardous Industry Planning Advisory Paper No 6 – Hazard Analysis, January 2011
3. Port Kembla Gas Terminal Key Process Design Parameters Technical Decision Note, 401010-01496-PR-TQY-0001 Rev A
4. IP Research Report, Ignition Probability Review, Model Development Lookup Correlations, January 2006
5. A.W. Cox, F.P. Lees and M.L. Ang, Classification of Hazardous Locations, IChemE, 1990
6. UK HSE, Offshore Hydrocarbon Release Statistics, 1999, Offshore Technology Report OTO 1999 079
7. Committee for the Prevention of Disasters, Methods for the Calculation of Physical Effects (Yellow Book), TNO, 3rd Ed., 1997
8. Guideline for Quantitative Risk Assessment (Purple Book), TNO, CPR 18E, December 2005
9. A Guide to Quantitative Risk Assessment for Offshore Installation, The Centre for Marine and Petroleum Technology (CMPT), 1999
10. Guidance on Risk Analysis and Safety Implications of a Large Liquefied Natural Gas (LNG) Spill Over Water, Sandia Report, SAND2004-6258, 2004
11. Preliminary Hazard Analysis, Port Kembla Bulk Liquids Terminal, Environmental Impact Statement, PJ-PK-0001-REPT-010, December 2015
12. Pipelines – Gas and Liquid Petroleum – Part 1: Design and Construction, AS 2885.1 – 2012
13. Pipelines – Gas and Liquid Petroleum – Part 3: Operation and Maintenance, AS 2885.3 – 2012
14. The Handling and Transport of Dangerous Cargoes in Port Areas, AS 3846 – 2005
15. International Safety Guide for Oil Tankers and Terminals (ISGOTT)
16. Port Kembla Gas Terminal HAZID and HAZOP Studies Report, 401010-01496-SR-RPT-0003 Rev A
17. The Storage and Handling of Flammable and Combustible Liquids, AS 1940 – 2017
18. UKOPA 8th Report of the Fault Database Management Group, Pipeline Product Loss Incidents 1962-2010, UKOPA/11/0076, November 2011
19. International Association of Oil and Gas Producers (OGP) Risk Assessment Data Directory, Report No 434-4, Riser and Pipeline Release Frequencies, March 2010
20. G.A. Melham, H. Ozog and S. Saraf, Understanding LNG Rapid Phase Transitions, Hydrocarbon Processing, July 2006

21. Soybean Processing and Biodiesel Production Facility, Environmental Impact Statement, December 2008
22. Port Kembla Gas Terminal Navigation Simulation – Summary of Outcomes, 401010-01496-MA-TEN-0011 Rev 1

Appendix A. Wind Roses

[Add Appendix Subtitle]

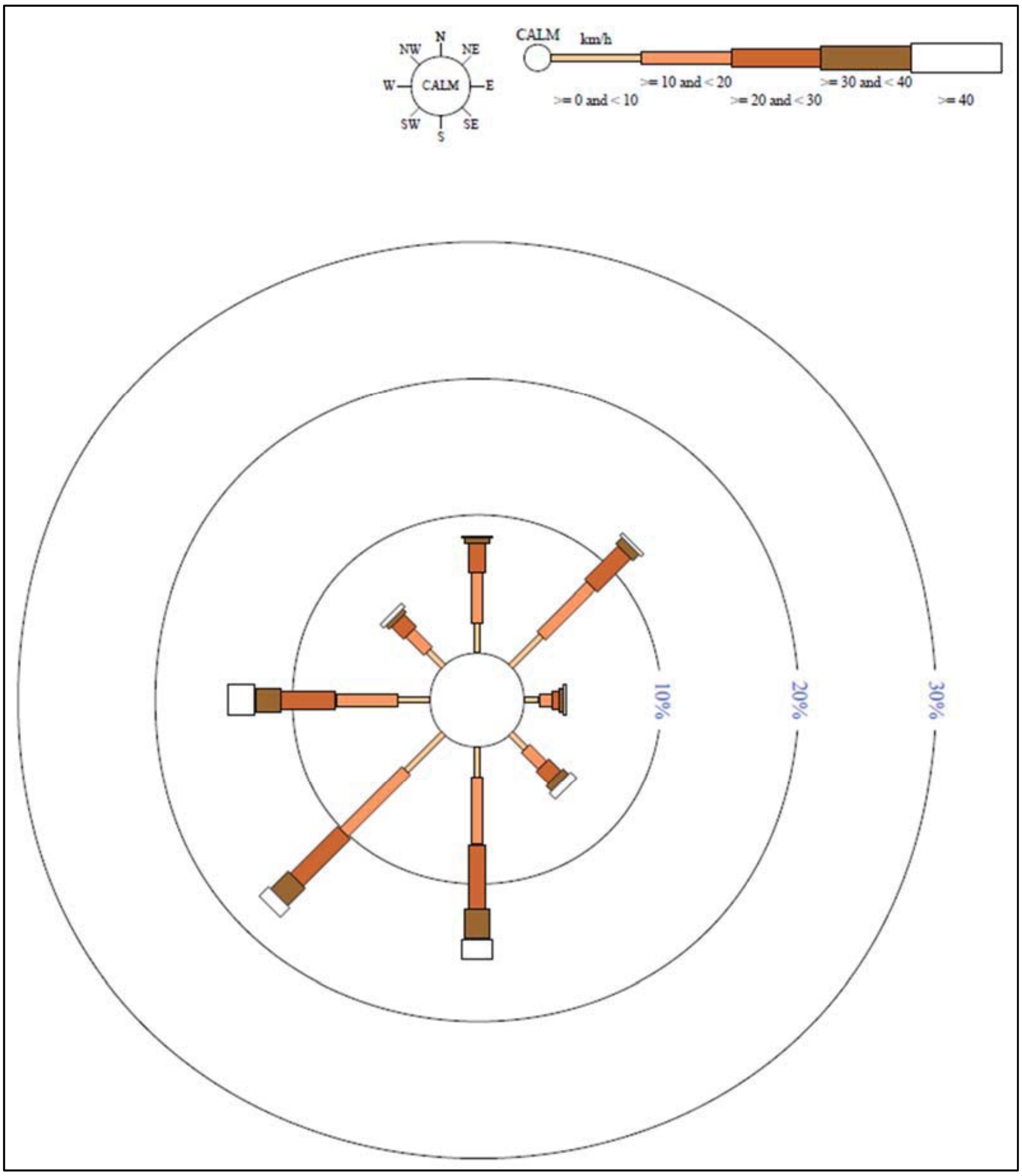


Figure 11-1: Wind Rose - Port Kembla - 9am

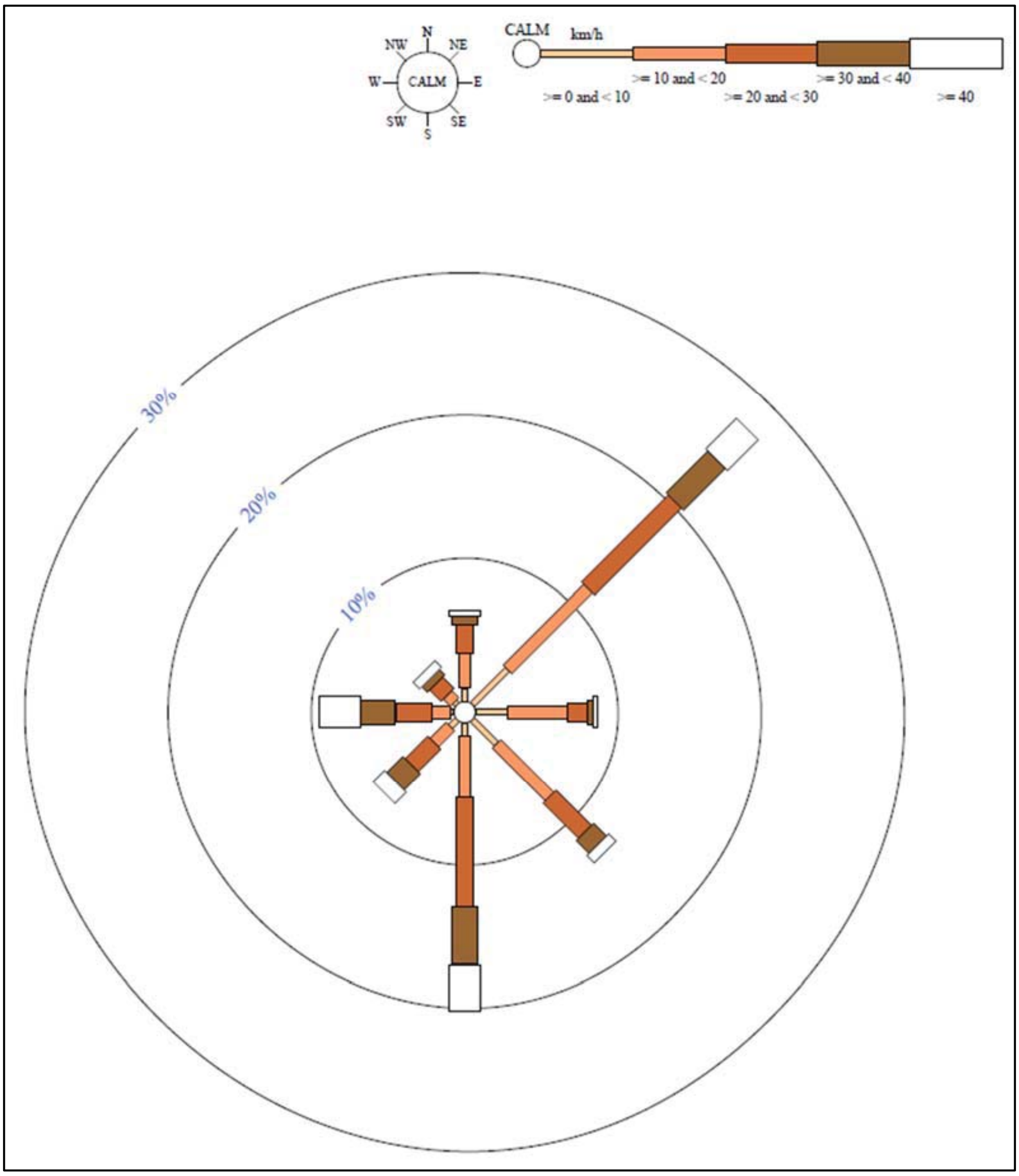


Figure 11-2: Wind Rose - Port Kembla - 3pm

Appendix B. Hazard Register

[Add Appendix Subtitle]

Node: 1. LNGC berthing and unloading

	Hazard Category & Guideword		Hazardous Event Description		Potential Consequences		Effective Safeguards		Comments
1	Natural Hazards - Extreme Weather	1	Cyclones / High Winds / Storms	1	Mechanical damage leading to LOC, fire / explosion	1	Designed for weather conditions in the area and reliant Australian Standards	1	Ship navigation and wave studies are being completed.
				2	Injury to ship crew and operators due to bad weather	2	Exclusion zone	2	Initially there will be two pilots per vessel and more stringent weather restrictions implemented. Subject to review once operations commence.
				3	Ship collision leading to damage to ship and LOC, fire / explosion	3	Warning protocols & ship movement procedures		
						4	Ignition Controls - Hazardous Area Classification and certified equipment		
						5	Fire and Gas Detection		
						6	Fire Protection		
						7	ESD		
						8	Tug support		
						9	Piloted vessels		
						10	Procedures - shutdown of FSRU		
		2	Fog	1	Reduced visibility causing collision with other ships leading to LOC, fire / explosion	1	SOPs	1	Initially there will be two pilots per vessel and more stringent weather restrictions implemented. Subject to review once operations commence.
						2	Navigational aids		
						3	Collision avoidance systems		
						4	Warning protocols & ship movement procedures		
						5	Ignition Controls - Hazardous Area Classification and certified equipment		
						6	Fire and Gas Detection		
						7	Fire Protection		
						8	ESD		
						9	Tug support		
						10	Piloted vessels		
						11	Exclusion zone		
		3	High ambient temperature	1	Heat stress on people	1	SOPs		
						2	Heat stress training		
2	Natural Hazards - Lightning	1	Lightning Strike	1	Damage to control systems and equipment	1	SOPs		
				2	Ignition of a LOC leading to fire / explosion	2	Lightning protection system		
						3	Fire and Gas Detection		
						4	Fire Protection		
						5	Vents designed at Safe locations/elevations		
						6	Earthing/Grounding system		
3	Natural Hazards - Seismic Activity	1	No significant hazard						
4	Natural Hazards - Erosion	1	No significant hazard						
5	Natural Hazards - Subsidence / Sediment Buildup	1	No significant hazard						
6	Environmental Impact - Discharges to Air	1	No significant hazard						
7	Environmental Impact - Discharges to Water	1	Transfer hose failure	1	Low pressure LOC of LNG, potential pool fire	1	Hose pressure testing and inspection		
				2	Low pressure LOC of LNG and potential rapid phase transition leading to damage of hull	2	Stainless steel wall on FSRU		
				3	Steel embrittlement leading to damage of hull	3	Water curtain between ships during transfer for cryogenic protection		
				4	Frost burns	4	Ignition Controls - Hazardous Area Classification and certified equipment		
						5	Fire and Gas Detection		
						6	Fire Protection		
						7	ESD		
		2	Waste / ballast from LNGC	1	Environmental incident	1	Regulated via Australian Marine Operations		
8	Environmental Impact - Discharges to Soil	1	No additional hazards					1	Wharf will be bunded
9	Environmental Impact - Noise	1	Transfer operations	1	No significant consequence				

	Hazard Category & Guideword		Hazardous Event Description		Potential Consequences		Effective Safeguards	Comments
10	External & Third Party Hazards - Sabotage	1	Refer Hazard #11					
11	External & Third Party Hazards - Terrorist Activity	1	Terrorist attack during transfer	1	Potential personal injury	1	Security plan in compliance with NSW counter terrorist police department	
				2	Equipment damage			
				3	Loss of supply / production			
12	External & Third Party Hazards - Third Party Activities	1	Low impact collision due to failure of one or more tugs (i.e. approach of LNGC to FSRU is disrupted due to the failure of one or more tugs)	1	Structural damage to LNGC, FSRU and jetty	1	SOPs	
				2	Loss of production	2	Emergency response	
		2	High impact collision from other vessel (i.e. cruise ships in harbour)	1	Ship collision leading to damage to ship and LOC, fire / explosion	1	Exclusion zone	
				2	Loss of production	2	Warning protocols & procedures	
				3	Rupture of fender	3	Ignition Controls - Hazardous Area Classification and certified equipment	
						4	Fire and Gas Detection	
						5	Fire Protection	
						6	ESD	
						7	Tug support	
						8	Piloted vessels	
13	External & Third Party Hazards - Helicopter / Aircraft Crash / Drone	1	No additional hazards					
14	Fire and Explosion Hazards - Stored Flammables	1	LNG release	1	Ignition of a LOC leading to fire / explosion	1	Fire & gas systems	
				2	Cryogenic effects on structure and potential injury to personnel / frost burn	2	Ignition Controls - Hazardous Area Classification and certified equipment	
						3	Fire Protection	
						4	Water curtain between ships during transfer	
						5	ESD systems	
15	Fire and Explosion Hazards - Sources of Ignition	1	Instrumentation, electrical equipment	1	Ignition of a LOC leading to fire / explosion	1	Fire & gas systems	
						2	Ignition Controls - Hazardous Area Classification and certified equipment	
						3	Permit to work	
						4	Separation	
		2	Engines including diesel and gas generators	1	Ignition of a LOC leading to fire / explosion	1	Ignition Controls - Hazardous Area Classification and certified equipment	
						2	Fire & gas systems	
						3	Permit to work	
						4	Separation	
		3	Static	1	Ignition of a LOC leading to fire / explosion	1	Earthing / grounding system	
						2	Fire & gas systems	
16	Fire and Explosion Hazards - Equipment Layout	1	Refer Hazard #12, exclusion zones around vessel					
17	Fire and Explosion Hazards - Fire Protection and Response	1	No additional hazards					
18	Fire and Explosion Hazards - Operator Protection	1	Exposure to fire	1	Burns to skin	1	PPE, fire alarm and procedures	
						2	Fire fighting aids / vessels	
						3	Escape routes and temporary refuge on FSRU and LNGC	
						4	Pre transfer meeting prior to LNGC berthing	
						5	LNGC to comply with port authority regulations	
19	Process Hazards - Start-up / Shutdown	1	Thermal shock	1	Mechanical damage / equipment failure and LOC leading to potential fire / explosion	1	Start up procedures	
						2	System designed for cool down during start up	
						3	Control systems and instrumented safety shutdown systems	
						4	Ignition Controls - Hazardous Area Classification and certified equipment	
						5	Fire and Gas Detection	

Hazard Category & Guideword		Hazardous Event Description		Potential Consequences		Effective Safeguards		Comments
						6	Fire Protection	
						7	ESD	
20	Process Hazards - Inventory	1	Refer Hazard #14					
21	Process Hazards - Pressure / Corrosion / Temperature	1	External / internal corrosion	1	LOC leading to potential fire / explosion	1	Corrosion protection system (CP) on FSRU - switched off during LNGC berthing / transfer	
						2	Material selection	
						3	Periodic inspection	
						4	Anti-corrosive coating	
						5	ESD	
						6	Ignition Controls - Hazardous Area Classification and certified equipment	
						7	Fire and Gas Detection	
						8	Fire Protection	
						9	Internal corrosion - dry product	
		2	Thermal expansion and overpressure of low pressure systems	1	Overpressure leading to LOC, potential fire	1	Overpressure protection systems	
						2	ESD	
						3	Ignition Controls - Hazardous Area Classification and certified equipment	
						4	Fire and Gas Detection	
						5	Fire Protection	
22	Process Hazards - Release of Inventory	1	Transfer hose failure	1	Low pressure LOC of LNG, potential pool fire	1	Hose pressure testing and inspection	
				2	Low pressure LOC of LNG and potential rapid phase transition leading to damage of hull	2	Stainless steel wall on FSRU	
				3	Steel embrittlement leading to damage of hull	3	Water curtain between ships during transfer for cryogenic protection	
				4	Frost burns	4	Ignition Controls - Hazardous Area Classification and certified equipment	
						5	Fire and Gas Detection	
						6	Fire Protection	
						7	ESD	
23	Process Hazards - Overfilling FSRU / LNGC cargo tank	1	Overfilling FSRU / LNGC cargo tank leading to liquid in vapour lines	1	Material damage leading to LOC, potential explosion	1	SOPs	
						2	Instrumented protection	
						3	Ignition Controls - Hazardous Area Classification and certified equipment	
						4	Fire and Gas Detection	
						5	Fire Protection	
						6	ESD	
24	Process Hazards - Toxic Substances	1	Nitrogen release	1	Potential asphyxiation but very low probability	1	SOPs	
						2	Open areas with natural ventilation	
						3	Small nitrogen inventory	
25	Process Hazards - Overpressure	1	Refer Hazard #21					
26	Process Hazards - Hot / Cold Surfaces	1	Operator exposed to cryogenics or cold surfaces	1	Injury to personnel / frost burn	1	PPE	
						2	Guarding	
27	Utility Systems - Failure of Firewater Systems	1	Insufficient fire fighting system (water / inerting)	1	Escalation of a fire event	1	Design to relevant standards and redundancy	
				2	Loss of production	2	Testing and maintenance	
						3	ESD	
						4	Ignition Controls - Hazardous Area Classification and certified equipment	
						5	Fire and Gas Detection	
						6	Fire Protection	
						7	Emergency response	

	Hazard Category & Guideword		Hazardous Event Description		Potential Consequences		Effective Safeguards	Comments
28	Utility Systems - Failure of Fuel Gas	1	Loss of fuel gas leading to controlled venting	1	No significant consequence	1	Diesel fuel back-up	
29	Utility Systems - Failure of Heating Medium	1	No significant hazard					
30	Utility Systems - Failure of Diesel Fuel / Fuel Oil	1	Loss of power	1	Venting of gas (environmental incident)	1	Emergency generator and UPS	
				2	Loss of maneuverability of LNGC	2	Controlled gas venting to safe location	
						3	Tug support	
31	Utility Systems - Failure of Power Supply	1	Refer Hazard #30					
32	Utility Systems - Failure of Steam	1	Not applicable					
33	Utility Systems - Failure of Drains	1	No additional hazards					
34	Utility Systems - Failure of Inert Gas	1	Loss of nitrogen	1	Loss of inerting gas to LNG tank leading to potential air ingress, flammable mixture, fire / explosion	1	Alarms	
						2	Backup nitrogen generation system	
						3	ESD	
						4	Ignition Controls - Hazardous Area Classification and certified equipment	
						5	Fire and Gas Detection	
						6	Fire Protection	
35	Utility Systems - Failure of Waste Storage and Treatment	1	Discharge to harbour	1	Environmental incident	1	Compliance with MARPOL	
						2	Increased tank holding capacity on FSRU	
36	Utility Systems - Failure of Chemical / Fuel Storage	1	No significant hazard					
37	Utility Systems - Failure of Potable Water	1	No significant hazard					
38	Utility Systems - Failure of Sewerage	1	Refer Hazard #35					
39	Maintenance Hazards - Access Requirements	1	Occupational hazards during LNGC berthing	1	Over tensioning in ropes and mooring lines leading to personal injury	1	Mooring procedure for both FSRU and LNGC	
				2	Loss of mooring leading to delays	2	Checklist for inspection of mooring and rope lines	
						3	Emergency response	
						4	Quick release hooks with load monitoring	
40	Maintenance Hazards - Override Necessary	1	No additional hazards					
41	Maintenance Hazards - Bypasses Required	1	No additional hazards					
42	Maintenance Hazards - Commonality of Equipment	1	No additional hazards					
43	Maintenance Hazards - Heavy Lifting Requirements	1	Crane transfer activities	1	Potential dropped / swinging object leading to equipment damage and personal injury	1	SOPs	
44	Maintenance Hazards - Transport	1	Personnel transfer	1	Potential dropped / swinging object leading to equipment damage and personal injury	1	SOPs	
						2	Crane certified for personnel transfer	
45	Maintenance Hazards - Adequate Lighting	1	No additional hazards					
46	Construction / Existing Facilities - Tie-ins (Shutdown Requirements)	1	Not applicable					
47	Construction / Existing Facilities - Concurrent Operations	1	Not applicable					
48	Construction / Existing Facilities - Contaminated Material	1	Not applicable					
49	Construction / Existing Facilities - Existing Equipment Condition	1	No significant hazard					
50	Construction / Existing Facilities - Common Equipment Capacity	1	No additional hazards					
51	Construction / Existing Facilities - Interface (Shutdown / Blowdown / ESD)	1	No additional hazards					
52	Construction / Existing Facilities - Skid Dimensions (Weight Handling / Equipment (Congestion))	1	No additional hazards					
53	Construction / Existing Facilities - Soil Contamination (Existing Facilities)	1	Not applicable					
54	Construction / Existing Facilities - Mobilisation / Demobilisation	1	Not applicable					

Hazard Category & Guideword	Hazardous Event Description	Potential Consequences	Effective Safeguards	Comments
55 Excessive relevant movement between LNGC and FSRU	1 Movement between LNGC and FSRU leading to snapping of mooring lines	1 Tension on transfer hoses leading to LP LOC of LNG, potential pool fire	1 SOPs	
		2 Personal injury from mooring line impact	2 Weather operating window	
			3 Designed for passing vessel loads	
			4 Emergency release system with proximity sensor (wire)	
56 LNGC berthing and departure	1 Impact with northern quay wall during berthing and departure	1 Damage to LNGC vessel and rudder system leading to loss of steering	1 Training	
			2 Piloted vessels	
			3 LNGC compatibility with mooring layout	

Node: 2. FSRU and port operations

Hazard Category & Guideword	Hazardous Event Description	Potential Consequences	Effective Safeguards	Comments
1 Natural Hazards - Extreme Weather	1 Cyclones / High Winds / Storms	1 Mechanical damage leading to LOC, fire / explosion	1 Designed for weather conditions in the area and reliant Australian Standards (including dynamic mooring analysis to establish survival limits)	
		2 Injury to ship crew and operators due to bad weather	2 Exclusion zone	
		3 Ship collision leading to damage to ship and LOC, fire / explosion	3 Warning protocols & ship movement procedures	
			4 Ignition Controls - Hazardous Area Classification and certified equipment	
			5 Fire and Gas Detection	
			6 Fire Protection	
			7 ESD	
			8 Tug support	
			9 Piloted vessels	
			10 Procedures - shutdown of FSRU	
	2 Fog	1 Reduced visibility causing collision with other ships leading to LOC fire / explosion	1 SOPs	
			2 Navigational aids	
			3 Collision avoidance systems	
			4 Warning protocols & ship movement procedures	
			5 Ignition Controls - Hazardous Area Classification and certified equipment	
			6 Fire and Gas Detection	
			7 Fire Protection	
			8 ESD	
			9 Tug support	
			10 Piloted vessels	
			11 Exclusion zone	
	3 High ambient temperature	1 Heat stress on people	1 SOPs	
			2 Heat stress training	
2 Natural Hazards - Lightning	1 Lightning Strike	1 Damage to control systems and equipment	1 Lightning protection system	
		2 Ignition of a LOC leading to fire / explosion	2 Fire and Gas Detection	
			3 Fire Protection	
			4 Vents designed at Safe locations/elevations	
			5 Lighting Risk Assessment to Australian Standards	
			6 Earthing/Grounding system	
3 Natural Hazards - Seismic Activity	1 Not applicable			
4 Natural Hazards - Erosion	1 No significant hazard			
5 Natural Hazards - Subsidence / Sediment Buildup	1 Sediment build-up underneath of FSRU	1 Damage to hull	1 Design clearance	
		2 Sea water system draws in sediment leading to potential	2 Instrumented protection	

No.	Hazard Category & Guideword	No.	Hazardous Event Description	No.	Potential Consequences	No.	Effective Safeguards	No.	Comments
					loss of heating resulting in loss of vapourisation, potential LOC, fire / explosion	3	Ignition Controls - Hazardous Area Classification and certified equipment		
						4	Fire and Gas Detection		
						5	Fire Protection		
						6	ESD		
6	Environmental Impact - Discharges to Air	1	Venting BOG	1	Greenhouse gas emission	1	System is designed with BOG recovery and Gas Combustion Unit.		
		2	Emergency venting	1	Greenhouse gas emission	1	Controlled emergency venting to safe location/elevation		
		3	Power generation	1	Greenhouse gas emission	1	Venting to safe location/elevation		
						2	Fuel selection - high sulphur fuel oil is not used		
						3	Compliant with IMO regulations		
		4	Odorant release	1	Community complaints	1	Non-toxic		
		5	Maintenance / depressuring / purging / sampling activities	1	Greenhouse gas emission	1	Venting to safe location/elevation		
						2	Small volume release (for sampling)		
						3	Compliant with IMO regulations		
7	Environmental Impact - Discharges to Water	1	Low temperature discharge to marine environment from regas system	1	Impact marine life, sea grass and fish population	1	Regulatory control and design		
						2	Control systems and instrumented safety shutdown systems (temperature monitoring of seawater inlet and outlet)		
						3	Marine plume modelling to determine impact		
		2	Greywater, raw sewage and bilge water	1	Impact marine life, sea grass and fish population	1	Regulatory control and design		
						2	Onshore disposal		
		3	Chlorine and other biological control	1	Impact marine life, sea grass and fish population	1	Regulatory control and design		
						2	SOPs		
		4	Leak / tube rupture in intermediate glycol loop leading to glycol discharge to sea via rupture disk	1	Impact marine life, sea grass and fish population	1	QA / QC on heat exchangers		
				2	Loss of production	2	Maintenance on heat exchangers		
						3	No identified erosion / corrosion mechanism on either side of heat exchanger		
		5	Seawater lift pump oil circulation failure leading to discharge of oil to sea	1	Impact marine life, sea grass and fish population	1	Instrumented protection		
				2	Loss of production	2	QA / QC		
						3	Maintenance on seawater lift pump		
		6	Bunkering of liquid fuel (diesel) - infrequent activity	1	Impact marine life, sea grass and fish population	1	SOPs		
						2	Port authority controlled activity		
		7	Anti-fouling and hull cleaning (required for five yearly surveys)	1	Impact marine life, sea grass and fish population	1	SOPs		
8	Environmental Impact - Discharges to Soil	1	No additional hazards					1	Wharf will be bunded.
9	Environmental Impact - Noise	1	Power generation	1	Potential personnel injury	1	Acoustic enclosure		
				2	Community complaints	2	PPE		
						3	Equipment specifications		
		2	Gas pressure letdown system	1	Potential personnel injury	1	PPE	1	Need for a letdown station is not yet defined.
				2	Community complaints	2	Equipment specifications		
		3	Pumps	1	Potential personnel injury	1	PPE		
				2	Community complaints	2	Equipment specifications		
		4	Compressors	1	Potential personnel injury	1	PPE		
				2	Community complaints	2	Equipment specifications		
		5	Vents	1	Potential personnel injury	1	PPE		
				2	Community complaints	2	Equipment specifications		
10	External & Third-Party Hazards - Sabotage	1	Sabotage	1	LOC leading to potential fire and explosion.	1	Exclusion zone		
						2	Security fencing and CCTV		

Hazard Category & Guideword	Hazardous Event Description	Potential Consequences	Effective Safeguards	Comments
			3 Security patrols	
			4 Ignition Controls - Hazardous Area Classification and certified equipment	
			5 Fire and Gas Detection	
			6 Fire Protection	
			7 ESD	
			8 Security plan in compliance with NSW counter terrorist police department	
11 External & Third-Party Hazards - Terrorist Activity	1 Terrorist activity	1 LOC leading to potential fire and explosion	1 Exclusion zone	
			2 Security fencing and CCTV	
			3 Security patrols	
			4 Ignition Controls - Hazardous Area Classification and certified equipment	
			5 Fire and Gas Detection	
			6 Fire Protection	
			7 ESD	
			8 Security plan in compliance with NSW counter terrorist police department	
12 External & Third-Party Hazards - Third Party Activities	1 High impact collision from other vessel (i.e. cruise ships in harbour)	1 Ship collision leading to damage to ship and LOC, fire / explosion	1 Exclusion zone	
		2 Loss of production	2 Warning protocols & procedures	
		3 Rupture of fender	3 Ignition Controls - Hazardous Area Classification and certified equipment	
			4 Fire and Gas Detection	
			5 Fire Protection	
			6 ESD	
			7 Tug support	
			8 Piloted vessels	
	2 Coal terminal facilities - escalation from FSRU to coal terminal	1 Escalation of fire event leading to coal stockpile fire	1 ESD	
		2 Coal fire escalation leading to LOC within facility	2 Ignition Controls - Hazardous Area Classification and certified equipment	
			3 Fire and Gas Detection	
			4 Active Fire Protection	
			5 ESD	
			6 Fire and Gas Detection	
			7 Fire Protection	
			8 Emergency response	
	3 Steelworks - escalation from steelworks to FSRU	1 Iron ore dust impacting FSRU equipment / instrumentation		
13 External & Third-Party Hazards - Helicopter / Aircraft Crash	1 Aircraft movements	1 No credible consequences		
14 Fire and Explosion Hazards - Stored Flammables	1 Storage of paint / grease / chemicals and lube oil	1 Fire and personal injury	1 Dedicated storage area with CO2 fire protection (excluding lube oil)	
15 Fire and Explosion Hazards - Sources of Ignition	1 Instrumentation, electrical equipment	1 Ignition of a LOC leading to fire / explosion	1 Ignition Controls - Hazardous Area Classification and certified equipment	
			2 Fire & gas systems	
			3 Permit to work	
			4 Separation	
	2 Engines including diesel and gas generators	1 Ignition of a LOC leading to fire / explosion	1 Ignition Controls - Hazardous Area Classification and certified equipment	
			2 Fire & gas systems	
			3 Permit to work	

No.	Hazard Category & Guideword	No.	Hazardous Event Description	No.	Potential Consequences	No.	Effective Safeguards	Comments
						4	Separation	
		3	Static	1	Ignition of a LOC leading to fire / explosion	1	Earthing/Grounding system	
						2	Fire & gas systems	
16	Fire and Explosion Hazards - Equipment Layout	1	Refer Hazard #12					
17	Fire and Explosion Hazards - Fire Protection and Response	1	No additional hazards					
18	Fire and Explosion Hazards - Operator Protection	1	No additional hazards					
19	Process Hazards - Start-up / Shutdown	1	Not covered in this node as related to FSRU design - refer to generic FSRU HAZID					
20	Process Hazards - Inventory	1	Not covered in this node as related to FSRU design - refer to generic FSRU HAZID					
21	Process Hazards - Pressure / Corrosion / Temperature	1	Not covered in this node as related to FSRU design - refer to generic FSRU HAZID					
22	Process Hazards - Release of Inventory	1	Not covered in this node as related to FSRU design - refer to generic FSRU HAZID					
23	Process Hazards - Toxic Substances	1	Not covered in this node as related to FSRU design - refer to generic FSRU HAZID					
24	Process Hazards - Overpressure	1	Not covered in this node as related to FSRU design - refer to generic FSRU HAZID					
25	Process Hazards - Hot / Cold Surfaces	1	Not covered in this node as related to FSRU design - refer to generic FSRU HAZID					
26	Utility Systems - Failure of Firewater Systems	1	Insufficient fire fighting system (water / inerting)	1	Escalation of a fire event	1	Design to relevant standards and redundancy	
						2	Testing and maintenance	
						3	ESD systems	
						4	Ignition Controls - Hazardous Area Classification and certified equipment	
						5	Fire and Gas Detection	
						6	Fire Protection	
27	Utility Systems - Failure of Fuel Gas	1	Not covered in this node as related to FSRU design - refer to generic FSRU HAZID					
28	Utility Systems - Failure of Heating Medium	1	Not covered in this node as related to FSRU design - refer to generic FSRU HAZID					
29	Utility Systems - Failure of Diesel Fuel / Fuel Oil	1	Not covered in this node as related to FSRU design - refer to generic FSRU HAZID					
30	Utility Systems - Failure of Power Supply	1	Not covered in this node as related to FSRU design - refer to generic FSRU HAZID					
31	Utility Systems - Failure of Steam	1	Not covered in this node as related to FSRU design - refer to generic FSRU HAZID					
32	Utility Systems - Failure of Drains	1	Not covered in this node as related to FSRU design - refer to generic FSRU HAZID					
33	Utility Systems - Failure of Inert Gas	1	Not covered in this node as related to FSRU design - refer to generic FSRU HAZID					
34	Utility Systems - Failure of Waste Storage and Treatment	1	Not covered in this node as related to FSRU design - refer to generic FSRU HAZID					
35	Utility Systems - Failure of Chemical / Fuel Storage	1	Not covered in this node as related to FSRU design - refer to generic FSRU HAZID					
36	Utility Systems - Failure of Potable Water	1	Not covered in this node as related to FSRU design - refer to generic FSRU HAZID					
37	Utility Systems - Failure of Sewerage	1	Not covered in this node as related to FSRU design - refer to generic FSRU HAZID					
38	Maintenance Hazards - Access Requirements	1	Maintenance dredging	1	Dredging operations collision leading to ship damage	1	Warning protocols & ship movement procedures	
		2	External FSRU inspection and maintenance	1	Personnel injury	1	Minimised requirement for external maintenance work	
						2	Procedures / Diving controls	

#	Hazard Category & Guideword	#	Hazardous Event Description	#	Potential Consequences	#	Effective Safeguards	Comments
						3	Permit to work	
39	Maintenance Hazards - Override Necessary	1	Not covered in this node as related to FSRU design - refer to generic FSRU HAZID					
40	Maintenance Hazards - Bypasses Required	1	Not covered in this node as related to FSRU design - refer to generic FSRU HAZID					
41	Maintenance Hazards - Commonality of Equipment	1	Not covered in this node as related to FSRU design - refer to generic FSRU HAZID					
42	Maintenance Hazards - Heavy Lifting Requirements	1	Lifting of provisions from wharf to FSRU	1	Potential dropped / swinging object leading to equipment damage and personal injury			
43	Maintenance Hazards - Transport	1	Not covered in this node as related to FSRU design - refer to generic FSRU HAZID					
44	Maintenance Hazards - Adequate Lighting	1	Not covered in this node as related to FSRU design - refer to generic FSRU HAZID					
45	Construction / Existing Facilities - Tie-ins (Shutdown Requirements)	1	Not applicable					
46	Construction / Existing Facilities - Concurrent Operations	1	Not applicable					
47	Construction / Existing Facilities - Contaminated Material	1	Not applicable					
48	Construction / Existing Facilities - Existing Equipment Condition	1	Not applicable					
49	Construction / Existing Facilities - Common Equipment Capacity	1	Not applicable					
50	Construction / Existing Facilities - Interface (Shutdown / Blowdown / ESD)	1	Not covered in this node as related to FSRU design - refer to generic FSRU HAZID					
51	Construction / Existing Facilities - Skid Dimensions (Weight Handling / Equipment (Congestion))	1	Not applicable					
52	Construction / Existing Facilities - Soil Contamination (Existing Facilities)	1	Not applicable					
53	Construction / Existing Facilities - Mobilisation / Demobilisation	1	Not covered in this node as related to FSRU design - refer to generic FSRU HAZID					

Node: 3. Gas unloading arms and wharf facilities

#	Hazard Category & Guideword	#	Hazardous Event Description	#	Potential Consequences	#	Effective Safeguards	Comments
1	Natural Hazards - Extreme Weather	1	Cyclones / High Winds / Storms	1	Mechanical damage to MLA leading to LOC, fire / explosion	1	Designed for weather conditions in the area and reliant Australian Standards	
						2	Weather warning system	
						3	Ignition Controls - Hazardous Area Classification and certified equipment	
						4	Fire and Gas Detection	
						5	Fire Protection	
						6	ESD	
						7	Procedures - shutdown of FSRU	
		2	High ambient temperature	1	Heat stress on people	1	SOPs	
						2	Heat stress training	
2	Natural Hazards - Lightning	1	Lightning Strike	1	Damage to control systems and equipment	1	Lightning protection system	
				2	Ignition of a LOC leading to fire / explosion	2	Fire and Gas Detection	
						3	Fire Protection	
						4	Vents designed at Safe locations/elevations	
						5	Lighting Risk Assessment to Australian Standards	

No.	Hazard Category & Guideword	No.	Hazardous Event Description	No.	Potential Consequences	No.	Effective Safeguards	Comments
						6	Earthing / Grounding system	
3	Natural Hazards - Seismic Activity	1	Earthquake	1	Mechanical damage leading to LOC, fire / explosion	1	Design is based on seismic zone classification and relevant Australian Standard	
						2	HPLA proximity sensors	
						3	Ignition Controls - Hazardous Area Classification and certified equipment	
						4	Fire and Gas Detection	
						5	Fire Protection	
						6	ESD	
4	Natural Hazards - Erosion	1	Erosion under wharf piles	1	Equipment and wharf damage leading to injury / equipment damage	1	Rock socket design for piles	
		2	Erosion of the harbour	1	Damage to harbour walls	1	Revetment at north and south of wharf	
5	Natural Hazards - Subsidence / Sediment Buildup	1	Subsidence due to settlement	1	Overstressing of pipework leading to LOC, potential fire	1	Compaction of backfill material	
						2	Expansion loops on some pipework	
6	Environmental Impact - Discharges to Air	1	Maintenance vent	1	No significant consequence			
		2	Odorant release	1	Community complaints	1	Non-toxic	
						2	Enclosed building	
7	Environmental Impact - Discharges to Water	1	Firewater testing / rainwater from site	1	No significant consequence	1	Drainage philosophy for design	
8	Environmental Impact - Discharges to Soil	1	Refer Hazard #7					
9	Environmental Impact - Noise	1	Power generation	1	No significant consequence			
		2	Gas transfer operations via MLA	1	No significant consequence			
10	External & Third-Party Hazards - Sabotage	1	Sabotage	1	LOC leading to potential fire and explosion	1	Security fencing and CCTV	
						2	Security patrols	
						3	Ignition Controls - Hazardous Area Classification and certified equipment	
						4	Fire and Gas Detection	
						5	Fire Protection	
						6	ESD	
						7	Security plan in compliance with NSW counter terrorist police department	
11	External & Third-Party Hazards - Terrorist Activity	1	Terrorist activity	1	LOC leading to potential fire and explosion	1	Security fencing and CCTV	
						2	Security patrols	
						3	Ignition Controls - Hazardous Area Classification and certified equipment	
						4	Fire and Gas Detection	
						5	Fire Protection	
						6	ESD	
						7	Security plan in compliance with NSW counter terrorist police department	
12	External & Third-Party Hazards - Third Party Activities	1	No additional hazards					
13	External & Third-Party Hazards - Helicopter / Aircraft Crash	1	No additional hazards					
14	Fire and Explosion Hazards - Stored Flammables	1	Diesel storage for firewater pump and generator	1	Uncontrolled leakage leading to environmental incident, potential fire and personal injury	1	Secondary containment system for diesel	
						2	Fire Protection	
15	Fire and Explosion Hazards - Sources of Ignition	1	Instrumentation, electrical equipment	1	Ignition of a LOC leading to fire / explosion	1	Separation	
						2	Ignition Controls - Hazardous Area Classification and certified equipment	
						3	Fire & gas systems	
						4	Permit to work	
		2	Hot works	1	Ignition of a LOC leading to fire / explosion	1	Separation	

No.	Hazard Category & Guideword	No.	Hazardous Event Description	No.	Potential Consequences	No.	Effective Safeguards	Comments
						2	Ignition Controls - Hazardous Area Classification and certified equipment	
						3	Fire & gas systems	
						4	Permit to work	
		3	Engines including firewater pump and diesel generator	1	Ignition of a LOC leading to fire / explosion	1	Separation	
						2	Ignition Controls - Hazardous Area Classification and certified equipment	
						3	Fire & gas systems	
						4	Permit to work	
		4	Static	1	Ignition of a LOC leading to fire / explosion	1	Earthing/Grounding system	
						2	Fire & gas systems	
16	Fire and Explosion Hazards - Equipment Layout	1	No additional hazards					
17	Fire and Explosion Hazards - Fire Protection and Response	1	No additional hazards					
18	Fire and Explosion Hazards - Operator Protection	1	Exposure to fire	1	Burns to skin	1	PPE, fire alarm and procedures	
						2	Fire fighting aids	
						3	Escape routes	
19	Process Hazards - Start-up / Shutdown	1	No additional hazards					
20	Process Hazards - Inventory	1	No additional hazards					
21	Process Hazards - Pressure / Corrosion / Temperature	1	External / internal corrosion	1	LOC leading to potential fire / explosion	1	Material selection	
						2	Periodic inspection	
						3	Anti-corrosive coating	
						4	Ignition Controls - Hazardous Area Classification and certified equipment	
						5	Fire and Gas Detection	
						6	Fire Protection	
		2	High pressure system - gas systems	1	Overpressure leading to LOC and potential fire / explosion	1	Overpressure protection systems	
						2	Ignition Controls - Hazardous Area Classification and certified equipment	
						3	Fire and Gas Detection	
						4	Fire Protection	
		3	Low Temperature exposure due to failure of regas system by fouling, loss of heating medium, excess demand	1	LNG contact with downstream system causing brittle failure of piping / equipment leading to release, potential fire / explosion	1	Control systems and instrumented safety shutdown systems	
						2	ESD	
						3	Ignition Controls - Hazardous Area Classification and certified equipment	
						4	Fire and Gas Detection	
						5	Fire Protection	
		4	LNG release on FSRU from high pressure systems, mechanical failure, fatigue etc.	1	Potential for brittle fracture, causing structure failure leading to LOC and potential fire / explosion	1	Fire Protection	
						2	Fire and Gas Detection	
						3	Ignition Controls - Hazardous Area Classification and certified equipment	
						4	ESD	
						5	Control systems and instrumented safety shutdown systems	
22	Process Hazards - Release of Inventory	1	Failure of loading arms	1	Release of gas leading to fire and injury	1	Equipment inspection	
						2	ESD	
						3	Ignition Controls - Hazardous Area Classification and certified equipment	
						4	Fire and Gas Detection	
						5	Wharf design limits potential for gas ingress under wharf.	
23	Process Hazards - Toxic Substances	1	Nitrogen release	1	Potential asphyxiation but very low probability	1	SOPs	

No.	Hazard Category & Guideword		Hazardous Event Description		Potential Consequences		Effective Safeguards	Comments
						2	Open areas with natural ventilation	
						3	Small nitrogen inventory	
24	Process Hazards - Overpressure	1	Surge caused by quick closing valves on MLA	1	Overpressure leading to equipment damage	1	Equipment design	
						2	HIPPs valve closure	
						3	Infrequent occurrence	
25	Process Hazards - Hot / Cold Surfaces	1	No additional hazards					
26	Utility Systems - Failure of Firewater Systems	1	Insufficient fire fighting system (water / inerting)	1	Escalation of a fire event	1	Design to relevant standards and redundancy	
						2	Testing and maintenance	
						3	ESD systems	
						4	Ignition Controls - Hazardous Area Classification and certified equipment	
						5	Fire and Gas Detection	
						6	Fire Protection on FSRU	
						7	Escape routes	
27	Utility Systems - Failure of Fuel Gas	1	Not applicable					
28	Utility Systems - Failure of Heating Medium	1	Not applicable					
29	Utility Systems - Failure of Diesel Fuel / Fuel Oil	1	Loss of diesel fuel to firewater pump or generator	1	Refer Hazard #26 for insufficient fire fighting system. Failure of diesel to generator results in safe shutdown of process.			
30	Utility Systems - Failure of Power Supply	1	Loss of power supply	1	Loss of power leading to PSD	1	UPS	
						2	Back-up generator	
31	Utility Systems - Failure of Steam	1	Not applicable					
32	Utility Systems - Failure of Drains	1	No additional hazards					
33	Utility Systems - Failure of Inert Gas	1	Loss of nitrogen	1	Loss of inerting gas to MLA leading to inability to purge MLA			
34	Utility Systems - Failure of Waste Storage and Treatment	1	Offloading sewerage and greywater from FSRU	1	Spills to wharf leading to environmental incident	1	SOPs	
35	Utility Systems - Failure of Chemical / Fuel Storage	1	Refer Hazard #6 for odourant release					
		2	Firewater treatment (biocide)	1	Spills to wharf leading to environmental incident			
36	Utility Systems - Failure of Potable Water	1	Not applicable					
37	Utility Systems - Failure of Sewerage	1	Not applicable					
38	Maintenance Hazards - Access Requirements	1	Failure of mooring lines	1	Personal injury from mooring line impact			
39	Maintenance Hazards - Override Necessary	1	No additional hazards					
40	Maintenance Hazards - Bypasses Required	1	No additional hazards					
41	Maintenance Hazards - Commonality of Equipment	1	No additional hazards					
42	Maintenance Hazards - Heavy Lifting Requirements	1	Lifting of provisions from wharf to FSRU	1	Potential dropped / swinging object leading to equipment damage and personal injury			
43	Maintenance Hazards - Transport	1	No additional hazards					
44	Maintenance Hazards - Adequate Lighting	1	No additional hazards					
45	Construction / Existing Facilities - Tie-ins (Shutdown Requirements)	1	No additional hazards					
46	Construction / Existing Facilities - Concurrent Operations	1	No additional hazards					
47	Construction / Existing Facilities - Contaminated Material	1	No additional hazards					
48	Construction / Existing Facilities - Existing Equipment Condition	1	No additional hazards					
49	Construction / Existing Facilities - Common Equipment Capacity	1	No additional hazards					
50	Construction / Existing Facilities - Interface (Shutdown / Blowdown / ESD)	1	No additional hazards					

Hazard Category & Guideword	Hazardous Event Description	Potential Consequences	Effective Safeguards	Comments
51 Construction / Existing Facilities - Skid Dimensions (Weight Handling / Equipment (Congestion))	1 No additional hazards			
52 Construction / Existing Facilities - Soil Contamination (Existing Facilities)	1 No additional hazards			
53 Construction / Existing Facilities - Mobilisation / Demobilisation	1 No additional hazards			

Node: 4. Pipeline from wharf to eastern gas pipeline tie in point

Hazard Category & Guideword	Hazardous Event Description	Potential Consequences	Effective Safeguards	Comments
1 Natural Hazards - Extreme Weather	1 Not covered in this review - refer to pipeline SMS review (HOLD for Doc No.)			
2 Natural Hazards - Lightning	1 Not covered in this review - refer to pipeline SMS review (HOLD for Doc No.)			
3 Natural Hazards - Seismic Activity	1 Not covered in this review - refer to pipeline SMS review (HOLD for Doc No.)			
4 Natural Hazards - Erosion	1 Not covered in this review - refer to pipeline SMS review (HOLD for Doc No.)			
5 Natural Hazards - Subsidence / Sediment Buildup	1 Not covered in this review - refer to pipeline SMS review (HOLD for Doc No.)			
6 Environmental Impact - Discharges to Air	1 Not covered in this review - refer to pipeline SMS review (HOLD for Doc No.)			
7 Environmental Impact - Discharges to Water	1 Not covered in this review - refer to pipeline SMS review (HOLD for Doc No.)			
8 Environmental Impact - Discharges to Soil	1 Not covered in this review - refer to pipeline SMS review (HOLD for Doc No.)			
9 Environmental Impact - Noise	1 Not covered in this review - refer to pipeline SMS review (HOLD for Doc No.)			
10 External & Third-Party Hazards - Sabotage	1 Not covered in this review - refer to pipeline SMS review (HOLD for Doc No.)			
11 External & Third-Party Hazards - Terrorist Activity	1 Not covered in this review - refer to pipeline SMS review (HOLD for Doc No.)			
12 External & Third-Party Hazards - Third Party Activities	1 Not covered in this review - refer to pipeline SMS review (HOLD for Doc No.)			
13 External & Third-Party Hazards - Helicopter / Aircraft Crash	1 Not covered in this review - refer to pipeline SMS review (HOLD for Doc No.)			
14 Fire and Explosion Hazards - Stored Flammables	1 Not applicable			
15 Fire and Explosion Hazards - Sources of Ignition	1 Instrumentation, electrical equipment	1 Ignition of a LOC leading to fire / explosion	1 Ignition Controls - Hazardous Area Classification and certified equipment 2 Permit to work	
	2 Hot works	1 Ignition of a LOC leading to fire / explosion	1 Ignition Controls - Hazardous Area Classification and certified equipment 2 Permit to work	
16 Fire and Explosion Hazards - Equipment Layout	1 No additional hazards			
17 Fire and Explosion Hazards - Fire Protection and Response	1 No additional hazards			
18 Fire and Explosion Hazards - Operator Protection	1 No additional hazards			
19 Process Hazards - Start-up / Shutdown	1 No additional hazards			
20 Process Hazards - Inventory	1 No additional hazards			
21 Process Hazards - Pressure / Corrosion / Temperature	1 Above ground facilities external / internal corrosion	1 LOC leading to potential fire and explosion.	1 Material selection 2 Periodic inspection	

No.	Hazard Category & Guideword	No.	Hazardous Event Description	No.	Potential Consequences	No.	Effective Safeguards	No.	Comments
						3	Anti-corrosive coating		
						4	Ignition Controls - Hazardous Area Classification and certified equipment		
		2	Below ground facilities external / internal corrosion	1	Not covered in this review - refer to pipeline SMS review (HOLD for Doc No.)				
22	Process Hazards - Release of Inventory	1	Not covered in this review - refer to pipeline SMS review (HOLD for Doc No.)						
23	Process Hazards - Toxic Substances	1	Nitrogen release	1	Asphyxiation	1	SOPs		
						2	Open areas with natural ventilation		
24	Process Hazards - Overpressure	1	Not covered in this review - refer to pipeline SMS review (HOLD for Doc No.)						
25	Process Hazards - Hot / Cold Surfaces	1	No additional hazards						
26	Utility Systems - Failure of Firewater Systems	1	Not applicable						
27	Utility Systems - Failure of Fuel Gas	1	Not applicable						
28	Utility Systems - Failure of Heating Medium	1	No additional hazards						
29	Utility Systems - Failure of Diesel Fuel / Fuel Oil	1	Not applicable						
30	Utility Systems - Failure of Power Supply	1	Loss of power supply	1	Loss of nitrogen leading to off-spec gas	1	Alarm on loss of power at FSRU		
31	Utility Systems - Failure of Steam	1	Not applicable						
32	Utility Systems - Failure of Drains	1	Not applicable						
33	Utility Systems - Failure of Inert Gas	1	Loss of nitrogen	1	Loss of nitrogen leading to off-spec gas	1	Alarms		
34	Utility Systems - Failure of Waste Storage and Treatment	1	Not applicable						
35	Utility Systems - Failure of Chemical / Fuel Storage	1	No additional hazards						
36	Utility Systems - Failure of Potable Water	1	Not applicable						
37	Utility Systems - Failure of Sewerage	1	Not applicable						
38	Maintenance Hazards - Access Requirements	1	No additional hazards						
39	Maintenance Hazards - Override Necessary	1	No additional hazards						
40	Maintenance Hazards - Bypasses Required	1	No additional hazards						
41	Maintenance Hazards - Commonality of Equipment	1	No additional hazards						
42	Maintenance Hazards - Heavy Lifting Requirements	1	No additional hazards						
43	Maintenance Hazards - Transport	1	No additional hazards						
44	Maintenance Hazards - Adequate Lighting	1	No additional hazards						
45	Construction / Existing Facilities - Tie-ins (Shutdown Requirements)	1	See comment					1	Construction reviews to be conducted at later stage in the project
46	Construction / Existing Facilities - Concurrent Operations	1	See comment					1	Construction reviews to be conducted at later stage in the project
47	Construction / Existing Facilities - Contaminated Material	1	See comment					1	Construction reviews to be conducted at later stage in the project
48	Construction / Existing Facilities - Existing Equipment Condition	1	See comment					1	Construction reviews to be conducted at later stage in the project
49	Construction / Existing Facilities - Common Equipment Capacity	1	See comment					1	Construction reviews to be conducted at later stage in the project
50	Construction / Existing Facilities - Interface (Shutdown / Blowdown / ESD)	1	See comment					1	Construction reviews to be conducted at later stage in the project

Hazard Category & Guideword		Hazardous Event Description		Potential Consequences	Effective Safeguards	Comments	
51	Construction / Existing Facilities - Skid Dimensions (Weight Handling / Equipment (Congestion))	1	See comment			1	Construction reviews to be conducted at later stage in the project
52	Construction / Existing Facilities - Soil Contamination (Existing Facilities)	1	See comment			1	Construction reviews to be conducted at later stage in the project
53	Construction / Existing Facilities - Mobilisation / Demobilisation	1	See comment			1	Construction reviews to be conducted at later stage in the project

Appendix C. Consequence Modelling Results

Flammable Cloud / Flash Fire Results

Table 1. Dispersion Results – Scenario 1 – FSRU

Scenario 1												
Leak Size	10mm			25mm			50mm			100mm		
Initial Leak Rate (kg/s)	0.01			0.06			0.25			1.01		
Weather	Flammable Mass in Cloud (kg)	Time to Steady State (s)	LFL Downwind Impact Distance (m)	Flammable Mass in Cloud (kg)	Time to Steady State (s)	LFL Downwind Impact Distance (m)	Flammable Mass in Cloud (kg)	Time to Steady State (s)	LFL Downwind Impact Distance (m)	Flammable Mass in Cloud (kg)	Time to Steady State (s)	LFL Downwind Impact Distance (m)
Horizontal												
Calm	Negligible	0.09	2.00	Negligible	0.53	4.76	0.13	1.35	9.05	0.93	2.25	16.97
Average	Negligible	0.18	2.05	Negligible	0.32	4.61	Negligible	0.67	8.40	0.50	1.25	15.12
Windy	Negligible	0.12	2.05	Negligible	0.22	4.46	Negligible	0.38	7.90	0.31	0.70	13.93
Vertical (Up)												
Calm	Negligible	0.13	0.19	Negligible	0.32	0.47	Negligible	0.61	0.91	0.41	0.79	1.79
Average	Negligible	0.05	0.25	Negligible	0.12	0.62	Negligible	0.20	1.21	0.17	0.40	2.36
Windy	Negligible	0.03	0.33	Negligible	0.08	0.78	Negligible	0.10	1.50	0.10	0.20	2.90
Vertical (Down)												
Calm	Negligible	1.04	3.11	Negligible	1.96	6.35	0.36	3.13	10.63	2.36	5.27	17.32
Average	Negligible	0.41	3.32	Negligible	0.81	6.65	0.16	1.50	11.08	1.01	2.41	18.09
Windy	Negligible	0.15	2.64	Negligible	0.39	5.62	0.08	0.71	9.79	0.55	1.26	16.91

Table 2. Dispersion Results – Scenario 2 – FSRU

Scenario 2												
Leak Size	10mm			25mm			50mm			100mm		
Initial Leak Rate (kg/s)	0.03			0.2			0.8			3.2		
Weather	Flammable Mass in Cloud (kg)	Time to Steady State (s)	LFL Downwind Impact Distance (m)	Flammable Mass in Cloud (kg)	Time to Steady State (s)	LFL Downwind Impact Distance (m)	Flammable Mass in Cloud (kg)	Time to Steady State (s)	LFL Downwind Impact Distance (m)	Flammable Mass in Cloud (kg)	Time to Steady State (s)	LFL Downwind Impact Distance (m)
Horizontal												
Calm	Negligible	0.12	2.13	Negligible	0.31	5.23	0.18	0.63	10.28	1.43	1.27	20.10
Average	Negligible	0.09	2.18	Negligible	0.23	5.16	0.13	0.40	9.83	0.98	0.82	18.57
Windy	Negligible	0.07	2.20	Negligible	0.18	5.04	0.10	0.32	9.37	0.73	0.59	17.25
Vertical (Up)												
Calm	Negligible	0.08	0.16	Negligible	0.20	0.39	Negligible	0.39	0.78	0.88	0.70	1.57
Average	Negligible	0.04	0.21	Negligible	0.09	0.51	Negligible	0.18	1.01	0.33	0.20	2.04
Windy	Negligible	0.02	0.24	Negligible	0.06	0.58	Negligible	0.11	1.17	0.26	0.20	2.29
Vertical (Down)												
Calm	Negligible	0.48	3.94	0.13	1.72	9.03	0.96	2.90	16.61	6.85	5.10	29.98
Average	Negligible	0.27	3.86	Negligible	0.78	8.37	0.45	1.33	14.81	3.18	2.33	25.90
Windy	Negligible	0.18	3.75	Negligible	0.43	7.86	0.28	0.80	13.63	1.89	1.40	23.43

Table 3. Dispersion Results – Scenario 3 – FSRU

Scenario 3												
Leak Size	10mm			25mm			50mm			100mm		
Initial Leak Rate (kg/s)	1.08			6.75			27			108		
Weather	Flammable Mass in Cloud (kg)	Time to Steady State (s)	LFL Downwind Impact Distance (m)	Flammable Mass in Cloud (kg)	Time to Steady State (s)	LFL Downwind Impact Distance (m)	Flammable Mass in Cloud (kg)	Time to Steady State (s)	LFL Downwind Impact Distance (m)	Flammable Mass in Cloud (kg)	Time to Steady State (s)	LFL Downwind Impact Distance (m)
Horizontal												
Calm	1.30	2.71	16.76	21.70	11.56	50.58	436.1	54.75	140.0	5767	179.5	312.0
Average	0.66	1.50	16.82	7.38	2.90	32.00	44.85	4.89	53.67	1750	41.53	270.0
Windy	0.44	0.99	16.91	4.96	1.93	32.65	30.20	3.02	51.57	379.9	11.55	148.4
Vertical (Up)												
Calm	1.56	3.65	5.82	20.28	6.06	10.59	108.1	9.45	15.48	2255	92.49	139.7
Average	0.35	0.80	4.70	5.98	2.46	13.70	61.83	6.06	34.69	449.8	9.17	52.60
Windy	0.20	0.51	5.04	3.01	1.19	12.20	23.60	2.28	24.99	198.9	4.99	56.49
Vertical (Down)												
Calm	1.44	3.68	11.56	456.1	181.9	104.2	4317	261.2	150.3	16302	313.2	213.4
Average	0.71	1.90	13.88	7.17	3.34	22.25	185.0	21.15	102.4	2440	52.14	273.9
Windy	0.50	1.37	15.84	5.14	2.34	25.94	29.68	3.42	35.73	926.0	20.34	176.2

Table 4. Dispersion Results – Scenario 4 – FSRU

Scenario 4												
Leak Size	10mm			25mm			50mm			100mm		
Initial Leak Rate (kg/s)	0.08			0.48			1.93			7.71		
Weather	Flammable Mass in Cloud (kg)	Time to Steady State (s)	LFL Downwind Impact Distance (m)	Flammable Mass in Cloud (kg)	Time to Steady State (s)	LFL Downwind Impact Distance (m)	Flammable Mass in Cloud (kg)	Time to Steady State (s)	LFL Downwind Impact Distance (m)	Flammable Mass in Cloud (kg)	Time to Steady State (s)	LFL Downwind Impact Distance (m)
Horizontal												
Calm	Negligible	0.07	2.59	Negligible	0.26	6.38	0.38	0.52	12.61	2.94	1.05	24.78
Average	Negligible	0.06	2.66	Negligible	0.21	6.36	0.29	0.43	12.23	2.20	0.81	23.31
Windy	Negligible	0.05	2.69	Negligible	0.17	6.26	0.23	0.30	11.75	1.73	0.58	21.86
Vertical (Up)												
Calm	Negligible	0.08	0.18	Negligible	0.20	0.44	Negligible	0.38	0.89	2.00	0.66	1.82
Average	Negligible	0.04	0.24	Negligible	0.10	0.60	Negligible	0.19	1.17	0.80	0.19	2.37
Windy	Negligible	0.03	0.28	Negligible	0.06	0.69	Negligible	0.10	1.33	0.65	0.19	2.58
Vertical (Down)												
Calm	Negligible	0.52	4.82	0.29	1.58	11.21	2.13	2.74	20.82	15.40	5.16	38.17
Average	Negligible	0.32	4.69	0.16	0.83	10.31	1.13	1.46	18.40	7.39	2.54	32.54
Windy	Negligible	0.22	4.56	0.10	0.49	9.69	0.72	0.86	16.96	5.01	1.55	29.40

Table 5. Dispersion Results – Scenario 5 – FSRU

Scenario 5												
Leak Size	10mm			25mm			50mm			100mm		
Initial Leak Rate (kg/s)	5.05			31.6			126			505		
Weather	Flammable Mass in Cloud (kg)	Time to Steady State (s)	LFL Downwind Impact Distance (m)	Flammable Mass in Cloud (kg)	Time to Steady State (s)	LFL Downwind Impact Distance (m)	Flammable Mass in Cloud (kg)	Time to Steady State (s)	LFL Downwind Impact Distance (m)	Flammable Mass in Cloud (kg)	Time to Steady State (s)	LFL Downwind Impact Distance (m)
Horizontal												
Calm	3.65	1.96	30.16	52.16	4.48	70.83	524.7	12.60	167.5	4621	27.41	349.4
Average	2.27	1.17	27.00	31.04	2.58	59.56	223.0	4.96	111.9	3387	21.14	346.8
Windy	1.62	0.82	24.75	21.50	1.75	53.69	147.9	3.00	94.61	1728	10.54	258.5
Vertical (Up)												
Calm	1.75	0.68	2.49	31.50	2.45	6.89	240.9	5.29	14.36	33490	167.9	533.2
Average	0.86	0.39	3.03	14.29	1.21	7.42	111.4	2.38	15.78	888.1	4.98	35.46
Windy	0.58	0.29	3.43	8.62	0.73	8.76	66.68	1.43	17.93	517.1	2.90	38.23
Vertical (Down)												
Calm	10.23	5.28	32.18	452.0	46.93	144.8	5329	136.0	305.8	20654	93.80	607.2
Average	4.85	2.42	29.95	57.35	4.56	61.58	2104	43.53	296.1	4032	14.03	608.6
Windy	3.27	1.73	30.09	35.33	3.05	55.92	532.2	13.10	172.9	8822	39.01	468.6

Table 6. Dispersion Results – Scenario 6 – Wharf

Scenario 6												
Leak Size	10mm			25mm			50mm			100mm		
Initial Leak Rate (kg/s)	2.11			13.2			52.8			211.3		
Weather	Flammable Mass in Cloud (kg)	Time to Steady State (s)	LFL Downwind Impact Distance (m)	Flammable Mass in Cloud (kg)	Time to Steady State (s)	LFL Downwind Impact Distance (m)	Flammable Mass in Cloud (kg)	Time to Steady State (s)	LFL Downwind Impact Distance (m)	Flammable Mass in Cloud (kg)	Time to Steady State (s)	LFL Downwind Impact Distance (m)
Horizontal												
Calm	0.79	1.08	16.39	20.97	4.70	53.56	208.3	12.27	125.7	1843	27.38	275.6
Average	0.44	0.58	12.85	15.00	3.33	53.90	158.3	9.34	137.3	1468	22.74	320.5
Windy	0.29	0.39	10.17	12.55	2.80	54.91	152.7	8.77	157.7	1430	19.64	356.2
Vertical (Up)												
Calm	Negligible	0.64	1.01	5.80	0.85	2.80	47.74	2.28	5.75	338.6	4.18	12.25
Average	0.22	0.24	1.41	3.19	0.63	3.50	23.66	1.12	7.25	181.3	2.28	15.38
Windy	0.13	0.13	1.49	1.95	0.34	3.92	15.06	0.70	8.18	114.8	1.41	16.65
Vertical (Down)												
Calm	9.37	14.10	40.08	210.3	53.00	126.0	1713	100.8	253.7	12584	176.8	486.3
Average	2.72	3.71	26.51	95.47	17.56	113.1	795.5	35.44	240.4	6266	68.49	489.8
Windy	1.04	1.41	16.40	53.68	8.98	93.91	508.0	20.22	221.0	3877	38.95	462.5

Jet Fire Results

Table 7. Jet Fire Results – Scenario 1 – FSRU

Scenario 1: Gas																				
Release from	All boil-off gas from the tanks, BOG header, discharge from cargo room vaporisers and inlet to cargo room											Fluid	Rich LNG	Pressure		0 barg	Temperature		-160 °C	
Leak size	10mm					25mm					50mm					100mm				
Initial Leak Rate, kg/s	0.01					0.06					0.25					1.01				
Weather	Flame Length (m)	Rad. Impact Dist. (m) at EL +14 m				Flame Length (m)	Rad. Impact Dist. (m) at EL +14 m				Flame Length (m)	Rad. Impact Dist. (m) at EL +14 m				Flame Length (m)	Rad. Impact Dist. (m) at EL +14 m			
		4.73 kW/m²	12.5 kW/m²	23 kW/m²	35 kW/m²		4.73 kW/m²	12.5 kW/m²	23 kW/m²	35 kW/m²		4.73 kW/m²	12.5 kW/m²	23 kW/m²	35 kW/m²		4.73 kW/m²	12.5 kW/m²	23 kW/m²	35 kW/m²
Horizontal																				
Calm	2.70	3.46	2.81	2.56	n/a	6.00	8.39	7.21	7.00	7.00	10.92	15.80	13.59	12.54	11.92	19.80	29.51	25.29	23.34	22.08
Average	1.82	2.73	2.07	1.76	n/a	4.03	6.71	5.48	5.03	5.03	7.34	12.72	10.42	9.38	8.74	13.30	23.90	19.51	17.55	16.38
Windy	1.62	2.56	1.91	1.57	n/a	3.60	6.30	5.08	4.60	4.60	6.56	11.96	9.68	8.65	8.04	11.88	22.47	18.13	16.21	15.07
Vertical (Up)																				
Calm	1.75	1.68	1.22	1.22	1.22	3.88	3.64	1.23	1.19	1.19	7.06	6.84	1.82	1.18	1.18	12.80	13.26	3.17	1.18	1.18
Average	1.17	2.26	2.09	2.09	2.09	2.61	5.03	3.77	3.22	2.89	4.75	9.35	6.56	5.18	4.69	8.60	17.30	11.39	9.24	7.87
Windy	1.05	2.03	1.47	1.08	0.91	2.33	5.05	3.89	3.37	3.33	4.24	9.58	7.45	6.55	6.04	7.68	17.44	13.07	11.14	10.03
Vertical (Down)																				
Calm	2.70	1.53	0.77	0.06	n/a	6.00	4.06	3.13	2.59	2.40	10.92	7.82	6.43	5.54	4.88	19.80	14.79	12.38	11.12	10.15
Average	1.82	1.34	0.77	0.32	n/a	4.03	3.48	2.59	2.14	1.89	7.34	6.65	5.15	4.47	3.94	13.30	12.87	9.86	8.67	7.99
Windy	1.62	1.30	0.75	0.33	n/a	3.60	3.34	2.45	2.02	1.81	6.56	6.44	4.83	4.19	3.72	11.88	12.47	9.27	8.11	7.41

Table 8. Jet Fire Results – Scenario 2 – FSRU

Scenario 2: Gas																				
Release from	Discharge from cargo room HD compressors for return to shore during cargo loading											Fluid	Rich LNG	Pressure		1 barg	Temperature		-120 °C	
Leak size	10mm					25mm					50mm					100mm				
Initial Leak Rate, kg/s	0.03					0.20					0.80					3.20				
Weather	Flame Length (m)	Rad. Impact Dist. (m) at EL +14 m				Flame Length (m)	Rad. Impact Dist. (m) at EL +14 m				Flame Length (m)	Rad. Impact Dist. (m) at EL +14 m				Flame Length (m)	Rad. Impact Dist. (m) at EL +14 m			
		4.73 kW/m²	12.5 kW/m²	23 kW/m²	35 kW/m²		4.73 kW/m²	12.5 kW/m²	23 kW/m²	35 kW/m²		4.73 kW/m²	12.5 kW/m²	23 kW/m²	35 kW/m²		4.73 kW/m²	12.5 kW/m²	23 kW/m²	35 kW/m²
Horizontal																				
Calm	2.91	3.87	3.87	3.87	n/a	6.52	8.17	7.16	6.55	6.41	11.83	16.77	13.88	12.11	11.58	20.25	33.29	26.09	22.11	20.48
Average	3.24	3.37	n/a	n/a	n/a	7.75	9.08	8.74	8.74	8.74	14.31	18.08	16.20	15.31	14.76	24.28	33.98	29.40	27.32	26.07
Windy	3.66	n/a	n/a	n/a	n/a	8.58	9.11	8.54	n/a	n/a	15.79	17.88	16.90	16.79	16.79	28.92	34.13	32.01	31.09	30.56
Vertical (Up)																				
Calm	2.98	1.71	0.28	0.12	0.05	6.73	3.28	n/a	n/a	n/a	12.38	6.70	n/a	n/a	n/a	22.69	14.27	n/a	n/a	n/a
Average	2.07	2.76	1.88	1.36	1.31	4.67	6.25	3.77	1.87	0.46	8.60	11.86	6.64	2.56	n/a	15.75	22.57	12.23	3.58	n/a
Windy	1.90	3.41	2.82	2.82	2.82	4.29	7.49	5.42	4.31	3.92	7.89	13.65	8.97	7.34	5.73	14.44	24.88	16.21	12.46	8.19
Vertical (Down)																				
Calm	2.91	1.45	1.21	1.21	n/a	6.52	3.79	2.98	2.62	2.55	11.83	9.19	6.26	5.18	4.91	20.25	21.41	12.53	9.75	8.64
Average	3.24	0.87	n/a	n/a	n/a	7.75	4.14	3.71	3.32	3.13	14.31	8.63	7.31	6.69	6.28	24.28	20.01	13.61	12.18	11.35
Windy	3.66	n/a	n/a	n/a	n/a	8.58	4.06	2.73	n/a	n/a	15.79	8.40	7.61	7.39	2.50	28.92	16.65	14.86	14.07	13.62

Table 9. Jet Fire Results – Scenario 3 – FSRU

Scenario 3: Liquid																				
Release from	LNG liquid pumped up from cargo tanks to suction drum module to regasification booster pumps											Fluid	Rich LNG		Pressure		5.5 barg	Temperature		-160 °C
Leak size	10mm					25mm					50mm					100mm				
Initial Leak Rate, kg/s	1.08					6.75					27.01					108.04				
Weather	Flame Length (m)	Rad. Impact Dist. (m) at EL +14 m 4.73 kW/m^2	12.5 kW/m^2	23 kW/m^2	35 kW/m^2	Flame Length (m)	Rad. Impact Dist. (m) at EL +14 m 4.73 kW/m^2	12.5 kW/m^2	23 kW/m^2	35 kW/m^2	Flame Length (m)	Rad. Impact Dist. (m) at EL +14 m 4.73 kW/m^2	12.5 kW/m^2	23 kW/m^2	35 kW/m^2	Flame Length (m)	Rad. Impact Dist. (m) at EL +14 m 4.73 kW/m^2	12.5 kW/m^2	23 kW/m^2	35 kW/m^2
Horizontal																				
Calm	22.14	32.94	28.10	25.78	24.14	47.87	74.39	63.00	57.75	54.40	85.50	137.49	115.72	105.88	99.81	152.35	253.67	212.16	193.66	182.54
Average	14.88	26.45	21.58	19.37	18.01	32.17	60.13	48.69	43.61	40.57	57.45	111.59	89.84	80.26	74.62	102.38	206.50	165.34	147.31	136.83
Windy	13.29	24.58	19.94	17.87	16.64	28.73	55.81	44.96	40.18	37.38	51.32	103.40	82.86	73.87	68.66	91.45	190.92	152.28	135.41	125.70
Vertical (Up)																				
Calm	14.32	15.06	1.77	1.36	1.28	30.96	36.58	12.04	3.17	1.40	55.29	71.65	28.17	7.30	3.30	98.53	139.88	62.83	19.04	7.83
Average	9.62	19.05	12.78	10.32	8.97	20.80	43.07	27.89	22.41	18.45	37.16	80.22	51.80	40.94	33.08	66.21	149.74	96.64	75.57	60.68
Windy	8.60	18.99	14.35	12.30	11.10	18.58	43.56	31.33	25.71	21.98	33.19	81.28	56.59	44.66	37.76	59.14	145.06	98.22	75.59	65.71
Vertical (Down)																				
Calm	22.14	16.59	13.85	12.44	11.36	47.87	37.56	31.44	28.63	26.93	85.50	69.73	57.96	52.80	49.76	152.35	134.44	106.71	96.91	91.02
Average	14.88	13.86	10.98	9.69	8.87	32.17	33.16	24.95	22.10	20.55	57.45	64.01	46.41	41.04	37.89	102.38	123.12	86.17	75.94	70.00
Windy	13.29	13.50	10.20	8.98	8.21	28.73	32.15	23.14	20.42	18.98	51.32	61.73	42.93	37.88	34.96	91.45	118.57	79.60	70.01	64.50

Table 10. Jet Fire Results – Scenario 4 – FSRU

Scenario 4: Gas																				
Release from	BOG compressed by cargo room LD compressors, through header to BOG cooler in regasification unit											Fluid	Rich LNG		Pressure		5.5 barg	Temperature		60 °C
Leak size	10mm					25mm					50mm					100mm				
Initial Leak Rate, kg/s	0.08					0.48					1.93					7.71				
Weather	Flame Length (m)	Rad. Impact Dist. (m) at EL +14 m 4.73 kW/m^2	12.5 kW/m^2	23 kW/m^2	35 kW/m^2	Flame Length (m)	Rad. Impact Dist. (m) at EL +14 m 4.73 kW/m^2	12.5 kW/m^2	23 kW/m^2	35 kW/m^2	Flame Length (m)	Rad. Impact Dist. (m) at EL +14 m 4.73 kW/m^2	12.5 kW/m^2	23 kW/m^2	35 kW/m^2	Flame Length (m)	Rad. Impact Dist. (m) at EL +14 m 4.73 kW/m^2	12.5 kW/m^2	23 kW/m^2	35 kW/m^2
Horizontal																				
Calm	3.93	4.89	4.89	4.89	4.89	8.82	11.56	10.11	9.44	8.87	16.11	24.07	19.99	18.03	16.46	28.97	49.00	38.92	34.09	30.52
Average	4.06	5.03	5.03	5.03	5.03	9.79	11.96	10.86	10.35	10.15	18.37	24.83	21.66	20.21	19.28	33.24	49.54	41.76	38.21	35.92
Windy	4.21	4.29	n/a	n/a	n/a	11.00	12.56	11.99	11.99	11.99	21.24	26.00	23.96	23.05	22.53	38.85	50.85	45.76	43.50	42.20
Vertical (Up)																				
Calm	4.01	2.08	n/a	n/a	n/a	9.11	4.48	n/a	n/a	n/a	16.85	9.48	n/a	n/a	n/a	30.98	20.28	n/a	n/a	n/a
Average	2.79	3.65	2.25	1.28	1.15	6.33	8.46	4.49	1.30	n/a	11.70	16.07	8.04	n/a	n/a	21.52	30.65	15.15	4.25	n/a
Windy	2.56	4.30	3.08	2.47	2.24	5.81	9.45	6.20	4.75	3.00	10.73	17.22	11.23	7.75	3.60	19.73	31.82	20.56	13.30	5.40
Vertical (Down)																				
Calm	3.93	1.97	1.58	1.43	1.43	8.82	5.54	4.17	3.66	3.30	16.11	14.15	8.71	7.38	6.51	28.97	32.04	19.14	14.44	12.15
Average	4.06	1.11	1.10	1.09	1.09	9.79	4.91	4.05	3.79	3.69	18.37	13.31	9.42	8.43	7.93	33.24	30.53	18.74	16.27	14.80
Windy	4.21	1.25	n/a	n/a	n/a	11.00	5.58	5.00	4.86	4.42	21.24	12.01	10.49	9.82	9.42	38.85	28.47	20.59	18.93	17.99

Table 11. Jet Fire Results – Scenario 5 – FSRU

Scenario 5: Liquid																				
Release from	LNG discharge from regasification booster pump											Fluid	Rich LNG	Pressure		120 barg	Temperature		-160 °C	
Leak size	10mm					25mm					50mm					100mm				
Initial Leak Rate, kg/s	5.05					31.56					126.24					504.95				
Weather	Flame Length (m)	Rad. Impact Dist. (m) at EL +14 m				Flame Length (m)	Rad. Impact Dist. (m) at EL +14 m				Flame Length (m)	Rad. Impact Dist. (m) at EL +14 m				Flame Length (m)	Rad. Impact Dist. (m) at EL +14 m			
		4.73 kW/m²	12.5 kW/m²	23 kW/m²	35 kW/m²		4.73 kW/m²	12.5 kW/m²	23 kW/m²	375 kW/m²		4.73 kW/m²	12.5 kW/m²	23 kW/m²	35 kW/m²		4.73 kW/m²	12.5 kW/m²	23 kW/m²	35 kW/m²
Horizontal																				
Calm	34.71	53.38	45.63	42.18	40.10	76.52	121.94	103.49	95.39	90.62	138.53	227.03	191.60	176.15	167.16	249.90	421.52	353.75	324.32	307.37
Average	23.33	43.11	35.22	31.79	29.82	51.42	98.94	80.29	72.24	67.64	93.09	184.72	149.17	133.84	125.13	167.94	343.54	276.19	247.16	230.70
Windy	20.84	40.96	32.98	29.50	27.50	45.93	93.89	75.17	67.06	62.42	83.15	174.95	139.57	124.24	115.49	150.01	324.44	258.07	229.27	212.89
Vertical (Up)																				
Calm	22.45	25.09	5.48	1.14	1.11	49.49	61.88	18.29	2.06	0.83	89.59	122.05	44.81	4.72	n/a	161.61	239.22	102.73	12.19	4.94
Average	15.08	29.58	19.11	13.53	8.90	33.26	67.30	42.62	29.24	18.36	60.20	117.34	72.47	47.05	25.88	108.61	203.21	121.94	74.34	36.22
Windy	13.47	32.15	22.26	17.43	14.91	29.71	70.05	46.19	36.07	30.99	53.78	119.61	77.68	61.47	50.34	97.01	201.88	132.74	102.23	78.79
Vertical (Down)																				
Calm	34.71	27.26	22.52	20.62	19.33	76.52	65.66	51.43	47.16	44.68	138.53	126.88	95.31	87.36	82.73	249.90	243.88	176.14	161.05	152.38
Average	23.33	25.42	17.76	15.85	14.72	51.42	60.61	40.53	36.21	33.75	93.09	116.64	75.39	67.24	62.63	167.94	224.38	142.86	124.59	115.89
Windy	20.84	24.31	16.80	14.84	13.71	45.93	57.73	38.31	33.86	31.37	83.15	111.04	71.30	62.97	58.28	150.01	211.87	134.21	116.78	107.91

Table 12. Jet Fire Results – Scenario 6 – Wharf

Scenario 6: Gas																				
Release from	Gas from HP Unloading Manifold to Wharf Facility and Pipeline											Fluid	Rich LNG	Pressure		120 barg	Temperature		10 °C	
Leak size	10 mm					25 mm					50 mm					100 mm				
Initial Leak Rate, kg/s	2.11					13.20					52.82					211.28				
Weather	Flame Length (m)	Rad. Impact Dist. (m) at EL +14 m				Flame Length (m)	Rad. Impact Dist. (m) at EL +14 m				Flame Length (m)	Rad. Impact Dist. (m) at EL +14 m				Flame Length (m)	Rad. Impact Dist. (m) at EL +14 m			
		4.73 kW/m²	12.5 kW/m²	23 kW/m²	35 kW/m²		4.73 kW/m²	12.5 kW/m²	23 kW/m²	35 kW/m²		4.73 kW/m²	12.5 kW/m²	23 kW/m²	35 kW/m²		4.73 kW/m²	12.5 kW/m²	23 kW/m²	35 kW/m²
Horizontal																				
Calm	17.41	26.96	21.73	18.89	17.51	34.73	64.84	48.88	40.75	36.97	60.41	123.57	89.83	73.56	66.81	110.27	235.57	167.55	138.97	124.68
Avg	20.72	28.12	24.53	22.88	21.87	40.35	63.26	52.61	47.82	44.89	67.96	115.96	93.77	83.90	77.84	119.78	216.47	171.60	151.77	139.55
Windy	23.72	28.50	26.53	25.67	25.17	49.14	61.30	56.55	54.51	53.37	82.22	110.63	99.69	95.04	92.43	143.29	208.28	183.40	172.76	166.76
Vertical (Up)																				
Calm	18.60	11.05	n/a	n/a	n/a	41.28	29.90	n/a	n/a	n/a	75.10	62.34	n/a	n/a	n/a	136.07	127.73	26.81	n/a	n/a
Avg	12.92	18.16	9.68	2.37	n/a	28.66	42.65	22.56	7.20	n/a	52.13	81.45	43.69	17.10	0.00	94.43	155.24	84.94	40.20	18.66
Windy	11.84	20.03	13.07	9.93	6.21	26.28	44.70	29.19	20.63	11.97	47.78	82.69	54.02	37.34	22.07	86.53	155.49	100.38	69.00	42.99
Vertical (Down)																				
Calm	17.41	16.42	9.97	8.14	7.37	34.73	45.17	27.01	18.75	15.77	60.41	89.25	53.73	37.69	29.58	110.27	172.07	103.82	73.08	56.99
Avg	20.72	15.36	11.14	10.08	9.57	40.35	42.93	25.59	21.55	19.57	67.96	85.84	52.17	39.12	34.72	119.78	165.77	102.04	74.05	63.96
Windy	23.72	13.59	12.08	11.49	11.24	49.14	37.66	26.89	24.99	23.91	82.22	81.31	49.35	44.70	42.08	143.29	158.16	96.03	82.64	76.65

Pool Fire Results

Table 13. Pool Fire Results – Scenario 3 – FSRU

Scenario 3	Release from LNG liquid pumped up from cargo tanks to suction drum module to regasification booster pumps									
Fluid	Rich LNG		Temperature		-160 °C		Pressure		5.5 barg	
Leak size	50 mm					100 mm				
Weather	Pool Diameter (m)	Rad. Impact Dist. (m) at EL +14 m				Pool Diameter (m)	Rad. Impact Dist. (m) at EL +14 m			
		4.73 kW/m²	12.5 kW/m²	23 kW/m²	35 kW/m²		4.73 kW/m²	12.5 kW/m²	23 kW/m²	35 kW/m²
	Vertical (Down)									
Calm	7.4	46.0	34.4	29.8	27.3	30.9	148.6	103.7	84.1	72.7

Note: All other release scenarios did not generate sufficient liquid drop-out to form pool fires.

Explosion Results

Table 14. Tank 1 to 4 Explosion

Area	Tank 1 - 4		
Gas Volume in Congested Area (m^3)	71.2	Explosion Flammable Mass (kg)	5.5
Blast Strength	6	Peak Overpressure (kPa)	51

Overpressure Impact Distance (m)				
7 kPa	**14 kPa**	**21 kPa**	**35 kPa**	**70 kPa**
49.7	28.1	20.4	12.7	n/a

Table 15. Cargo Machinery Room Explosion

Area	Cargo Machinery Room		
Gas Volume in Congested Area (m^3)	2112	Explosion Flammable Mass (kg)	163.7
Blast Strength	8	Peak Overpressure (kPa)	203

Overpressure Impact Distance (m)				
7 kPa	**14 kPa**	**21 kPa**	**35 kPa**	**70 kPa**
154.2	91.3	69.2	50.7	35.1

Table 16. Suction Drum Module Explosion

Area	Suction Drum Module		
Gas Volume in Congested Area (m^3)	281.6	Explosion Flammable Mass (kg)	21.8
Blast Strength	6	Peak Overpressure (kPa)	51

Overpressure Impact Distance (m)				
7 kPa	**14 kPa**	**21 kPa**	**35 kPa**	**70 kPa**
78.6	44.5	32.3	20.1	n/a

Table 17. Top Half of Regasification Module Explosion

Area	Top half of Regasification Module		
Gas Volume in Congested Area (m^3)	2647	Explosion Flammable Mass (kg)	205.2
Blast Strength	6	Peak Overpressure (kPa)	51

Overpressure Impact Distance (m)				
7 kPa	**14 kPa**	**21 kPa**	**35 kPa**	**70 kPa**
166.0	93.8	68.1	42.5	n/a

Table 18. Bottom Half of Regasification Module Explosion

Area	Bottom half of Regasification Module		
Gas Volume in Congested Area (m^3)	1285	Explosion Flammable Mass (kg)	99.6
Blast Strength	7	Peak Overpressure (kPa)	101

Overpressure Impact Distance (m)				
7 kPa	**14 kPa**	**21 kPa**	**35 kPa**	**70 kPa**
130.7	77.4	58.7	42.9	26.2

Appendix D. Leak Frequency Summary

Leak Frequency Summary

The leak frequencies were determined as outlined in Section 7.2. The table below contains a summary of the leak frequency per hole size for each section of the FSRU, LNGC and wharf process systems.

Table 1. Overall Leak Frequency Summary

Location	Area	Leak Frequency by Size, per annum					TOTAL Leak Frequency (pa)
		10mm	25mm	50mm	100mm	Rupture	
LNGC	Cargo Tank 1–4	1.66E-03	1.50E-04	7.07E-05	5.25E-06	1.29E-05	1.90E-03
	Headers	4.54E-03	4.76E-04	1.94E-04	4.65E-06	1.34E-04	5.35E-03
	LNG Unloading Manifold	2.50E-03	2.85E-04	6.78E-05	1.60E-05	4.94E-05	2.92E-03
LNGC to FSRU	LNG Transfer Hoses	5.56E-04	6.41E-05	1.07E-04	0.00E+00	4.27E-05	7.69E-04
FSRU	LNG Loading Manifold	2.50E-03	2.85E-04	6.78E-05	1.60E-05	4.94E-05	2.92E-03
	Cargo Tank 1–4	2.91E-02	2.44E-03	1.39E-03	7.75E-05	2.52E-04	3.33E-02
	Headers	9.10E-02	9.18E-03	3.78E-03	1.65E-04	3.73E-03	1.08E-01
	Suction Drum Module	3.08E-02	2.14E-03	1.21E-03	7.69E-05	1.74E-04	3.44E-02
	Regasification Module	1.49E-01	1.40E-02	5.37E-03	1.85E-04	1.64E-03	1.70E-01
	Gas Unloading Manifold	1.41E-02	1.37E-03	2.93E-04	1.06E-05	5.72E-04	1.63E-02
FSRU to Wharf	Marine Loading Arms	3.33E-04	2.00E-04	6.67E-05	4.50E-05	1.50E-05	6.60E-04
Wharf	Wharf Facility	2.36E-02	2.39E-03	1.14E-03	5.47E-06	7.72E-04	2.79E-02
Pipeline	Wharf to Metering Station	2.47E-04 (as 20mm)		8.89E-05	8.89E-05	6.92E-05	4.94E-04

A single leak frequency was determined for a ship collision with either the LNGC or FSRU for the maximum credible hole size, as summarised in the following table:

Table 2. Leak Frequency – Ship Collision

Vessel	Leak Frequency per Cargo Tank (pa)
LNGC	4.71E-07
FSRU	7.72E-06

Fire and Explosion Frequency Summary

The fire and explosion frequencies can be calculated based on the leak frequencies and ignition probabilities. While immediately ignited releases result in jet fires or pool fires, delayed ignition releases result in flash fires or explosions (depending on the level of confinement and congestion surrounding the release).

The table below summarises the fire and explosion frequencies for the identified FSRU, LNGC, wharf and pipeline areas.

Table 3. Overall Fire and Explosion Frequency Summary

Location	Area	Fire Frequency (pa)	Explosion Frequency (pa)	TOTAL Fire & Explosion Frequency (pa)
LNGC	Cargo Tank 1–4	1.20E-05	1.73E-06	1.38E-05
	Cargo Machinery Room	-	8.38E-06	8.38E-06
	Headers	6.32E-05	1.72E-05	8.03E-05
	LNG Unloading Manifold	3.00E-05	8.41E-06	3.84E-05
	Ship Collision (Tanks 1–4)	1.98E-07	8.48E-08	2.83E-07
LNGC to FSRU	LNG Transfer Hoses	1.87E-05	4.64E-06	2.33E-05
FSRU	LNG Loading Manifold	3.00E-05	8.41E-06	3.84E-05
	Cargo Tank 1–4	2.39E-04	3.75E-05	2.76E-04
	Cargo Machinery Room	-	1.17E-04	1.17E-04
	Headers	1.49E-03	4.35E-04	1.93E-03
	Suction Drum Module	2.87E-04	5.41E-05	3.41E-04
	Regasification Module	2.83E-03	6.27E-04	3.46E-03
	Gas Unloading Manifold	2.84E-04	8.07E-05	3.65E-04
	Ship Collision (Tanks 1–4)	3.24E-06	1.39E-06	4.63E-06
FSRU to Wharf	Marine Loading Arms	3.20E-05	1.16E-05	4.36E-05
Wharf	Wharf Facility	5.14E-04	1.51E-04	6.65E-04
Pipeline	Wharf to Metering Station	7.72E-05	3.17E-05	1.09E-04