Department of Planning and Environment

Our ref: SSI-9471-PA-105

Alexandra Lovell
HSE Manager
Australian Industrial Energy
PO Box 1070
Wollongong, NSW, 2500

6 October 2023

Subject: Final Hazard Analysis for Port Kembla Gas Terminal (SSI-9471)

Dear Ms. Lovell

I refer to your submission requesting review and approval of the Final Hazard Analysis for the Port Kembla Gas Terminal.

I note the Final Hazard Analysis has been prepared in accordance with DPE's HIPAP 6.

The Department has carefully reviewed the document and is satisfied that it meets the requirements under SSI 9471 Schedule 3, Condition 21(c).

Accordingly, as nominee of the Planning Secretary, I approve the Final Hazard Analysis (Rev 3, dated 15 September 2023), subject to the Applicant:

1. Implementing an automatic emergency shutdown system of the onshore receiving facility (ORF) to the satisfaction of SafeWork NSW.
2. Submitting a Safety Management System (SMS) and Emergency Plan (EP) under Schedule 3, Condition 23 while clearly specifying:
    a. the separate entities (Squadrion Energy or Jemena – see below) operating within the project;
    b. the operating and emergency responsibilities for these entities; especially if any entity will primarily be operating the site by remote means; and
    c. the coordination of these entities to ensure that the:
        i. design and operation of the project remains consistent with all hazards-related studies, plans or systems submitted under the consent; and
        ii. cumulative risks from the project do not exceed the assumptions and results of the Final Hazard Analysis (revision 3, dated 15 September 2023).

In regard to Item 2a above, at the time of review, it is currently understood that Squadron Energy will be operating the floating storage and regasification unit (FSRU) and Jemena operating the onshore receiving facility (ORF) with accompanying pipelines and their connections. It will be important for the

Applicant to specify these operating entities, or any other entities if there are changes, in the SMS and EP.

Please ensure you make the document publicly available on the project website at the earliest convenience.

If you wish to discuss the matter further, please contact Wayne Jones on (02) 6575 3406.

Yours sincerely

Stephen O'Donoghue
Director
Resource Assessments
as nominee of the Secretary

AUSTRALIAN INDUSTRIAL ENERGY

Port Kembla Gas Terminal Project

Final Hazard Analysis Report

Doc No. Rev 3: PKGT-WOR-ORF-SAF-RPT-0018
Worley Document No Rev 3: 411010-00417-SR-REP-0008
15 September 2023

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WORLEY PROJECT: 411010-00417 - Port Kembla Gas Terminal Project - Final Hazard Analysis Report

Rev	Description	Originator	Reviewer	Worley Approver	Revision Date	Customer Approver	Approval Date
Rev 0	Issued for Use	AS	AF	FL	10 Feb 2023		
		A. Stembridge	A. Ferguson	F. Losty			
Rev 1	Re-Issued for Use	AS	AF	FL	15 Jun 2023		
		A. Stembridge	A. Ferguson	F. Losty			
Rev 2	Re-Issued for Use	AS	AF	FL	21 Jun 2023		
		A. Stembridge	A. Ferguson	F. Losty			
Rev 3	Re-Issued for Use	Date: 2023.09.15 15:17:25+10'00'	Andrew Fergusson 2023.09.15 15:27:17 +10'00'	Digitally signed by Frank Losty DN: cn=Frank Losty, ou=Users, email=Frank.Losty@worley.com Date: 2023.09.18 08:09:46 +01'00'	15 Sept 2023		
		A. Stembridge	A. Ferguson	F. Losty			

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Appendices

Revision History	
Revision 0	
Location	**Description**
-	Issued for Use
Revision 1	
Location	**Description**
General	Report updated to provide further clarity based on comments provided by Safework NSW and NSW Ports.
Section 3.4	Section updated to provide further clarity regarding surrounding land users.
Section 3.7	Section updated to provide further clarity regarding control of the ORF tower mounted fire water monitors.
Section 5.1	Section updated to provide further clarity of how actions raised during the HAZID and HAZOP workshops are managed and tracked to closure by AIE. Further details provided regarding HAZID workshop findings.
Section 5.2	Sections 5.2.1 and Section 5.2.3 updated to provide further clarity regarding the storage conditions of the LNG cargo on board the FSRU and odourant at the ORF
Section 6	Table 6-1 revised to detail updated assumption regarding the split between immediate and delayed ignition for the Port Kembla Pipeline.
Section 6.2	Section updated to provide further clarity regarding odourant storage tank conditions and dosing rates. Table 6-2 updated to add odourant dosing conditions and revise LNG from booster pumps isolatable inventory.
Section 7.2	Figure 7-2 updated to present the potential LNGC grounding and collision with land or a moored vessel locations used in the LNGC transit risk modelling. Section also updated to highlight that collision frequencies are not specific to LNGC vessels and that there are no recorded ship collision events that have occurred at Port Kembla.
Section 8.1.2	Section added to detail societal risk criteria.
Section 8.2	Section updated to present ‘base case’ LSIR contours for the three operational modes i.e. FSRU only, FSRU with LNGC ship-to-ship loading and FSRU with LNGC transit occurring and to provide further clarity regarding the risk associated with a LNGC movements within Port Kembla.
Section 8.2.1	Section added to present key risk contributors at identified locations of interest.
Section 8.4.1	Figure 8-12 updated for ‘base case’ LSIR contours with no risk reduction measures considered for the FSRU only operational mode.
Section 8.4.2	Section updated to present ‘high season’ LSIR contours for the three operational modes i.e. FSRU only, FSRU with LNGC ship-to-ship loading and FSRU with LNGC transit occurring.
Section 8.5	Section added present societal risk results.
Appendix C	New appendix added to detail population data used in the societal risk assessment.
Appendix E	New appendix added to present top 5 ‘high’ and ‘significant’ risk ranked hazards from the HAZID studies.
Appendix F	New appendix added to reproduce consequence modelling results presented in the Fire Safety Study.

Revision History	
Revision 3	
Location	**Description**
General	Report updated to provide further clarity based on comments provided by the NSW Department of Planning and Environment and Safework NSW.
Section 1	Section updated to detail response from Port Authority NSW regarding recommendation raised in previous revision of the report.
Section 3.7	Section update to provide further clarity of the ORF fire and gas system.
Section 7.1	Section updated to provide further clarity of the consequence operating conditions and QRA sections.
Appendix F	Appendix updated to provide further clarity regarding the definition of worst case consequences.
Appendix I	Appendix updated to provide further clarity of the consequence operating conditions and QRA sections and their application in the frequency analysis

1. Executive Summary

A Final Hazard Analysis (FHA) for the Port Kembla Gas Terminal (PKGT) project has been conducted in compliance with requirements of Condition 21(c) of the Infrastructure Approval SS 9471 [2] and in line with NSW Planning, Hazardous Industry Planning Advisory Paper No 6 (HIPAP6) - Hazard Analysis [3] to develop a comprehensive understanding of the hazards and risks associated with operation of the PKGT and of the adequacy of safeguards. The FHA includes consideration of all loss of containment (LOC) of hazardous process related substances and associated escalation events emanating from the Floating Storage and Regasification Unit (FSRU) (or Liquified Natural Gas Carrier) and onshore receiving facilities (ORF) including the above ground section of the Port Kembla Pipeline (PKP) located at the berth and the below ground 4.3km section 'Segment 1.1' of the PKP up to KP4.3.

The FHA details the hazard identification studies conducted over various stages of the project with the outputs summarised in Appendix A presenting the possible incident initiating events, consequences and safeguards in place. The findings of these studies have been used as input for additional studies and analysis which have been conducted and include the following:

- Safety Integrity Level (SIL) determination study for which four Safety Instrument Functions (SIFs) were reviewed with three SIFs assigned a SIL-0 rating, and one (HP manifold LL temperature) assigned a SIL-1 requirement. An action was raised in the SIL Determination report to ensure that the HP manifold LL temperature function is able to achieve the risk reduction / integrity level of a SIL-1 function. This action remains open and will be tracked to closure by the project.
- Fire Safety Study (FSS) [4] which details the fire prevention, mitigation, protection and suppression (i.e. risk reduction) strategies for the potential hazardous scenarios identified for the project. This study was completed for the PKGT as required by Condition 21(a) of the Infrastructure Approval SSI 9471 [2] and in line with NSW Planning, Hazardous Industry Planning Advisory Paper No 2 (HIPAP2) - Fire Safety Study Guidelines [5] and has been issued for consultation with Safework NSW, Port Authority NSW and Fire and Rescue NSW (FRNSW). It has subsequently been approved by FRNSW.
- Escape, Mustering, Evacuation, Rescue Analysis (EMERA) [6] for the ORF to ensure adequate arrangements for EMER have been provided by the project.

A Pipeline Safety Management Study was carried out for the Jemena PKP [7] by others in accordance with the Australian Standard for Pipelines – Gas and Liquid Petroleum (AS 2885) and concluded that no unusual threats that cannot be controlled through the current design process were identified. The scope of the Pipeline Safety Management Study covers the entirety of the new lateral pipeline route from the PKGT to the existing Eastern Gas Pipeline (EGP) (i.e. including 'Segment 1.1' up to KP4.3). The Pipeline Safety Management Study has been reviewed by NSW Department of Planning and Environment and confirmed the study was conducted appropriately by all relevant stakeholders, in line with the requirements of AS 2885 [8].

FHA risk modelling using DNV SAFETI software was conducted to determine the location specific individual risk (LSIR) contours (offsite risk) associated with the PKGT. The overall findings from the 'base case' average seasonal demand risk modelling presented as LSIR contours for the three operational modes i.e. FSRU only, FSRU with LNGC ship-to-ship loading and FSRU with LNGC transit occurring are provided in Figure 1-1, Figure 1-2, and Figure 1-3 respectively. The 'base case' assumes an averaged flat demand profile of 309 TJ/day throughout the year based on the seasonal demands. On average, it is assumed 29 LNGC deliveries are required per year.

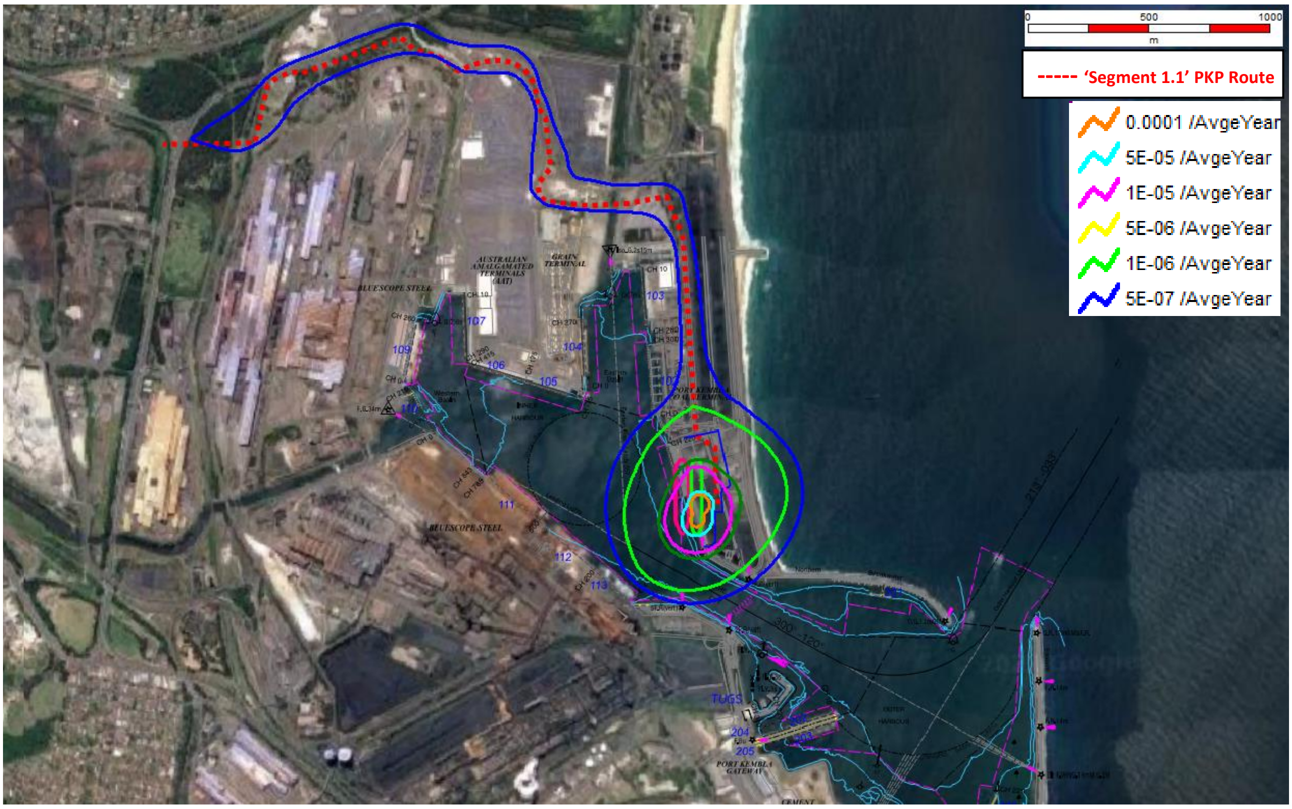

Figure 1-1: PKGT Base Case Fatality Risk Contours – FSRU Only

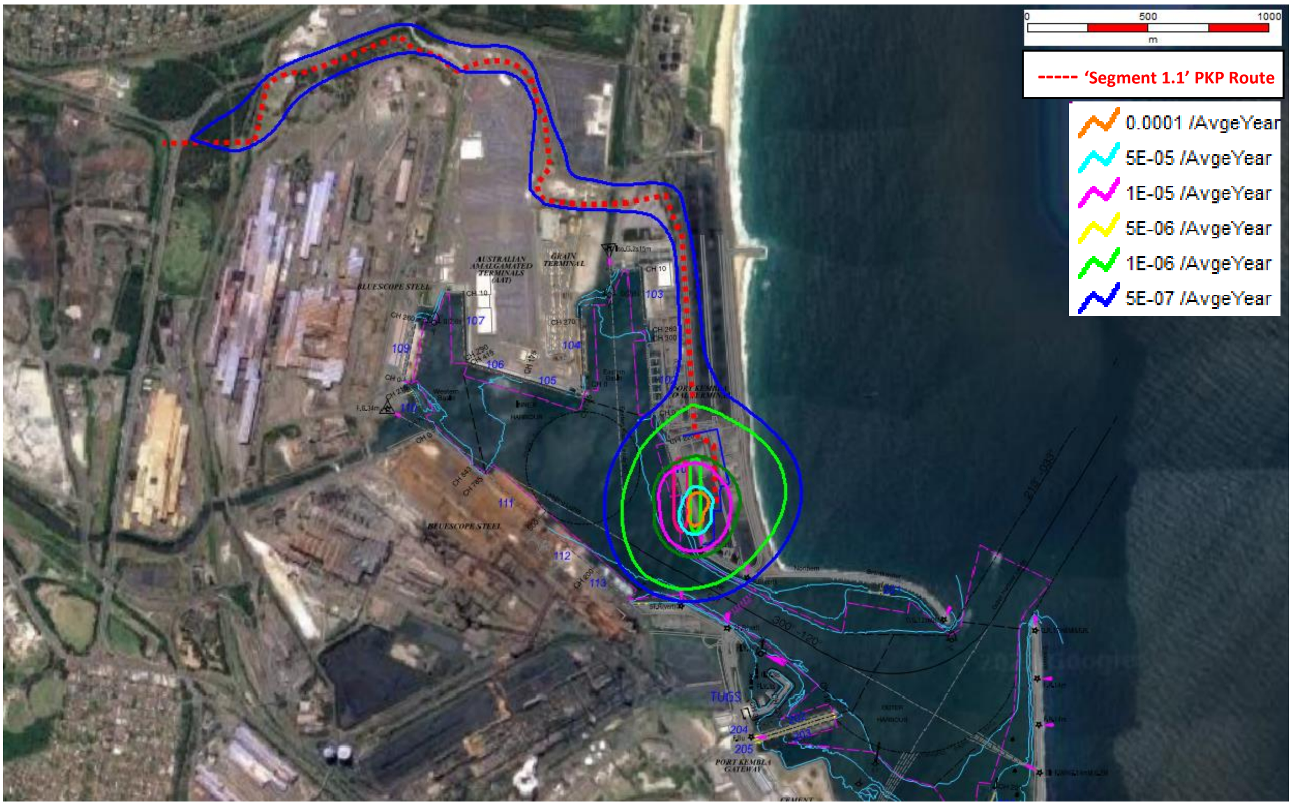

Figure 1-2: PKGT Base Case Fatality Risk Contours – FSRU with LNGC Ship-to-ship Loading

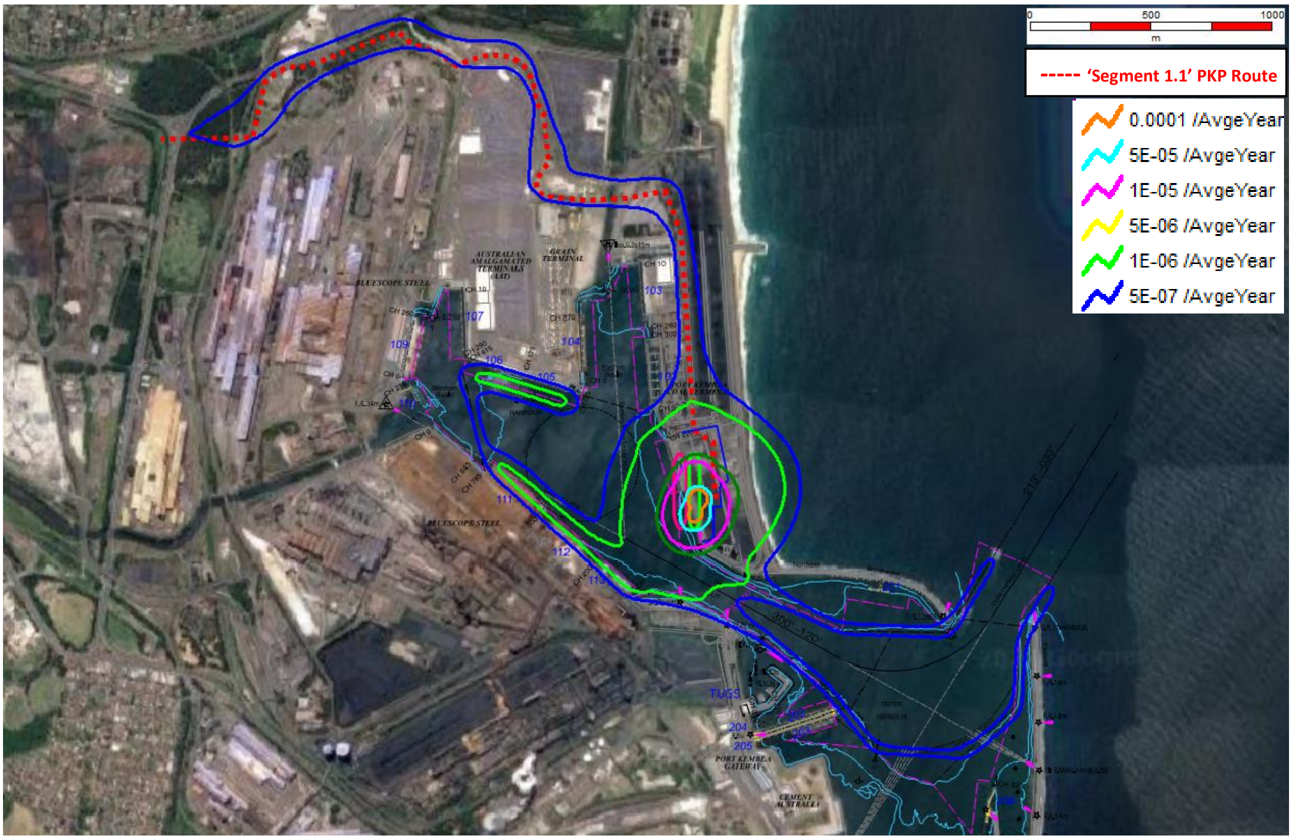

Figure 1-3: PKGT Base Case Fatality Risk Contours – FSRU with LNGC Transit Occurring

The LSIR results assessed against NSW Planning, Hazardous Industry Planning Advisory Paper No 4 (HIPAP4) - Risk Criteria for Land Use Safety Planning [9] are provided in Table 1-1. Note, LSIR is the risk of fatality and/or injury at a point in space to a hypothetical unprotected individual at a location for 365 days per annum (pa), 24 hours a day. Where hazards are not continually present i.e. those associated with LNGC vessel movements, the LSIR shown are an average over a year. For individuals to be exposed to risk they need to be present at a location at the time a hazardous event occurs.

Table 1-1: PKGT Base Case LSIR Results as Assessed against the HIPAP4 Fatality Risk Criteria

Risk (pa)		Land Use	Criteria Met
5E-07	(blue)	Hospitals, schools, child-care facilities, old age housing	Yes There are no hospitals, schools, child-care facilities, or old age housing within the contour area.
1E-06	(green)	Residential, hotels, motels, tourist resorts	Yes There are no residential developments, hotels, motels, tourist resorts within the contour area.
5E-06	(yellow)	Commercial developments including retail centres, offices and entertainment centres	Yes There are no commercial developments including retail centres, offices and entertainment centres within the contour area. The BlueScope Steel visitors centre located in the vicinity of 'Segment 1.1' has been considered to be equivalent of a commercial development and is outside the associated risk contour.

Risk (pa)		Land Use	Criteria Met
1E-05		Sporting complexes and active open space	Yes The 1E-05 pa risk contour does not reach any active open spaces (i.e. Seawall Road)
5E-05		Industrial	Yes The 5E-05 pa risk contour remains within the site boundary

The results show that on average throughout the year, with the risk reduction measures included in the PKGT design, the overall offsite fatality risk associated with the project meets all of the criteria specified in HIPAP4 [9].

The FHA frequency analysis determined the FSRU contains the majority of leak sources followed by the LNGC, and then the ORF. It is noted however, that the LNGC will only be berthed alongside the FSRU a fraction of the time which is factored into the risk modelling. Approximately 90% of the leaks are associated with the smaller leak sizes of 25mm and less. These leak sizes contribute the least to offsite risk due to their reduced consequence distances.

Additional risk models (sensitivities) were considered in the FHA to demonstrate the impact of implementation of risk reduction measures included in the PKGT design, and to present the risk associated with operating the FSRU with a greater throughput and receiving increased LNGC deliveries (i.e. when there is a higher seasonal demand, particularly from retail customers in winter months). The criteria specified in HIPAP4 [9] are met when the FSRU is operating at greater throughput .

Societal risk (in the form of an FN curve) has also been assessed. Noting the criteria provided in HIPAP4 [9] are indicative and do not represent a firm requirement in NSW. Societal risk for the project is generally in the 'Broadly Acceptable' region except when a population from a berthed cruise ship is included in the calculations the FN curve moves into the SFAIRP region. Therefore, in Revision 2 of this report, the following recommendation was made to reduce the coincidence of a cruise ship in berth and LNGC vessel movements.

Recommendation 1: PANSW to manage LNC vessel movements such that an LNGC shall not enter or leave the port while a cruise vessel is at berth 106.

Following the issue of the previous revision of this report, Port Authority NSW (PANSW) has confirmed [10] the following:

"Port Authority manages vessel movements under our port safety functions in accordance with the risk profile of Port Kembla. This includes management of Liquid Natural Gas and cruise vessel movements to ensure that they are performed in a safe manner that is consistent with relevant legislation and standards. In the unlikely event that a cruise vessel is at berth 106 during the visit of an LNGC vessel at berth 101, such a movement will be managed to ensure safe access and egress, including delaying an LNGC vessel to berth while the cruise vessel is at berth 106".

Overall, it is considered the FHA demonstrates that LOC of hazardous process related substances associated with the PKGT are well understood, a number of hazard studies have been conducted to identify controls and safeguards included in the design and risk associated with the PKGT meet the criteria defined in HIPAP4 [9].

2. Introduction and Background

Australian Industrial Energy (AIE) are developing an Liquified Natural Gas (LNG) import terminal on the east coast of NSW to provide gas to industrial and wholesale customers. AIE is planning to supply up to 115PJ per annum, depending on seasonal demands corresponding to approximately 75% of NSW gas demand.

LNG will be sourced from worldwide suppliers and transported by LNG Carrier (LNGC) vessels to the Port Kembla LNG import terminal. The LNG will be stored and regasified on a Floating Storage and Regasification Unit (FSRU) to supply the NSW gas transmission network. The project will be the first of its kind in NSW and provide a simple, flexible solution to the state’s gas supply challenges. The project consists of four key components:

- LNGC — There are many of these in operation worldwide transporting LNG from production facilities all around the world to demand centres.
- FSRU — the Höegh Galleon has been selected as the FSRU for the project and is a Cape-class ocean-going vessel which will be moored at Berth 101 in Port Kembla.
- Berth and wharf facilities – wharf topside facilities (also referred as the Onshore Receiving Facility (ORF)) include marine loading arms to transfer natural gas from the FSRU to shore, and odourant storage and injection facilities.
- Natural Gas pipeline – the Port Kembla Pipeline (PKP) is a DN450, high-pressure pipeline connection from the berth to the Eastern Gas Pipeline (EGP) which is part of the existing gas transmission network. The PKP is a new pipeline to be designed, constructed and commissioned by Jemena. Jemena currently operate a number of distribution and transmission pipelines across northern Australia and Australia's east coast.

The project was declared Critical State Significant Infrastructure in accordance with section 5.13 of the Environmental Planning and Assessment Act 1979 (EP&A Act). An environmental impact statement (EIS) was prepared for the project [1] and the project subsequently received approval from the Minister for Planning and Public Spaces on the 24th of April 2019.

The overall Infrastructure Approval SS 9471 [2] is subject to a number of conditions including Condition 21(c) which requires the development of a Final Hazard Analysis Study which shall be “*based on its final design, consistent with the Department’s Hazardous Industry Planning Advisory Paper No. 6, ‘Hazard Analysis’. The Final Hazard Analysis must be prepared in consultation with SafeWork NSW and the Port Authority of NSW”.*

Following project approval from the Minister for Planning and Public Spaces, subsequent modifications to the development consent have been made and include:

- Modification 1 (MOD1) - to allow increased volumes of gas to flow through the Terminal, satisfying the market need for more gas during winter months. This will be achieved by increasing the permitted output of the Terminal, as well as increasing the number of LNG cargoes able to be received by the Terminal.
- Modification 2 (MOD2) - minor modification to the compliance reporting guideline for the project.
- Modification 3 (MOD3) - minor modification to update the schedule of lands.
- Modification 4 (MOD4) - to allow increased odourant storage quantity and the removal of the dedicated process cold vent at the ORF. Modification to alignment of PKP ‘Segment 1.1’ route and minor modification to update the schedule of lands.

- Modification 5 (MOD5) - to allow for the relocation of natural materials to an offshore area in the outer harbour. The option for offshore disposal is a last-resort contingency to be utilised only if necessary, during the construction of the outer harbour emplacement cell.

The above modifications have all received approval from the Minister for Planning and Public Spaces with exception of the removal of the dedicated process cold vent at the ORF. A So Far As Is Reasonably Practicable (SFAIRP) assessment has been prepared and issued to Safework NSW for approval [11]. The SFAIRP Assessment documents the risk to individuals at the ORF with and without the cold vent in the design and concludes that the current design without the cold is SFAIRP.

As part of the Detailed Design scope and in line with Condition 21(c) of the Infrastructure Approval SS 9471 [2] AIE has engaged Worley to prepare the Final Hazard Analysis (FHA). The experience of the hazard analysis team is provided in Appendix B. Table 2-1 presents the items specified in Condition 21(c) required to be included in the Final Hazard Analysis (FHA) and where they have been addressed in this report.

Table 2-1: Infrastructure Approval SS 9471, Condition 21(c) Final Hazard Analysis Requirements

Condition 21(c) Requirement	Section of this FHA
• Re-evaluate and confirm all relevant data and assumptions of the Preliminary Hazard Analysis, and provide details on any differences between the Preliminary Hazard Analysis and Final Hazard Analysis;	Section 6
• Re-evaluate and confirm all control measures proposed for the prevention and mitigation of incidents;	Section 5, Appendix A
• Include Safety Integrity Level (SIL) allocation and verification studies;	Section 5
• Demonstrate the adequacy of the safety systems included in the final design;	Section 7
• Re-evaluate the risk from the development based on the outcomes of the SIL allocation and verification report for the development;	Section 7
• Include a risk assessment of the following:	
• the gas conditioning operation, including but not limited to addition of odorant to natural gas;	Section 8
• all potential escalation events;	Section 5
• cold venting operations;	Section 5
• the risk to the biophysical environment; and	Section 8
• the potential for propagation risk to other berths storing / receiving / transferring explosives or other dangerous goods.	Section 8
• Provide details of measures that would be implemented to minimise the risk to the surrounding land, including negotiated arrangements with other stakeholders to implement appropriate risk reduction measures; and	Section 3, Section 7
• Be undertaken based on recent site specific and local meteorological data.	Section 6

2.1 Objectives

In addition to the requirements of Condition 21(c) of the Infrastructure Approval SS 9471 [2] and in line with NSW Planning, Hazardous Industry Planning Advisory Paper No 6 (HIPAP6) - Hazard Analysis [3] the objectives of FHA is to develop a comprehensive understanding of the hazards and risks associated with operation of the PKGT and of the adequacy of safeguards. The FHA shall:

- Identify the major process risk contributors associated with the project;
- Identify controls and safeguards included in the design;
- Determine the offsite risk impacts from the gas terminal facilities; and
- Confirm the injury and fatality risk exposure to persons offsite meets nominated acceptance criteria.

2.2 Scope

This FHA includes consideration of potential LOC events of process related hazardous substances and the associated potential escalation events emanating from the FSRU (or LNGC) and onshore receiving facilities including the above ground section of the Port Kembla Pipeline tie-in (up to the boundary isolation valve MLV-064011) located at the berth and the 4.3km 'Segment 1.1' of the PKP up to KP4.3.

The scope excludes:

- Hazards associated with construction, commissioning and decommissioning activities, as well as provision for future facilities; and
- PKP downstream of 'Segment 1.1' where transfer of ownership of the PKP (from AIE to Jemena) occurs. This section of the PKP downstream of Segment 1.1 already been subject to FHA by Jemena [12]. Transfer of ownership occurs near the intersection of Masters Road and Spring Hill Road.

2.3 Acronyms and Abbreviations

In this document, the following acronyms and abbreviations apply.

Table 2-2: Acronyms and Abbreviations

Acronym/Abbreviation	Definition
AEGL	Acute Exposure Guideline Level
AIE	Australian Industrial Energy
AIP	Australian Industrial Power
AS	Australian Standards
AVSD	Abandon Vessel Shutdown
BLEVE	Boiling Liquid Expanding Vapor Explosion
BOG	Boil-off Gas
BOM	Bureau of Meteorology

Acronym/Abbreviation	Definition
BPCS	Basic Process Control System
CAAP	Critical Alarm and Action Panel
CCS	Cargo Containment System
CCTV	Closed Circuit Television
CFD	Computational Fluid Dynamics
CMMS	Computerised Maintenance Management System
DN	Nominal Diameter
DNV	Det Norske Veritas
DTL	Dangerous Toxic Load
EIS	Environmental Impact Statement
EGP	Eastern Gas Pipeline
EMERA	Evacuation, Muster, Escape and Rescue Assessment
EP&A	Environmental Planning and Assessment Act 1979
ERPG	Emergency Response Planning Guideline
ESD	Emergency Shutdown
ESDH	Emergency Shutdown High
ESDL	Emergency Shutdown Low
F&G	Fire and Gas
FB	Full Bore
FEED	Front End Engineering Design
FFS	Firefighting Support
FHA	Final Hazard Analysis
FRNSW	Fire and Rescue NSW
FSRU	Floating Storage Regasification Unit
FSS	Fire Safety Study
GTT	Gaztransport & Technigaz
HAZID	Hazard Identification Study
HAZOP	Hazard and Operability Study
HCRD	Hydrocarbon Release Database
HHV	Higher Heating Value
HIPAP	Hazardous Industry Planning Advisory Paper

Acronym/Abbreviation	Definition
HIPPS	High Integrity Pressure Protection System
HMI	Human-Machine Interface
HP	High Pressure
IACS	International Association of Classification Societies
IAS	Integrated Automation System
IEC	International Electrotechnical Commission
IDTL	Immediately Dangerous to Life
IG	Infragravity
IOGP	International Association of Oil & Gas Producers
IP	Ignition Probability
IR	Infrared
ISGOTT	International Safety Guide for Oil Tankers and Terminals
KGMS	Kembla Grange Metering Station
KOD	Knock Out Drum
LD	Low Duty
LFL	Lower Flammable Limit
LNG	Liquefied Natural Gas
LNGC	Liquefied Natural Gas Carrier
LOC	Loss of Containment
LSIR	Location Specific Individual Risk
MHF	Major Hazard Facility
MLA	Marine Loading Arm
MP	Muster Point
NSW	New South Wales
NE	North East
NG	Natural Gas
ORF	Onshore Receiving Facility
OS	Operator Station
PANSW	Port Authority NSW
PCS	Process Control System
PFD	Probability of Failure on Demand

Acronym/Abbreviation	Definition
PFP	Passive Fire Protection
PHA	Preliminary Hazard Analysis
P&ID	Piping & Instrumentation Drawing
PJ	Petajoule
PLC	Programmable Logic Controller
PKCT	Port Kembla Coal Terminal
PKGT	Port Kembla Gas Terminal
PKP	Port Kembla Pipeline
PSD	Process Shutdown
PSV	Pressure Safety Valve
SFAIRP	So Far As Is Reasonably Practicable
SIL	Safety Integrity Level
SIS	Safety Instrumented System
SLOD	Significant Likelihood of Death
SLOT	Specific Level of Toxicity
SMS	Safety Management System
SOLAS	Safety of Life at Sea
STEL	Short-Term Exposure Limit
SWW	South West
TBM	Tert-Butyl Mercaptan
THT	Tetra Hydro-Thiophene
TPSD	Total Process Shutdown
UFL	Upper Flammable Limit
UKHSE	United Kingdom Health and Safety Executive
UKOOA	United Kingdom Offshore Operators Association
VCE	Vapour Cloud Explosion

3. Facility Description

3.1 FSRU

The FSRU selected for the Port Kembla LNG Import Terminal Project is the Höegh Galleon (previously referred as SN2220) which is an ocean-going vessel approximately 297 metres in length and about 43 metres in breadth [13]. It is a DNV Class vessel subject to the relevant Rules for Classification including the additional Regas Notation [14, 15] and has a total capacity of about 170,000 m^3 or equivalent to approximately 4 PJs of gas. This equates to approximately 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 (refer Figure 3-1).

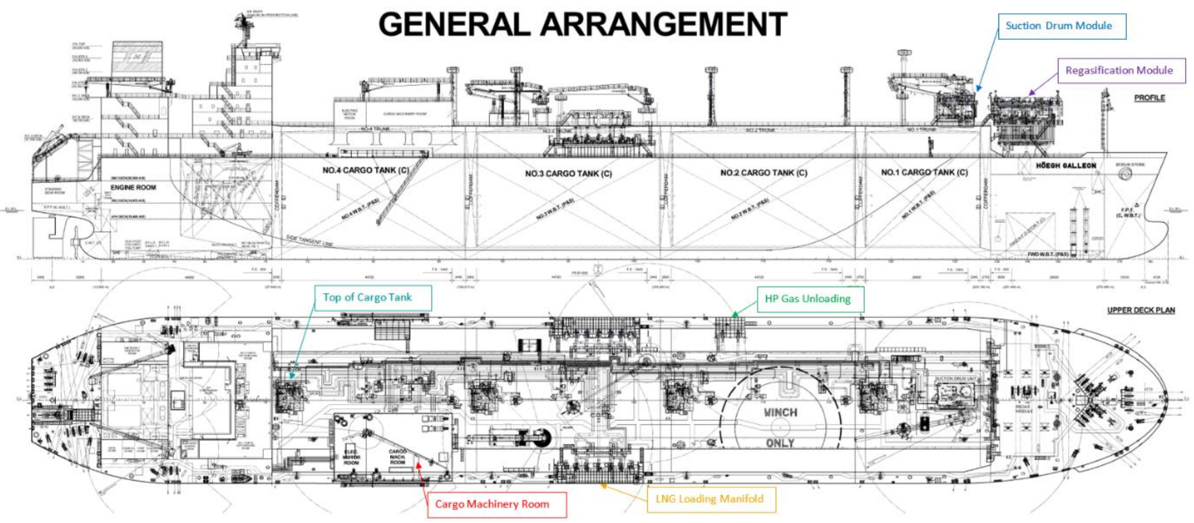

Figure 3-1: FSRU General Arrangement

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 purpose of the FSRU is to receive LNG from regularly scheduled LNGC visiting Port Kembla and regasify it for delivery into the PKP.

LNGC 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 LNGC will leave the port subject to suitable navigational conditions.

The FSRU has four key functional elements: facilities to receive LNG from LNGC; facilities to store LNG; facilities to convert LNG to high pressure gas; and facilities to transfer natural gas to the ORF and the gas pipeline.

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

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 electrically driven or supplied equipment on-board.

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

3.1.1 FSRU Seasonal Variation Production

Previous analysis of the NSW energy market identified that demand for gas is seasonally dependent, with higher demand, particularly from retail customers in winter months. The rate of production will need to respond to this demand and will also be influenced by operational parameters such as the calorific content of LNG delivered to the project. The seasonal variations in production was considered in Addendum 2 to the PKGT PHA [18].

Table 3-1 summarises the expected FSRU operating conditions, LNGC deliveries and quantity of 500L odourant containers required based on the seasonal demand. The average production 'base case' and 'high season' demands are considered separately in the FHA risk modelling. The 'low demand' case is not included as the risk will be less than the 'base case' as was confirmed in Addendum 2 to the PKGT PHA [18].

Table 3-1: Seasonal Variation in Production

Parameter	Base Case	Low Season	High Season
LNG Regasification Trains	2	1	2
LNG Regasification Trains Operating Pressure, barg	120	120	100
Seawater discharge, m^3/hr	10,500	3,250	13,000
LNGC Deliveries per year	29	26	52
Approximate TJ/day	309	120	500
Odourant container changes per year	72	28	116

3.2 LNGC Ship-to-ship transfer

It is expected that a LNGC would arrive at the FSRU once every two to three weeks dependent upon operational demand (refer Table 3-1). They will pull alongside the FSRU, tether to the FSRU and then transfer their load to the FSRU. The LNGC will tether alongside the FSRU for 24–36 hours while they transfer LNG cargo, still under atmospheric pressure, into the cargo holds of the FSRU. LNG is transferred to the FSRU via 4 DN250 purpose built cryogenic flexible transfer hoses (with a DN250 vapour return hose).

FSRU and LNGC water curtains will be in operation during ship-to-ship transfer. The intent of the water spray system is to mitigate cold temperature embrittlement of the hull. Only approved LNGC vessels in accordance with DNV Rules for Classification shall be selected for ship-to-ship transfer to the FSRU. LNGC will also have fire water spray system in accordance with International Association of Classification Societies (IACS).

During arrival and departure, the LNGC will be controlled by the Port Kembla Harbour Master, vessels are piloted and assisted. LNGCs and other vessels associated with the project will be required to comply with the port navigation protocols in place at Port Kembla.

Once operation commences, LNGCs operated by external suppliers will regularly visit Port Kembla with LNG shipments. While the capacity of LNGCs can vary, it is most likely that the LNG supplier to the project will seek to match the LNGC capacity to the FSRU capacity as closely as possible, in order to ensure a full transfer of cargo. As such, the LNGCs are assumed to be of similar capacity as the FSRU.

3.3 Berth Infrastructure

Berth topside facilities will be established at the wharf as part of the project. These facilities will include mooring infrastructure for the FSRU, and the ORF comprising 2 x 12” Marine Loading Arms (MLAs) to be used to transfer high pressure natural gas from the FSRU, odourant storage and injection facilities and pipeline tie-in facilities [19].

The intent of the ORF is to facilitate safe transfer of natural gas from the FSRU and for odourant to be injected prior to entering the PKP. The PKP will be approximately 11.5km in length and will tie-in to the EGP at an end of line facility near the Kembla Grange Metering Station (KGMS). The PKP route is presented in Figure 3-2.

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

Figure 3-2: PKGT Pipeline Route based on MOD4 to SSI 9471

3.4 Surrounding Land Use

The FSRU will be moored at Berth 101 in Port Kembla. Berth 101 is located in the Port Kembla Inner Harbour area between the existing Port Kembla Coal Terminal (PKCT) coal berth (B102) to the north, and “The Cut” shipping channel to the south. The PKCT employs approximately 60 staff to operate and maintain the terminal [20]. The land adjoining Berth 101 to the east is currently managed by NSW Ports.

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 LNGCs without limiting the existing navigability of the Inner Harbour.

The surrounding land use is primarily categorised as industrial with the BlueScope Steelworks located across the outer harbour to the west being the most populated industrial area. There are no significant commercial spaces that routinely have large number of people present. The public may have access to the northern breakwater for recreational use (i.e. fishing) which is accessible via Seawall Road. Seawall Road to the east of Berth 101 is a public road managed by NSW Ports. PHA Addendum 1 [17] addressed access via Seawall Road which is opened to the public during daylight hours only and regularly closed for poor weather and/or other operational needs, including bulk haulage, construction / maintenance, etc. Members of the public accessing Seawall Road and the northern breakwall do so for short durations and numbers are limited as indicated by NSW Ports [17]:

“The road tends to be used by surfers, rock fishers and occasional on-lookers for unusual events, such as the arrival of a large cruise ship. However, numbers of users are in the dozens, not the 100’s, with the largest crowds seen there for the arrival of the Port’s first cruise ship. Subsequent cruise ship arrivals have seen the crowd numbers dwindle.”

The public also have access to the eastern breakwater via Foreshore Road. The Port Kembla Outer Harbour Boat Ramp is also accessed via this road. Public access to the Port Kembla Inner harbour is not permitted and is under the control of the Port Authority NSW (PANSW). The closest residential areas are approximately 2km to the north and south of the Berth 101 site.

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. Australian Industrial Power (AIP) have also proposed for a gas-fired power station to be constructed adjacent to the PKGT.

There is also a cruise ship terminal (Berth 106) within the Inner Harbour, approximately 550m from the FSRU. Historically this has been used 2 to 3 times a year, for no longer than 12 hours. The largest known cruise ship that has visited Port Kembla had the capacity to accommodate 5000 people (including crew) [21]. There are no scheduled cruise ships for the next two years. However, it is possible that in the future, cruise ships will return to Port Kembla. Cruise ships have previously berthed for less than 12 hours but it is assumed they could remain on berth for up to 24 hours. As detailed above, the first arrivals of cruise ships in Port Kembla saw groups of up to 100 people gather at the northern breakwater.

Port Kembla Inner Harbour has numerous other berths and associated industrial facilities. Due to some of the identified surrounding areas routinely being populated, this study will consider societal risk. Population data for surrounding land users is summarised in Appendix C.

3.5 Manning

An operational workforce of 20 – 25 shall be employed on the FSRU.

The ORF and pipeline are designed to be operated from the Jemena EGP remote control room and therefore personnel are not present on site at the ORF. The remote control room will be manned 24/7. Personnel will only attend the ORF or pipeline on an as needed basis for routine, preventative and breakdown maintenance activities, inspections, deliveries to the FSRU and operational activities or as part of emergency response.

3.6 Safety Management System

A Safety Management System (SMS) is a systematic approach to managing safety. Schedule 3, Condition 23(b) of Infrastructure Approval SSI 9471 [2] requires a SMS to be developed and approved by the Planning Secretary prior to the commencement of operations of the facility.

AIE will develop a comprehensive SMS in consultation with SafeWork NSW based on local standards and industry best practice for facilities handling LNG. In compliance with the requirements of Condition 23(b) of Infrastructure Approval SSI 9471 [2] the SMS framework will:

- Cover all development operations, and clearly specify all safety related procedures, responsibilities and policies, along with details of mechanisms for ensuring adherence to the procedures;
- Include an inspection, testing and preventive maintenance program that will be implemented and maintained to ensure the reliability and availability of the key safety critical equipment is, at a minimum, consistent with the data estimated in the Final Hazard Analysis; and
- Include a security plan developed in consultation with the Terrorism Protection Unit and the Major Hazard Facilities Unit of the Counter Terrorism and Special Tactics Command of the NSW Police Force.

Typical SMS elements to be included are:

- 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 SMS 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 Detection, Protection and Suppression Strategies

A Fire Safety Study (FSS) [4] has been completed for the PKGT as required by Condition 21(a) of the Infrastructure Approval SSI 9471 [2] and in line with NSW Planning, Hazardous Industry Planning Advisory Paper No 2 (HIPAP2) - Fire Safety Study Guidelines [5]. The study details the fire prevention, mitigation, protection and suppression (i.e. risk reduction) strategies for the potential hazardous scenarios identified for the project. A high level overview of the FSRU (and LNGC) and ORF protections as detailed in the Fire Safety Study (FSS) [4] is provided below.

3.7.1 Ship-Based Fire Protection

The FSRU vessel is a DNV Class vessel subject to the relevant Rules for Classification including the DNV Rules for Classification Part 5 (Ship types) Chapter 7 (Liquified gas Tankers) (hereinafter referred as DNV-RU-SHIP-Pt5Ch7) [14] and the additional DNV Rules for Classification Part 6 (Additional Class Notations) Chapter 4 (Cargo Operations) Section 7 (Regasification Plant) (hereinafter referred as DNV-RU-SHIP-Pt6Ch4 Section 7) [15]. Marine Order 15 (Construction — fire protection, fire detection and fire extinction) [22] prepared by the Australian Maritime Safety Authority gives effect to Chapter II-2 of SOLAS. The fire protection, fire detection and fire extinction requirements outlined in the DNV Rules for Classification either specify compliance with Chapter II-2 of SOLAS or require additional protections. As such, it is considered the DNV Rules for Classification meet or exceed the standards referenced in Marine Order 15 [22].

The following safety philosophy for the FSRU has been provided by Höegh [23] and is in compliance with DNV-RU-SHIP-Pt5Ch7. *"Implementation of necessary risk reducing measures shall be made in the following order of preference unless quantitative evidence indicates other preferences:*

1. *Inherent safety / physical prevention of occurrence of hazards*
2. *Control occurrence (reduce probability of …)*
3. *Mitigate consequences (reduce consequence severity of …)*
4. *Escape and evacuation"*

LOC events from the FSRU process are mitigated through the FSRU storage and regasification design and application of the hierarchy of controls. The FSRU also has a fire and gas (F&G) detection system provided in compliance with the DNV Rules for Classification DNV-RU-SHIP-Pt5Ch7 [14] and DNV-RU-SHIP-Pt6Ch4 Section 7 (Regasification Plant) [15]. The F&G detection system is required to facilitate early detection of a flammable gas release and to alert personnel and allow control actions to be initiated manually or automatically to minimise the probability of explosion and fire. It forms a component of the Integrated Automation System (IAS) Emergency Shutdown (ESD) / Process Shutdown (PSD) systems. The IAS ESD / PSD is divided into several levels, to form a shutdown hierarchy as presented in Figure 3-3. This allows non affected sections of the FSRU to remain operative.

A hard wired link will be provided between the FSRU and ORF for ESD activation from the ORF to the FSRU [25]. FSRU F&G status will be displayed on ORF Emergency Control Room HMI; and ORF F&G status will be made available on the FSRU.

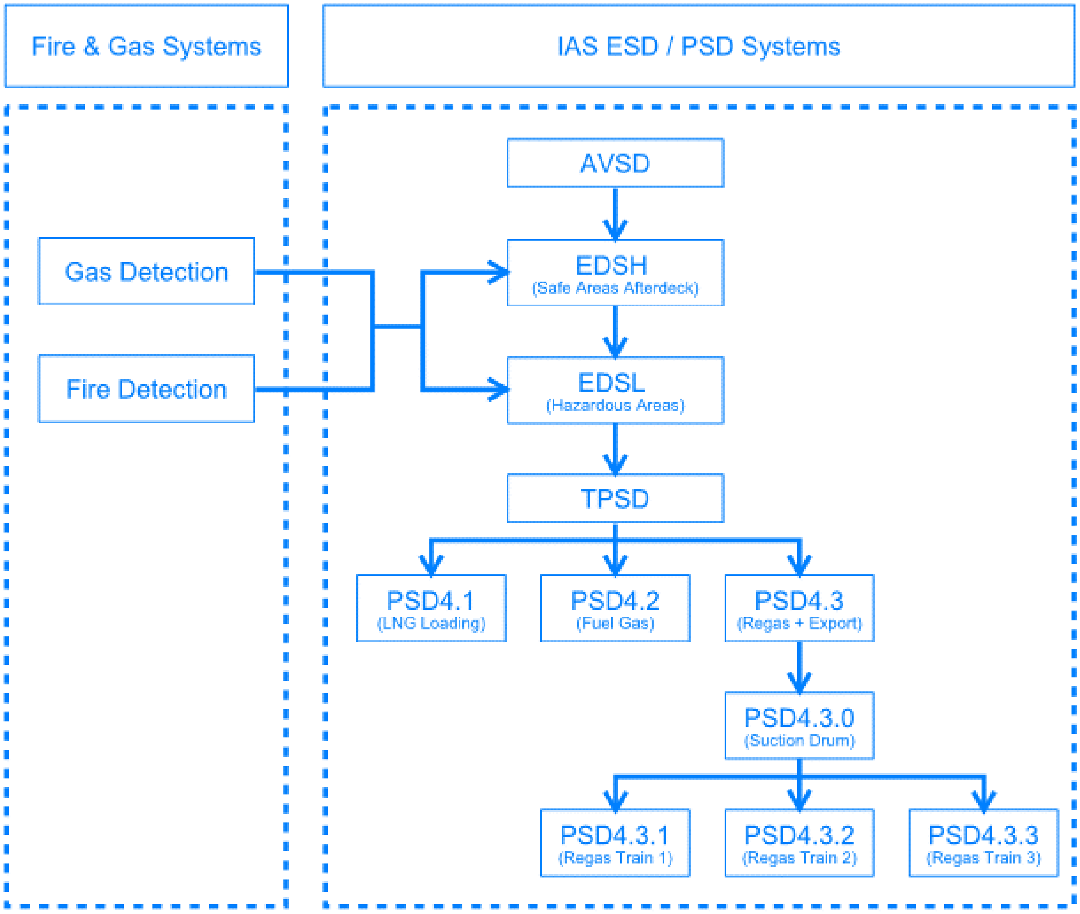

Figure 3-3: FSRU ESD / PSD Hierarchy [24]

Abandon Vessel Shutdown (AVSD)

AVSD is the highest shutdown level on the FSRU. AVSD activation is manual only via pushbutton and upon authorisation from the Captain in preparation for a total abandonment of the vessel. The intention of an AVSD is to ensure that the vessel is broadly electrically dead shortly after abandonment. AVSD implements the following actions:

- Initiates general emergency alarm
- Initiates ESDH (and all lower levels)

ESD High(ESDH) (Safe Areas)

ESDH is the highest automatic ESD level and is activated via AVSD, ESDH pushbuttons or via confirmed gas detected in air inlets to non-hazardous (safe) areas with essential equipment including the CCR, accommodation and engine room. The intent of this shutdown level is to isolate possible ignition sources by trip of all power supplies as well as trip of all ventilation to prevent further intake of gas into the safe area.

ESDH implements the following actions:

- Activates alarms on IAS OS and CAAP;
- Initiates ESDL (and all lower levels);
- Shutdown all main and auxiliary power generation

- Start emergency generator and activate emergency lights (if safe to do so – confirmed gas at emergency generator will inhibit this)
- Trip all ventilation in accommodation and engine room

The fire dampers in exhaust air openings and fresh air intakes in the accommodation and pneumatic damper in the engine room are closed remotely from the navigation bridge, cargo control room or fire control station with manual button available on damper panel located at fire control station.

Fire in safe areas should not automatically cause ESDH, rather ESDH will be initiated manually if required (based on evaluation of the severity of the incident case by case).

ESD Low (ESDL) (Hazardous Areas)

ESDL is activated via AVSD or ESDH, manual pushbuttons, confirmed gas and/or fire in hazardous areas (i.e. cargo or process) or failure of the F&G system. The intent of this shutdown level is prevention of escalation into safe areas, switch to liquid fuel, initialisation of process depressurising, closing of isolation valves, and activation of active fixed firewater protection systems.

ESDL implements the following actions:

- Activates alarms on IAS OS and CAAP;
- Initiate TPSD;
- Initiate alarms;
- Close FSRU ESD valves and main gas valves;
- Initiate blowdown (confirmed fire in the regasification plant, gas metering or HP export manifold areas only);
- Send gas trip signal to main engines and boilers control system (confirmed fire only)
- Start fire water spray pump (confirmed fire only)
- Start fire water pump (confirmed fire only)

Major failure of the IAS ESD or F&G detection system logic will also automatically activate ESDL.

Total PSD (TPSD)

TPSD is only activated via higher ESD levels or upon critical process upsets serious enough to shut down all cargo related processes. Typical examples of such an upset include loss of hydraulic oil pressure, instrument air or electrical supply. Noting the overall Safety Instrumented System including the PSD System is independent from the process control system (PCS).

TPSD will initiate all PSD levels and implements the following actions:

- Activates alarms on IAS OS and CAAP;
- Initiate PSD4.1 (LNG loading);
- Initiate PSD4.2 (Fuel gas); and
- Initiate PSD4.3 (Regasification and export).

Typical actions from PSD systems include trip of driven units (e.g. compressors, pumps), isolation of hydrocarbon inventories by closing ESD or PSD valves, and isolation and/or trip of utility systems serving the process.

In addition to the above, the FSRU also has active fire protection and suppression provided for liquid fires and gas fires in compliance with the DNV Rules for Classification DNV-RU-SHIP-Pt5Ch7 and DNV-RU-SHIP-

Pt6Ch4 Section 7 (Regasification Plant). The FSRU ship-based firefighting system is provided with fire protection equipment, including but not limited to:

- Fire water pumps to distribute water via a ring main system with hydrants located in compliance with requirements of DNV-RU-SHIP-Pt5Ch7.
- Water spray pumps to distribute water to the water spray system in compliance with requirements of DNV-RU-SHIP-Pt5Ch7 and DNV-RU-SHIP-Pt6Ch4;
- Emergency fire pump;
- High expansion foam system for firefighting in the engine room and steering gear room;
- CO_2 extinguishing system for protection of the cargo machinery room, electric motor room, cargo switchboard rooms, emergency generator room, emergency and main switchboard rooms, engine control room, regasification switchboard room and forward pump room;
- Dry powder extinguishing system for firefighting on the deck in the cargo area and the regasification plant; and
- Fire extinguishers and minor fire protection equipment as required by Australian and International Standards.

Only approved LNGC vessels in accordance with DNV Rules for Classification shall be selected for ship-to-ship transfer to the FSRU. As such, it is expected that LNGC vessels will be provided fire protection equipment in compliance with requirements of DNV-RU-SHIP-Pt5Ch7.

When a LNGC vessel is tethered alongside the FSRU while they transfer their LNG cargo, a ship-to-ship link shall be established (i.e. via electrical connection and/or fibre optic connection). If the ship-to-ship link has not been successfully established, LNG transfer cannot commence. The main functions of the LNGC-FSRU link are to avoid the following scenarios:

- Overfilling of FSRU LNG tanks;
- Escalation of gas leaks and fire scenarios on board FSRU, LNGC or ORG;
- Risk of damage or spillage due to excessive movement of the ships; and
- Damage due to excessive surge pressures.

ESD on the LNGC will activate the onboard alarm sounding, close the LNG transfer manifold valves (on LNGC and FSRU) and trip transfer machinery on the LNGC. Höegh have carried out surge studies in the past for LNG transfer via cryogenic hoses as part of their technology qualification [26, 27].

3.7.2 Shore-Based (ORF) Fire Protection

F&G detectors at the ORF are also provided to facilitate early detection of a flammable gas release or subsequent fire. The ORF will have an Emergency Shutdown System which upon initiation the following executive actions are initiated [28]:

- Raise alarm locally and at control room;
- Activate PAGA
- Send ESD signal to FSRU and MLA packages;
- Close MLA ESD valves;
- Close ORF ESD valve;
- Stop odourant injection package;
- Operator to use CCTV to investigate and ascertain if further mitigation actions are required.

Confirmed fire detection will also start the firewater pumps. The F&G detection and alarm system is independent from the process control systems and like the ESD system, will be contained in the site Safety Instrumented System (SIS) and interface with the FSRU ESD system. As previously detailed, a hard wired link will be provided between the FSRU and ORF for ESD activation from the ORF to the FSRU [25]. FSRU F&G status will be displayed on ORF Emergency Control Room HMI; and ORF F&G status will be made available on the FSRU.

Active fire protection and suppression systems are provided for liquid fires and gas fires in compliance with International and Australian Standards as required. Primary firefighting strategy for gas fires (including liquefied gas fires) is isolate the inventory and to cool adjacent equipment to prevent escalation events due to mechanical or structural failure and to enable personnel evacuation.

The shore-based firefighting system is provided with fire protection equipment, including:

- Fire water storage tanks;
- Fire water pumps to distribute water via a ring main system with hydrants located with a maximum of 70 m spacing in compliance with requirements of AS 2419 and AS 3846;
- Remotely activated tower mounted fire water monitors; and
- Fire extinguishers and minor fire protection equipment as required by Australian and International Standards.

During an emergency event at the ORF, the primary point of control will be via the Jemena EGP control room which will be manned 24 hours a day. Communication between this location, the FSRU and site personnel will be via a dedicated fixed phone line, with radio link and mobile phone back-ups. The EGP control room will have full control of the berth tower mounted fire water monitors allowing steering and stream adjustment from fog nozzle to jet stream. Another set of fixed controls will be provided in the berth emergency control room and another two additional mobile control units will be available to operate at any point within at least 200m of the emergency control room where the receiver will be installed. One set of mobile controls will be located in the FSRU control room and another in the berth emergency control room. The ORF fire water pumps can be manually started at the control panel located adjacent to each fire water pump.

3.8 Escape, Mustering, Evacuation, and Rescue

In addition to the FSS, as part of the detailed design phase, an Escape, Mustering, Evacuation, Rescue Analysis (EMERA) was undertaken [6] for the ORF covering fire, toxic gas dispersion and explosion scenarios to ensure adequate arrangements for EMER have been provided by the project. The findings of the analysis indicate appropriate means for EMER have been provided. The ORF has two separate muster points (MPs) at the eastern side of ORF with primary MP and alternative MP / site evacuation area alongside the Seawall Road which are both located outside the 25mm unignited and ignited release impact zones.

A separate EMERA has not been carried out for the FSRU vessel. However, the safety philosophy for the FSRU provided by Höegh [23] indicates the FSRU is designed and constructed with respect to reducing risk in compliance with DNV-RU-SHIP-Pt5Ch7 as follows:

- Minimise the possibility of hazardous accumulations of both liquids and gaseous hydrocarbon and to provide for the rapid removal of any accumulations which do occur;
- Minimise the probability of ignition;

- Minimise the spread of flammable liquids or gases which may result in a hazardous event;
- Separate areas required to be non-hazardous from those designed as being hazardous;
- Minimise the consequences of fire and explosions;
- Provide for adequate arrangements for escape and evacuation; and
- Facilitate effective emergency response.

Provision for escape routes from the regasification plant are also provided in compliance with DNV-RU-SHIP-Pt6Ch4 Section 7. During the detailed design HAZID study [35] actions were raised to verify emergency response and muster on the FSRU.

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 HIPAP6 [3] which describes the methodology to be used in hazard and risk assessment in NSW as outlined in Figure 4-1

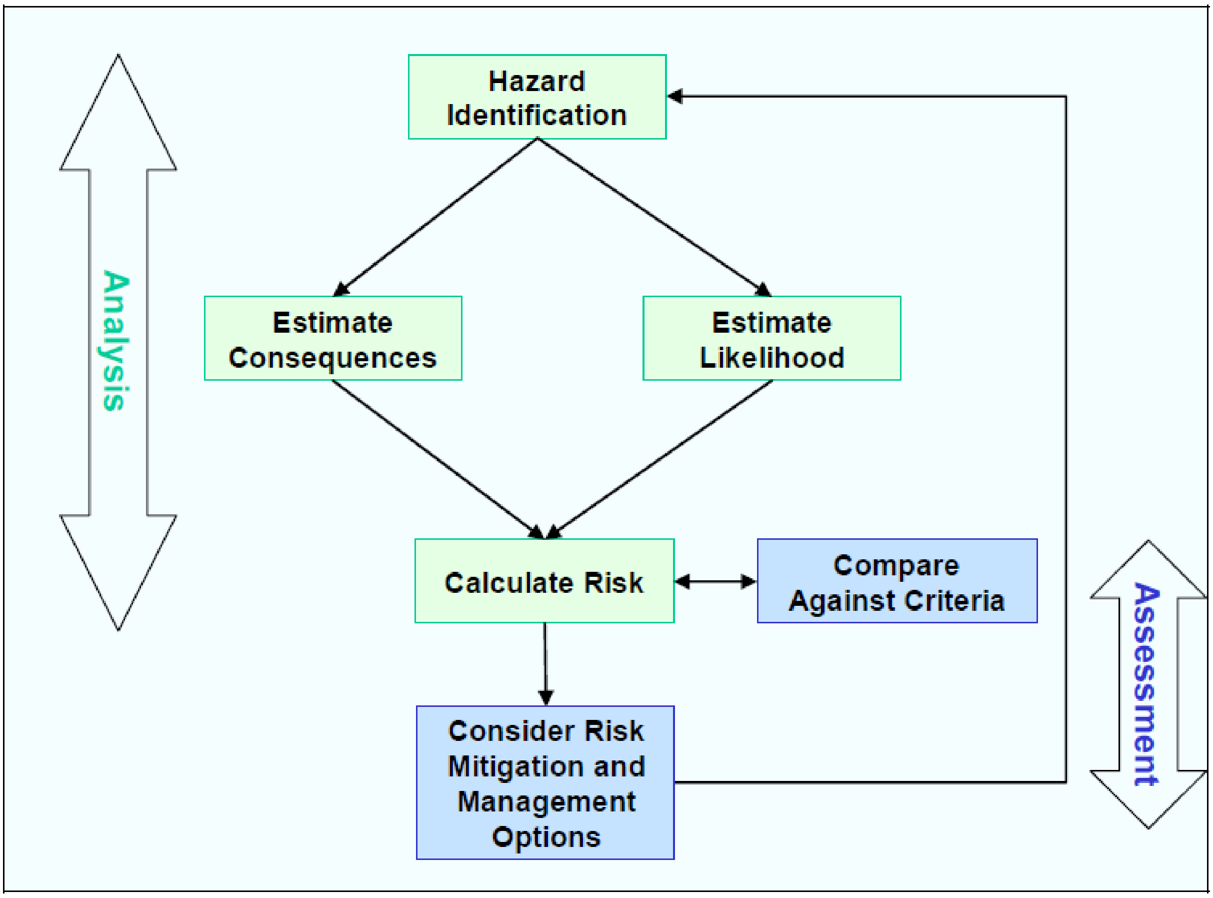

Figure 4-1: Hazard Analysis Methodology [3]

Table 4-1 presents each step and details the corresponding section of this report.

Table 4-1: HIPAP6 Final Hazard Analysis Process [3]

Step	Description	Section of this FHA
1	Hazard identification	Section 5
2	Consequence and impact analysis	Section 6
3	Analysis of consequences of incidents (frequency analysis)	Section 7
4	Risk analysis	Section 8

5. Hazard Identification

5.1 Hazard Identification

A number of Hazard Identification (HAZID) [29, 30, 32, 35] and Hazard and Operability (HAZOP) [30, 31, 33, 34] workshops have been held over the various phases of the project. The objective of the HAZID reviews were to identify all significant hazards associated with the various aspects of the project, with a view to eliminating or reducing the hazards through the application of inherent safety, while the HAZOP study identified hazards and operating concerns that may result from unexpected deviations from the intended design or operation.

The detailed design HAZID studies for the ORF and FSRU cargo system were carried out on the 21st – 25th February 2022 and were attended by representatives from Höegh, AIE, Arriscar, LogiCamms, Jemena and Port Authority NSW (PANSW). An additional study for the FSRU utility systems was carried out on the 12th – 14th December 2022 and was attended by representatives from Höegh, AIE, and Arriscar. These workshops were facilitated by a suitably qualified and experienced person independent from the project in accordance with the requirements of Condition 21(b) of the Infrastructure Approval SSI 9471 [2].

The methodology of a HAZID review is as follows:

- Identify all potential hazardous events and their significance to safe operations;
- Identify the potential consequences on personnel, the asset, or the environment;
- Identify existing safeguards (also termed barriers); and
- If existing safeguards are considered inadequate, the workshop team 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 HAZID study used a guideword approach with the guideword categories listed below:

- Natural Hazards;
- Process Hazards;
- Working Environment / Occupational Hazards;
- Construction Hazards; and
- Layout.

All of the hazards identified during the HAZID studies had their consequences, likelihoods and risk ranked using the AIE Risk Matrix based on the expertise of the workshop team (refer Appendix C). The overall findings of the studies are documented in the Detailed Design HAZID study report [35]. The HAZID studies found a total of 16 hazards ranked as 'high' risks, 45 hazards ranked as 'significant' risks, 43 hazards ranked as 'major' risks and 2 hazards ranked as 'low' risks. An extract of the top five 'high' and ' significant' risks are provided in Appendix E for information. As detailed above, where the workshop considered the existing safeguards as being inadequate, they proposed actions to undertake further hazard assessment and identify additional risk reduction measures. Actions raised have been added to the AIE action tracking system 'Noggin' for closure and approval. 'Noggin' is a cloud-based software program used to manage and track the status, close-out and approval of actions.

Detailed design HAZOP studies for the ORF were carried out on the 8th – 10th February 2022 and were attended by representatives from Höegh, AIE, Arriscar, LogiCamms, Jemena. Additional studies for ORF utility systems and the odourant injection package were carried out on the 17th and 29th November 2022 and the 14th December 2022 and were attended by representatives from AIE, Arriscar, and the vendor suppliers. These workshops were also facilitated by a suitably qualified and experienced person independent from the project in accordance with the requirements of Condition 21(b) of the Infrastructure Approval SSI 9471 [2].

The methodology of a HAZOP review is similar to HAZID and is as follows:

- Identify all potential causes of deviations normal operations;
- Identify the potential consequences;
- Identify existing safeguards; and
- If existing safeguards are considered inadequate, the workshop team 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. Actions raised have been added to the AIE action tracking system 'Noggin' for closure and approval.

A Pipeline Safety Management Study has also been carried out for the Jemena PKP [7] by others in accordance with the Australian Standard for Pipelines – Gas and Liquid Petroleum (AS 2885) and concluded that no unusual threats that cannot be controlled through the current design process were identified. The scope of the Pipeline Safety Management Study covers the entirety of the new lateral pipeline route from the PKGT to the existing EGP (i.e. including 'Segment 1.1' up to KP4.3). The Pipeline Safety Management Study has been reviewed by NSW Department of Planning and Environment and confirmed the study was conducted appropriately by all relevant stakeholders, in line with the requirements of AS 2885 [8].

The output from the above studies has been summarised in Appendix A to present the possible incident initiating events, possible consequences and confirms safeguards in place for each major process area. Based on this, the following loss of containment events have been identified:

- LOC of LNG, natural gas, glycol, diesel and hydraulic, lube, marine oils on the FSRU;
- LOC of LNG on the LNGC;
- LOC of natural gas, odourant, diesel and hydraulic oils at the ORF; and
- LOC of natural gas from underground PKP Segment 1.1.

The characteristics of the hazardous inventories and potential hazard consequences from the LOC scenarios are detailed in Section 5.2 and Section 5.3.

In addition to the above hazard identification studies, a Safety Integrity Level (SIL) determination study [36] for the ORF was caried out on the 18th February 2022 and was attended by representatives from AIE, Arriscar, LogiCamms, Jemena and Safework NSW. Four Safety Instrumented Functions (SIFs) were reviewed, with three assigned a SIL-0 rating, and one (HP manifold LL temperature) assigned a SIL-1 requirement. An action was raised in the SIL Determination report to ensure that the HP manifold LL temperature function meets is able to achieve the risk reduction / integrity level of a SIL-1 function. This action remains open and will be tracked to closure by the project. The FSRU pipework and equipment downstream of the booster pumps up to the FSRU ESD valves are protected with a High Integrity Pressure Protection System (HIPPS) which is SIL-3 by design [37]. The HIPPS is provided to protect the pipework downstream of the booster pumps from overpressure events.

5.2 Hazardous Inventories

5.2.1 Liquified Natural Gas

LNG is the liquid form of natural gas and is produced by cooling the gas to approximately -160 °C at atmospheric pressure. At liquid state it is 1/600th of its original natural gas volume. LNG is clear, colourless and odourless, and is non-toxic and non-corrosive. It is stored in the FSRU cargo area which consists of four cargo tanks suitable for carrying LNG at low temperatures and at atmospheric pressure. The FSRU has the capacity to store 170,000m^3 or equivalent to approximately 4 PJs of gas. Table 5-1 presents LNG compositions for the project as presented in the PKGT PHA [16] and 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 [16]

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

When LNG is warmed it returns to its gaseous state as natural gas, described in Section 5.2.2. The main hazards of handling LNG are flash fire, jet fire and/or explosion depending on the location of a release and/or presence of ignition source, time of ignition and confinement. LNG also has the potential for pool fire if pooling occurs and an ignition source is present.

5.2.2 Natural Gas

Natural gas is a gaseous mixture comprising mainly methane with some higher hydrocarbon components (mainly ethane, propane, and butane) and may contain trace / low amount of other non-hydrocarbon components. The density of natural gas at atmospheric pressure is typically 0.75 kg/m^3. As natural gas is made up of mainly methane, the Lower Flammable Limit (LFL) and Upper Flammable Limit (UFL) for natural gas would be similar to that of methane, which is 5% and 15% by volume, respectively.

Natural gas is not stored as part of the Port Kembla LNG Import Terminal Project. However, it is transported from the FSRU to the PKP via pressurised process pipework.

The main hazards associated with natural gas are fire and/or explosion depending on the location of a release and/or presence of ignition source, time of ignition and confinement. The consequences of a LOC event are discussed further in Section 5.3.

5.2.3 Odourant

Odourant is stored onsite in two 500L semi bulk containers (SBC) storing approximately 1,200kg. The SBCs are housed within a shipping container. The container has internal bunding and provision for a third SBC taking the total storage to 1,800kg [38]. The project has approval for a total on site storage of 2,400kg as a result of MOD4 to Infrastructure Approval SS 9471 [2]. As such, a total inventory of 2,400kg has been considered in this FHA. The shipping container will also contain the injection packages and is designed with a ventilation system to limit the rise of internal temperature within the shipping container such that the internal temperature should not exceed the maximum temperature ratings of the equipment installed. Odourant will be injected into the natural gas at a rate between 0.6 – 6 L/hr and a concentration of 9mg/Sm^3. The SBC's will be loaded into the shipping container onsite using forklifts, with the long side of the container adjacent to the road being open and accessible via forklift (i.e. shipping container will not be fully enclosed during these activities). SBC changeout is expected to occur every 3 days to 13 days depending on the send out rate from the FSRU.

The level within the SBC's onsite will be monitored using load cells, with a signal provided to the offsite control room. The odorant injection rate will be set based on the gas sendout flowrate, supplied from the site control room to the package PLC.

The odourant selected for use is known as Spotleak 1005 which is a 70:30 blend of Tetra Hydro-Thiophene (THT) and Tert-Butyl Mercaptan (TBM). THT is a flammable material while TBM is both flammable and toxic.

Like natural gas, hazards associated with Spotleak 1005 are fire and/or explosion depending on the location of a release and/or present of ignition source. The flammable and toxic consequences of a LOC event are discussed further in Section 5.3.

5.2.4 Glycol

Ethylene glycol is stored on the FSRU (in regasification plant and the electric motor room) and used as part of the water heating systems for the regasification process and cofferdam system. It is a combustible material but can pose a fire hazard at elevated temperatures especially above its flash point (~111°C) and can pose a fire hazard if it contacts a very hot surface. In the hot glycol water heating system for the cofferdam the glycol is heated using steam, the maximum temperature of the glycol is expected to be 100°C. The temperature of the glycol in the regasification process is expected to be lower than this and is heated using seawater. FSRU glycol processes are below the flash point. Should there be a fire event in either of these locations, there is potential for escalation to occur. However, a fire within the electric motor room will be contained within the space. Fire detection and protection is provided (refer Section 3.7.1). A fire in the regasification plant will be dominated by the pressurised LNG and natural gas release (refer Section 5.2.1 and 5.2.2). As such, glycol is not considered further in this study.

5.2.5 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 liquid per AS 1940 (i.e. a combustible liquid that has a flash point greater than 60°C and no greater than 93°C). Diesel will 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. It is well segregated from the processing area. As such, diesel is not considered further in this study.

5.2.6 Hydraulic Oil, Lube Oil, and Fuel Oils

Hydraulic oil, lube oil, and other marine fuel oils (heavy fuel oil, marine grade oil) are non-hazardous liquids and are classed as C2 combustible liquids per AS 1940 (i.e. a combustible liquid that has a flash point greater than 93°C). The lube oil and fuel oils are stored in multiple locations on board the FSRU (i.e. day tank in the cargo machinery room, or below deck in the forward pump room, and engine room) and are used by various machinery. Hydraulic oil is also expected to be stored onshore for use on the operation of the marine loading arms and will be at ambient pressure and temperature in storage, well below the flash point and is not considered to be flammable. As such, hydraulic oil, lube oil and other marine fuel oils are not considered further in this study.

5.2.7 Other Chemical Storage

Minor quantities of other chemicals (i.e. cleaning and maintenance products) will be stored on board the FSRU in designated lockers and/or appropriate cabinets [39]. A Hazardous Substance Log comprising the 'Hazardous Substance Log Sheet' and Safety Data Sheets for all hazardous substances carried onboard is maintained and used for recording movements of hazardous substances in and out of. Minor storage of hazardous substances are not considered further in this study.

5.2.8 Hazardous Material Storage

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

Table 5-2: Hazardous Materials Storage

Name	Class	UN No.	HAZCHEM Code	Inventory	Storage Type
LNG	2.1	1972	2WE	170,000m^{3-}	LNG cargo tank (membrane type)
Natural Gas	2.1	1971 (as Methane)	2SE	Nil in storage	Pipework
Spotleak1005	3PGII	3336	3WE	2 x 500L[Note 1]	Semi bulk containers

Note 1: Provision has been made for a third tank and a potential additional tank onsite bringing the total potential storage onsite to between 2,000kg and 2,400kg. A total inventory of 2,400kg has been used in this FHA.

5.3 Potential Hazard Consequences

Release of LNG, natural gas and odourant can potentially lead to flammable and/or toxic effects 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.

5.3.1 Flammable Gas Dispersion

LNG and natural gas dispersion comprise dominant quantities of methane and as such, flammable gas releases are considered to be a credible threat.

Following a release, a flammable gas cloud will form, the extent of which is determined by the operating conditions, size of the release, release orientation, weather conditions and degree of obstruction within the area. An unignited release could impair personnel if the hydrocarbon gas reduces the oxygen level to below breathable limits, however given the open ventilated location and layout of ORF and mechanically ventilated spaces / rooms within the FSRU, impairment of personnel due an unignited release of LNG or gas is not considered further. As detailed in Section 3.7.1, the FSRU has gas detection provided in compliance with the DNV Rules for Classification DNV-RU-SHIP-Pt5Ch7 [14] and DNV-RU-SHIP-Pt6Ch4 Section 7 (Regasification Plant) [15]. The gas detection system is further detailed in the PKGT FSS [4]. Gas detection is provided in (but not limited to) the cargo machinery room, and engine room.

If the portion of the cloud (i.e. the LFL) reaches an ignition source, the following consequences are credible.

5.3.1.1 Flash Fire

Flash fires may arise if released flammable gas fail 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. The burn zone is typically the boundary of flammable limit of the cloud. A flash fire is a short duration event that burns for an insufficient duration to cause structural and equipment damage.

The following flash fire criteria has been set for the project.

Table 5-3: Flash Fire Impact Criteria

Criteria	Impact on Personnel	Impact on Equipment
100% LFL	Potentially fatal for people in the ignited flammable cloud path	No effects on equipment

5.3.1.2 Vapour Cloud Explosion

Vapour Cloud Explosions (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, significant equipment damage and escalation.

The explosion overpressure levels specified in Table 5-4 are based on NSW Planning, Hazardous Industry Planning Advisory Paper No 4 (HIPAP4) - Risk Criteria for Land Use Safety Planning [9].

Table 5-4: Explosion Overpressure Criteria [9]

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	• No fatality	• 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

5.3.2 Jet Fire

Jet fire occurs either through rapid ignition or a flash fire / explosion from a delayed ignition burning back to the source of release. Jet fires are highly directional sonic momentum driven releases, and have high flame temperatures, because air-fuel mixing is efficient.

Noting, liquid and two-phase jet fires are larger than gas jets (for the same pressure and hole size) as the mass release rate is higher. Liquid rain-out only occurs when the pressure drops to below about 5-7 barg depending on the material released. Liquid jet fires also produce more smoke than gas jets.

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 a facility.

The radiant heat levels specified in Table 5-5 are based on HIPAP4 [9]. The 3 kW/m^2 radiant heat level contours are provided for information in compliance with AS 1940.

Table 5-5: Radiant Heat Criteria [9]

Radiation (kW/m^2)	Effect – People	Effect – Equipment
2.1	• Minimum level to cause pain after 1 minute	• Nil
3	• Personnel operating monitors shall not be exposed to radiant heat levels greater than this per AS 1940	• Nil
4.7	• Pain in 15-20 seconds • Injury after 30 seconds exposure (second degree burns minimum)	• Nil

Radiation (kW/m^2)	Effect – People	Effect – Equipment
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
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

5.3.3 Pool Fire

A pool fire may occur if there is a spill of flammable or combustible liquid (with low flash point) on the ground or into the harbour and is ignited. All pool fires are considered unbunded unless stated otherwise. Where the spill is unbunded or in the water, the pool can spread to a significant diameter. The pool will continue to grow in size until one of the following conditions is met:

- Burn rate matches the liquid feed in rate;
- The pool is physically constrained by bunding or kerbing; or
- All material is released, and minimum film thickness is achieved.

Drains to direct liquid releases are provided on board the FSRU to reduce risk of pool fires. Subsequent consequences of this are likely to be flammable dispersion (refer Section 5.3.1) or rapid phase transition (refer Section 5.3.4). Liquid release not directed overboard are considered to have a worst case pool fire diameter limited by the FSRU breadth of 43 m as detailed in Section 3.1. Although this is the case, the FHA model conservatively does not restrict the size of FSRU pool fires.

The ORF odourant is stored within a shipping container. Potential pools would be confined inside the container with the exception of leaks that occur during changeout of the odourant SBC's as the shipping container will not be fully enclosed during these activities. SBC changeout is expected to occur every 3 days to 13 days depending on the send out rate from the FSRU. Pools may also form as a result of leaks in the odourant injection line. However, these releases will be limited by the dosing rate (i.e. 0.6 – 6 L/hr).

Like jet fires, pool fires pose a hazard to personnel and surrounding equipment, however radiant heat levels are lower. The same radiant heat criteria specified in Table 5-5 apply.

5.3.4 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 (i.e. seawater). 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 [41].

A significant leak from an LNG transfer hose (i.e. during ship-to-ship transfer between the FSRU and LNGC) 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. Details of an explosion between the FSRU and LNGC are included in the consequence analysis (refer Section 6.3).

5.3.5 Toxic Gas Dispersion

Spotleak 1005 is a 70:30 blend of THT and TBM. THT is a flammable material while TBM is both flammable and toxic.

Like flammable gas dispersion, following a release, a toxic gas cloud will form, the extent of which is determined by the operating conditions, size of the release, release orientation, weather conditions and degree of obstruction within the area. A release could impair personnel if they are exposed to harmful concentrations.

There is no suitable toxicity data published for THT or TBM to be used to assess potential injury impacts (i.e. Emergency Response Planning Guideline (ERPG), Acute Exposure Guideline Level (AEGL), Short-Term Exposure Limit (STEL), or Immediately Dangerous to Life (IDTL)). However, AEGL toxicity data is available for Ethyl Mercaptan. Noting the following definitions for AEGL:

- AEGL 1 is defined as the airborne concentration of a substance above which it is predicted that the general population could experience notable discomfort, irritation or certain asymptomatic, non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.
- AEGL 2 is defined as the airborne concentration of a substance above which it is predicted that the general population could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.

Safety datasheets for Spotleak 1005 [42] and Ethyl Mercaptan [43] indicate both materials have Acute Toxicity Category 4 classifications meaning they can be harmful if personnel are exposed. UK HSE Specified Level of Toxicity (SLOT) and Significant Likelihood of Death (SLOD) Dangerous Toxic Loads (DTLs) data [44] indicates the DTL for TBM is 6 times higher than Ethyl Mercaptan. Therefore, based on the 6 times difference in toxicity levels between Ethyl Mercaptan and TBM, the AEGL 1 and 2 for TBM are estimated to be 6 ppm and 900 ppm, respectively, for 30 minutes exposure duration [44]. The HIPAP4 injury risk criteria specify exposure to a short duration and hence AEGL thresholds with 30 minutes exposure time have been used.

Table 5-6: Toxic Criteria

Toxic Concentration (ppm)		Effect – People	Effect – Equipment
AEGL 1	6	• Less severe – irritation to eyes or throat, coughing or other acute physiological responses	• Nil
AEGL 2	900	• Severe	• Nil

5.3.6 Escalation Events

An escalation event will typically occur when a jet fire or pool fire impacts an adjacent inventory resulting in a secondary failure, subsequent LOC and fire event. The impacts of the secondary fire event are typically considered as being represented by the primary fire event for that inventory (being impacted). Consequence modelling results and analysis of fire events for the PKGT project are contained in the PKGT FSS [4].

In addition to the above, specific escalation events for the FSRU and ORF processes have been considered and are detailed below.

5.3.6.1 FSRU Escalation Events

Boiling Liquid Expanding Vapor Explosion (BLEVE) events were reviewed in the PKGT FSS [4]. However, were not considered further as BLEVE of an LNG cargo storage tank requires a fire event to occur (i.e. either jet fire at ORF or pool fire on water from FSRU) and failure of numerous engineering design features including the tank / double hull of the FSRU vessel and sufficient heating to be applied to a (near atmospheric pressure) cargo storage tank in order to cause flashing of the LNG. Limited localised heating is not sufficient to allow flashing of the entire cargo storage tank contents. There would be virtually no overpressure as there is no bulk flashing of tank contents expanding at near sonic velocity [45].

The risk of other explosion events on board the FSRU (or LNGC) impacting equipment including the MLAs and transfer hoses was considered in PHA Addendum 1 [17] by determining the impact distance of overpressure levels of 35kPa which, according to HIPAP4 [9] can lead to overturned plant items and is therefore considered to cause enough damage to potentially lead to further escalation. PHA Addendum 1 [17] concluded the MLAs are not impacted by 35 kPa overpressure from any of the identified explosion sources. However, the ship-to-ship LNG transfer hoses may be impacted by an explosion emanating from the cargo machinery room. As such, the failure of all LNG transfer hoses was included in the PHA model and remains included in the FHA model.

5.3.6.2 ORF Escalation Events

Escalation of a fire event emanating from the ORF NG pipework to the odourant storage and injection equipment was also considered. However, as the odourant storage and injection equipment is located within a shipping container, it is not expected that external NG jet fires will directly impact the odourant storage and injection equipment for a long enough duration to lead to escalation. The shipping container, although not fire rated, will provide some protection from the short duration natural gas jet fires from ORF piping and equipment. Should there be an odourant tank pool fire within the shipping container, heating of the stored Spotleak1005 "can cause expansion or decomposition". However, the decomposition temperature of the material is 450°C. Expansion of the material may result in a sudden rise in pressure. However, increasing internal pressure is likely to result in a LOC from hose connections, flanges and/or instrument connections.

In addition to the above, the outputs of PKGT FSS [4] were also used for the ORF Passive Fire Protection Requirement Assessment [46]. Where, the objective of the Passive Fire Protection (PFP) requirement assessment was to determine areas of the ORF at risk of failure and specify the extent of PFP coverage required. The outcomes of this study indicate the above ground section of the PKP is required to be protected by PFP.

Noting that DNV-RU-SHIP-Pt5Ch7 does not specify the requirement for PFP for the FSRU cargo storage tanks. However, DNV-RU-SHIP-PtCh4 for the regasification plant specifies provision for physical barriers, distance separation and fire walls to be considered in the regasification plant design for the control of hazardous consequences. As previously detailed in Section 3.8, the safety philosophy for the FSRU provided by Höegh [23] indicates the FSRU is designed and constructed with respect to reducing risk by inventory minimisation, ignition control, and separation of areas required to be non-hazardous (i.e. accommodation) from those designed as being hazardous (i.e. regasification plant, cargo machinery room).

5.3.6.3 PKGT Escalation Risk to Surrounding Land Users

The risk of potential LOC events from the PKGT impacting the surrounding land users detailed in Section 3.4 is considered in this FHA by determining the accident propagation risk for the facilities in line with HIPAP4 [9] (refer Section 8.3).

5.3.7 Other Potential Scenarios

5.3.7.1 Natural Hazards

Potential natural hazards may include seismic events and extreme weather (i.e. high winds, storms, and lightning). The risk from seismic events and lightning impacts at the ORF have been minimised through compliance with relevant Australian or International standards. The FSRU has lightning protection provided in compliance with DNV-RU-SHIP-Pt5Ch7 [14].

As the PKGT is located within a harbour, the vessel may be exposed to adverse sea conditions within Port Kembla. Potential impacts under these conditions and safeguards are further detailed in Section 5.3.7.2.

5.3.7.2 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 has been designed to ensure it can accommodate the IG waves [48]. Nevertheless, the FSRU will maintain the necessary maritime crew levels required to enable the vessel to be moved out to sea if required by the Port Authority.

5.3.7.3 Security Hazards

Security hazards (intentional physical acts) include terrorism and vandalism. The potential consequences of these events are considered to be comparable with the process LOC events described in previous sections of this report. Public access to the Port Kembla Inner harbour is not permitted and is under the control of the PANSW. AIE have engaged a specialist consultant to carry out a security assessment as part of the PKGT Maritime Security Plan development in compliance with the Maritime Transport and Offshore Facilities Security Act 2003.

In addition, the ORF itself is enclosed by a security fence with access-controlled gates provided between public areas and the facility. It will have a Closed Circuit Television (CCTV) system provided and an external security provider will be employed for monitoring of the site.

Non-physical security hazards include cyber-attacks and have the potential to disrupt the supply of natural gas from the PKGT to industrial and wholesale customers. During the detailed design HAZID study [35] actions were raised regarding additional controls required to protect against and include the robustness of FSRU control system and business networks.

5.3.7.4 Ship Collision

A ship collision event with either the FSRU or LNGC resulting in the puncture of a cargo storage tank requires an incoming (or outgoing) vessel to be travelling at speed and be sufficiently large to generate the momentum required to puncture the FSRU / LNGC double hull plus the walls of the cargo tank itself.

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 3 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. The likelihood for a ship collision within the harbour is low due to the preventative controls in place which include ship movements within the port being controlled by vessel pilots and tugs (reducing potential impact speeds and the likelihood of loss of control) and FSRU / LNGC vessel double hull design. Ship collision events are more likely to occur in open water or along highly trafficked shipping routes. However, should a ship collision event occur there is potential for an LNG spill to the harbour. This could potentially lead to hazardous consequences of flash fire and pool fire as detailed in Section 5.3.1.1 and 5.3.3, respectively. The frequency analysis of ship collision is detailed in Section 7.2.

As detailed in the PKGT PHA [16], 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. During FEED, 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 Höegh, AIE, Worley, PANSW, NSW Ports, Svitzer Tugs [47].

The main outcomes from the simulations are listed below and remain valid:

- LNGC 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.

5.3.7.5 Ship to Ship Loading Hose Failure

Failure of or unintended decoupling of transfer hose(s) used to load LNG from LNGC to the FSRU may result in an LNG release on the surface of the water which has the potential to result in rapid phase transition as previously detailed in Section 5.3.4. A leak could also potentially lead to hazardous consequences of flash fire, jet fire and pool fire as detailed in Section 5.3.1.1, 5.3.2 and 5.3.3, respectively.

5.3.7.6 Tank Rollover

The hazard associated with rollover is spontaneous rapid mixing process which occurs in large tanks as a result of a density inversion, stratification develops when the liquid layer adjacent to a liquid surface becomes denser than the layers beneath, due to boil-off of lighter fractions from the cargo. Rollover can then result in boil off rates several times greater than normal, causing very rapid over-pressurisation of the storage tanks resulting in significant relief venting to the atmosphere.

Stratification of LNG can occur when an LNG tank is filled with LNG of different densities, e.g., LNG being introduced into the tank is either denser than that of the heel remaining in the tank and filling is at the top or LNG being introduced is lighter than the heel and filling is from the bottom of the tank.

However, due to design of relief devices, releases of rollover boil-off natural gas are vented in compliance with DNV-RU-SHIP-Pt5Ch7. Potential for overpressure due to tank rollover is controlled and eliminated by filling procedures and venting system, and not further considered in this FHA.

5.3.7.7 Cold Venting Activities

Each of the cargo tanks on the FSRU has a pressure relief system (pressure safety valves) in compliance with DNV-RU-SHIP-Pt5Ch7 [14]. The pressure relief systems releases vertically to the atmosphere via dedicated cargo vent masts as presented in Figure 5-1. Venting of the cargo tanks is only expected to occur during an emergency.

The regasification plant is also provided a cold vent pressure relief system (blowdown system) in compliance with DNV-RU-SHIP-Pt6Ch4 Section 7 (Regasification Plant) [15]. It is designed for the entire regasification system (and HP gas export system) including high and low pressure relief sources which tie-in to a common vent header and passes through a vent mast Knock-out Drum (KOD) before it releases vertically to the atmosphere via the dedicated regasification vent as presented in Figure 5-1.

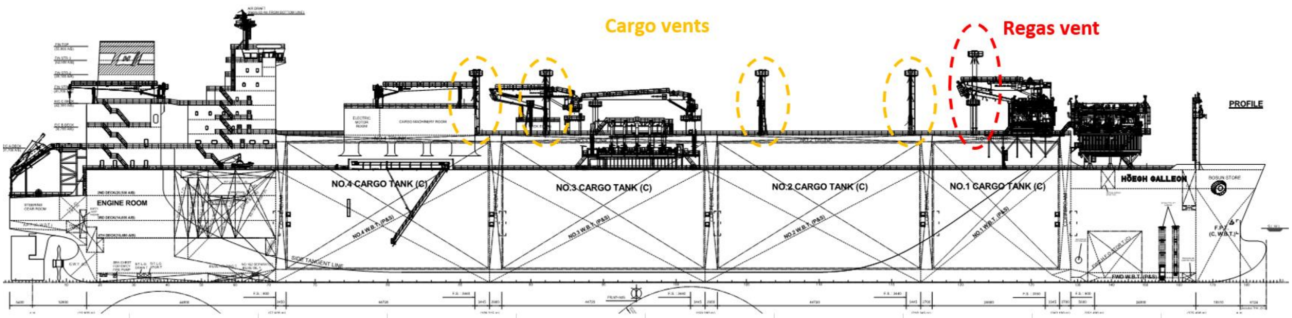

Figure 5-1: FSRU Emergency Cold Vents

The regasification plant blowdown system is automatically activated via ESD system upon "confirmed fire" in the regasification plant (trains, suction drum) and HP gas export area (including HIPPS, metering skid, and HP gas export manifold). Blowdown of process segments containing natural gas may be manually activated in case of a confirmed gas leak in the hazardous area previously described.

Blowdown of individual segments may also be initiated manually by operator (locally or from operator stations), e.g. in connection with gas-freeing prior to maintenance. CFD dispersion modelling [49] has been carried out by the ship builder for the regas mast. The results indicate that under calm or still weather conditions the vent will discharge vertically into the air and will not reach potential ignition sources. At higher windspeeds (i.e. 20 knots, or approximately 10m/s) discharges from the vent disperse further downwind and, also do not reach potential ignition sources including the FSRU accommodation decks and trunk deck. The risk of an ignited release from the regas mast vent is reduced via the vent design, elevation and location.

In addition to the CFD dispersion modelling, the DNV Rules for Classification DNV-RU-SHIP-Pt5Ch7 [14] requires the FSRU to have ignition control and hazardous area classification in compliance with IEC 60079-10-1.

The ORF does not include provision for emergency depressuring. A SFAIRP assessment has been prepared and issued to Safework NSW for approval [11]. The SFAIRP Assessment documents the risk to individuals at the ORF with and without a dedicated emergency cold vent in the design and concludes that the current design without the cold vent is SFAIRP.

6. Consequence Analysis

The following section describes the assumptions, inputs and scenario development for the flammable and toxic gas cloud, fire and explosion risk modelling. Table 6-1 presents details on any differences between the PHA and FHA in compliance with Condition 21(c) of the Infrastructure Approval [2]. The worst case consequence modelling results are contained in the PKGT FSS [4] and have been reproduced in Appendix F. Noting worst case results are selected from all release directions (vertical up, vertical down, and horizontal) and weather conditions modelled.

Table 6-1: PKGT Final Hazard Analysis Assumptions

Model Parameter / Assumption	PHA	FHA
Risk Modelling Software	• DNV Phast Risk (SAFETI) version 6.7	DNV SAFETI version 8.61
Fluid composition	• Lean and rich LNG compositions based on a range of potential suppliers were calculated. Rich LNG conservatively selected as representative composition . • PHA Addendum 1 [17] assumed Ethyl Mercaptan selected as odourant.	• Rich LNG composition maintained per PHA. • Odourant composition updated to Spotleak 1005.
Operating conditions	-	• Maintained per PHA and PHA Addendum 2, produced to support MOD1 (refer Section 6.2).
Leak Characteristics	-	• Hole size selection maintained per PHA (refer Section 6.4)
Leak Direction and Elevation	-	• Leak direction and elevations maintained per PHA (refer Section 6.5)
Full-bore release rate modelling	• Full-bore release rates are limited to the process flow rate / pump in rate. • Pipeline full-bore rupture release rates are based on the discharge at t = 30 second post initial event in line with AS 2885.6.	• Maintained per PHA (refer Section 6.4)
Environmental Conditions	• Environmental conditions based on climate data for Port Kembla Signal Station (ID:068253).	• Environmental conditions updated based on climate data for Port Kembla Signal Station (ID:068253) climate statistics reported for January 2017 to December 2021 (refer Section 6.6).
Leak Frequency	• Leak frequencies based on OGP database published in 2010. Database based on UK HSE analysis of Hydrocarbon Release Database (HCRD).	• Leak frequencies based on updated IOGP database published in 2019. This database now has two sets of data which include 1992-2015 or 2006-2015. The recommended values based on experience in the period 2006 – 2015 (inclusive) are used for the FHA. The IOGP release notes state that the number of incidents recorded per year in the database has been steadily decreasing, and it is considered appropriate to base the frequency on more recent data on the assumption that this is more representative of what will occur in the future (refer Section 7.1)

Model Parameter / Assumption	PHA	FHA
Parts Count	• Parts count for FSRU based on preliminary P&ID. A 15% safety factor was included to account for potential changes to drawings. • Parts count for the ORF based on FEED drawings.	• Parts count for FSRU maintained per PHA as there is no change on the As-built P&ID with the exception of piping lengths (refer Section 7.1). • Parts count for the ORF updated based on detailed design. • Parts count 15% safety factor has been removed as drawings have been issued for construction / use.

Ignition Probability	• Ignition probabilities based on the UKOOA ignition correlations for a Large Plant Gas LPG.
	• Split between immediate and delayed ignition based on Cox, Lees and Ang [50].
		• Ignition probability models revised (refer Section 7.3). The following ignition models have been selected:
		  • "Offshore FPSO Gas (Gas release from typical offshore FPSO process module)" for LNGC and FSRU;
		  • "Small Plant Gas LPG (Gas or LPG release from small onshore plant)" for ORF; and
		  • "Pipe Gas LPG Industrial (Gas or LPG release from onshore pipeline in an industrial area)" for PKP.
		• Split between immediate and delayed ignition maintained per PHA with the exception of the PKP which has been aligned with the Jemena FHA [12] and current practice for onshore pipelines.

Ship Collision Frequency	• Ship collision frequency based guidance developed by Sandia National Laboratories for U.S. Department of Energy to quantify potential threats to an LNG ship on and the calculation method specified in CMPT [40]	• Ship collision frequency updated based on the technical paper "A Quantitative Risk Analysis Approach to Port Hydrocarbon Logistics" [51]. This is considered a better method for ship collisions within a port area (refer Section 7.3) • Ship collision frequency also updated to include potential grounding events.

6.1 Risk Modelling Software

DNV SAFETI software has been used to carry out the risk analysis and model the potential consequences from releases of hazardous inventories by using a wide range of models for discharge and dispersion as well as flammable and explosive effects. The PHA risk modelling [16, 17, 18] was carried out in an older version of the DNV SAFETI software (version 6.7) while the FHA risk model has upgraded to DNV SAFETI version 8.61 which includes software updates and provides some improvement and accuracy in the modelling results.

6.1.1 Modelling Software Assumptions

The following assumptions were made for the modelling carried out with DNV SAFETI.

- 'Vessel or Pipe Source' model with 'Leak' scenario type used for FSRU (and LNGC) and ORF releases
- The 'Long Pipeline' model with 'Location Section Breach' scenario type was used for the buried PKP 'Segment 1.1' releases
- Risk calculation is based on initial fire impact characteristics (i.e. immediately post ignition) at 1.5m above ground.
- Vertical down releases at the ORF were modelled as angled from horizontal impinged (-90°).

- Vertical down releases onboard the FSRU (and LNGC) were modelled as horizontal impinged. This is due to the elevated deck of the FSRU.
- The standalone Multi Energy Explosion with 3D Obstructed Region models were used for explosion modelling.
- All other parameters were set to default unless specified within this report.

6.2 Fluid Compositions & Operating Conditions

The hazardous inventories, hazardous events, and credible hazard consequences from potential LOC identified in Section 5.2 and 5.3 are further refined into representative release scenarios to be modelled in DNV SAFETI and summarised in Table 6-2. This was done for simplification such that areas with small differences in pressure or temperature are grouped together with the more conservative operating conditions selected. The scenarios are further broken down for QRA parts count and frequency analysis (refer Section 7.1).

The operating conditions presented in Table 6-2 are for the 'base case' average seasonal demand case which assumes an averaged flat demand profile of 309 TJ/day. A 'high season' demand sensitivity which assumed a profile of 500 TJ/day is also considered in the FHA and modelled separately. During 'high season', the throughput of the regasification plant is higher and the resulting discharge pressure from the FSRU is limited to 100 barg due to performance characteristics of the on board LNG pumps. Where modifications to the operating pressure are made for the 'high season' demand case (i.e. high pressure gas releases reduced from 120 barg to 100 barg) these are indicated by '#' in Table 6-2.

The odourant is stored at 2.5 barg with an operating temperature ranging from 1 – 43°C. It is injected into the ORF above ground DN450 pipework at a pressure slightly higher than the operating pressure. The dosing rate of the pump ranges from 0.6 – 6L/hr depending on the demand (i.e. up to ~0.0015kg/s).

The following isolated inventories have been used in this FHA. Noting isolatable inventories for the FSRU were also considered in Addendum 2 to the PKGT PHA [18] in order to consider risk reduction from ESD systems (refer Section 7.3).

- For the FSRU cargo systems, the largest isolatable volume on the deck has been estimated to be 47m^3 and is based on the DN600 cargo liquid and vapour headers between cargo storage tank four and regasification unit. The volume is calculated from the piping length estimated in the PHA parts count and estimated volume size of the regasification suction drum [16].
- Downstream of the booster pumps, the available liquid inventory once the pumps have been tripped (i.e. on confirmed fire) will be limited to piping lengths between the booster pumps and heat exchangers. The volume is calculated from the piping length estimated in the PHA parts count [16].
- The natural gas in the regasification plant and HP export system is subject to blowdown. The largest isolatable inventory defined in the Relief and Blowdown Calculation Report [52] is used.
- For the ORF and PKP, isolatable volumes are based on updated design information i.e. 3D model and general arrangement plan.
- For the ship-collision and ship-to-ship loading hose failure scenarios, the inventory of a single cargo tank is used.

Table 6-2: Base Case Process Operating Conditions

No.	Release Location	Release Scenario	Pressure (barg)	Temp. (°C)	Isolatable Inventory (m^3)	QRA section
1	FSRU	BOG from cargo tanks via vapour header to cargo machinery room (compressor suction conditions)	0.1	-158.5	47	1, 5, 6, 7, 8, 10, 34
2		LNG from cargo tank via liquid header to regasification plant (including cargo spray main, and LNG loading headers)	5.5	-160	47	2, 3, 4, 15, 17, 18, 19, 20, 21, 22, 24, 31, 32, 33, 35, 36,
3		BOG from LD compressors in cargo machinery room for fuel gas or to BOG cooler for reliquefication (compressor discharge conditions)	5.5	60	47	13, 14, 25
4		LNG from regasification booster pumps	120 #	-160	3	23
5		NG from regasification plant to FSRU ESD Valve	120 #	10	56.6	26, 27, 28, 29, 30
6	MLA	NG from FSRU ESD Valve to ORF (up to SDV-064001 / SDV-064002) including MLA	120 #	10	5.7	37
7	ORF	NG from ORF Pipework (from SDV-064001 / SDV-064002 to SDV-064007)	120 #	10	4.7	38
8		NG from PKP (from SDV-064007 to MLV-064011) (~300m)	120 #	10	49	39
9a		Odourant Storage & Pipework	2.5	1	2400 kg	40
9b		Odourant Dosing	120 #	10	2400 kg	40
10	Harbour	LNG from Ship Collision	0	-160	42500	-
11		LNG Ship to Ship Loading Hose(s) Failure	2.4	-160	42500	-
12	PKP	NG from PKP (from ORF to KP4.3)	120 #	10	~1800	-

Scenarios 1, 2, 3, 10 and 11 are also expected to apply to LNGC vessels that deliver LNG to the FSRU. It is assumed the same hazardous consequences impacts will occur and an equivalent fire prevention strategy and controls will be implemented.

6.3 Determination of Obstructed Regions

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

- A - Piping directly above each LNG cargo tank;
- B - Cargo machinery room;
- C - Suction drum module;
- D - Regasification module (top and bottom half); and
- E - Space between FSRU and LNGC.

The location of the above are indicated in Figure 6-1. 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. However, they may be considered to be comparable with an explosion in the cargo machinery room.

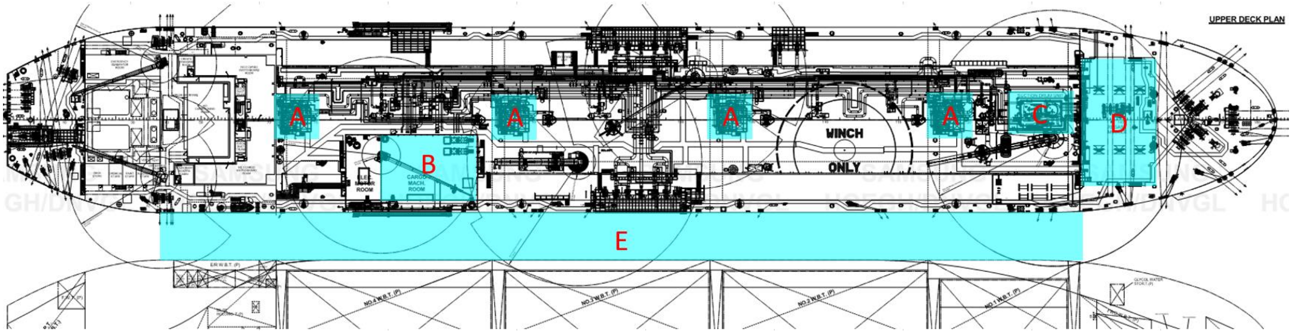

Figure 6-1: Obstructed Regions on FSRU

The ORF is considered an open facility with low levels of congestion and no areas with the potential for VCE were identified with the exception of an odourant release within the shipping container it is stored in.

VCE Blast Strength Selection

Table 6-3 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 [53].

Table 6-3: 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
Space between FSRU and LNGC	Low	None	Yes	2
Odorant Package Shipping Container	Low	Low	Yes	5

Figure 6-2 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 5.3.1.2) a blast strength of at least 4 is required [53]. All of the VCEs identified have a blast strength greater than 4 with exception of the space between the FSRU and LNGC. Therefore, the localised overpressure for the space between the FSRU and LNGC is not considered severe enough to cause damage to the vessel cargo tanks resulting in further loss of containment and escalation and has not been considered further.

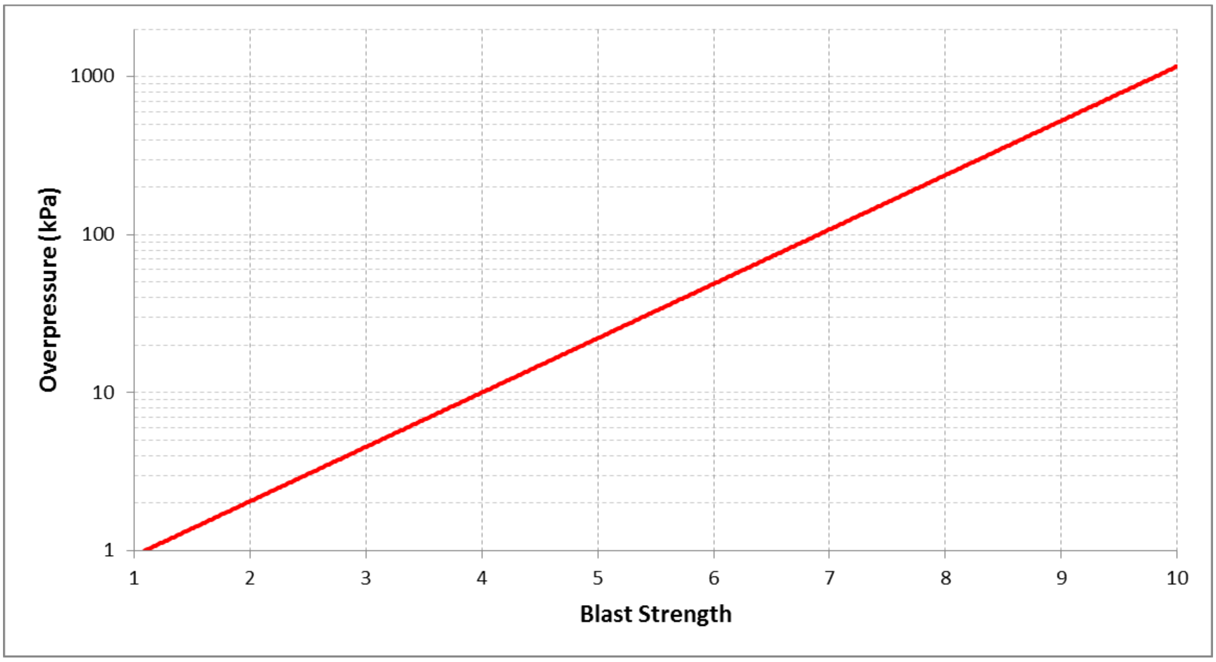

Figure 6-2: Theoretical Peak Overpressure [53]

VCE Stoichiometric Flammable Mass

Table 6-4 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 3-1).

Table 6-4: 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
Odourant Package Shipping Container	77.0	11.6	65.4	3.837	0.029	7.3

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

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

6.4 Leak Characteristics

Various leak sizes were considered in the PKGT PHA [16] and have been maintained for this study. The representative hole sizes are presented in Table 6-5 and are based on 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 and full-bore rupture releases are representative of high energy impacts such as catastrophic failure and ruptures primarily from mechanical defects.

Table 6-5: Release Leak Size

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

Table 6-6 presents the leak sizes and distribution modelled for ‘Segment 1.1’ of the PKP which are also consistent with the hole size selection for the Jemena pipeline FHA [12].

Table 6-6: Pipeline Leak Size

Leak Description	Leak Diameter (mm)	Leak Distribution
Small	20	70%
Medium	50	15%
Medium – Large	100	5%
Catastrophic (FB)	Rupture	10%

All leak modelling in the FHA is based on the initial discharge rate with the exception of full-bore ruptures. Modelling these full bore rupture cases with the initial release rate can result in unrealistically large consequence distances. Therefore, for liquid phase releases on the FSRU and LNGC the full bore rupture release rate is limited to the process flow rate / pump in rate (i.e., 72 kg/s at the ‘base case’ and 116 kg/s at the ‘high season’ demand).

During a full-bore rupture of the ‘Segment 1.1’ pipeline inventory, the initial release rate is expected to be significantly large. However, this initial large release rate cannot be sustained due to rapid pressure drop near the rupture location of the pipeline and hence a more suitable release rate, discharge at 30 seconds post initial release has been modelled in accordance with AS 2885.6.

6.5 Leak Direction and Elevation

Three release orientations with the following directional probabilities applied were considered:

- 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 assumed to be split 50% between the horizontal and vertical directions per the technical paper "A Quantitative Risk Analysis Approach to Port Hydrocarbon Logistics" [51] and a leak from the pipeline. A leak from the pipeline considers the following split based on guidance from the "Crater Depth and Width Model" from the Pipeline Research Committee International Report using soil type of mixed or gravel [54]:

- 20% for vertical (up); and
- 80% for 45° angled from horizontal.

Three release elevations were modelled as follows:

- 14m for all releases from the process on the FSRU including ship to ship loading hose;
- 0m for release from ship collision and buried pipeline; and
- 1m above grade for all releases from the ORF.

6.6 Environmental Conditions

Environmental conditions were sourced from the Port Kembla Signal Station (ID:068253) climate statistics reported for January 2017 to December 2021 by the Australian Government Bureau of Meteorology (BOM) and processed in accordance with the Sigma Theta methodology provided by the US EPA [55]. The weather parameters presented in Table 6-7 were used as the basis for the consequence modelling. These differ from those used in the PHA and have been updated applying the most recent data. It is assumed the surface temperature for a spill on water and/or ground are the same as the air temperature.

Table 6-7: Weather Parameters

Weather ID	Wind Speed (m/s)	Pasquil Stability	Air Temperature (°C)	Relative Humidity (%)	Average Solar Radiation (W/m^2)
Calm	1.7	F	17.3	72	0
Average	4	D	19.3	69	390
Windy	8	D	19.2	56	470

Surface roughness was estimated based on the topography of the land surrounding the different process areas as follows:

- 0.2 mm (representative of open water) was used for release scenarios from the FSRU and LNGC.
- 30 mm (open flat terrain, grass, few isolation objects) was conservatively used for release scenarios from the ORF and pipeline.

The probability of the wind blowing in a certain direction and up to a certain speed was also taken from the BOM statistics available [55]. The weather probability distributions and resulting wind rose are provided in Appendix G. The wind rose updated based on more recent data is similar to the PHA wind rose. Overall, the prevailing winds at Port Kembla are from the NE and SWW.

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7. Frequency Analysis

The frequency of an event is the number of occurrences of the event in specific time period; typically 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. The failure frequency data used in this study is from the most recent release of the Hydrocarbon Release Database (HCRD) maintained by the United Kingdom Health and Safety Executive (UKHSE) [56, 57] and published by the International Association of Oil & Gas Producers (IOGP). 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 flammable and toxic release events as a basis for this FHA with the exception of releases from ship collision, which is based on the "A Quantitative Risk Analysis Approach to Port Hydrocarbon Logistics" technical paper [51] and presented in Section 7.2.

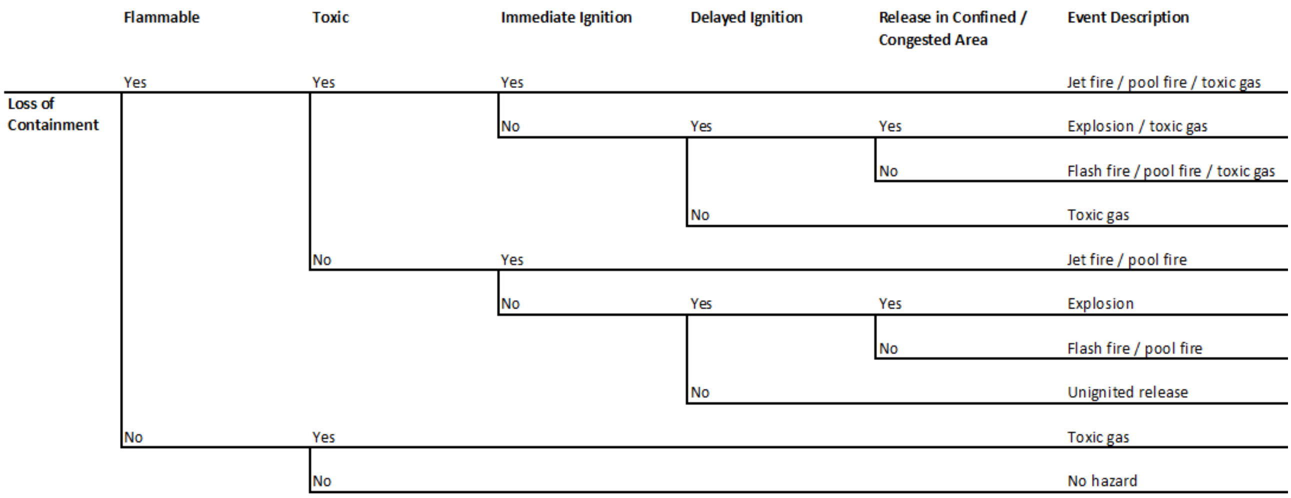

Figure 7-1: FHA Event Tree

The leak / event frequencies and ignition probabilities determined using the methodologies defined in this Section are applied in DNV SAFETI version 8.61. The resultant LSIR contours are assessed in Section 8.

7.1 Parts Count and Leak Frequencies

The PHA 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. A 15% contingency was applied to account for future changes to the design.

The FHA parts count was updated using (at least) the Revision 0 (Issued for Construction or Issued for Use) P&IDs with the 15% contingency removed. The parts count was conducted with the following rule set applied:

- Single flange count comprises of two flange faces, a gasket and two welds to the pipe.
- Single manual / actuated valve count comprises of valve body, stem and packer.
- Single instrument count comprises of the instrument itself plus up to 2 instrument valves, 4 flanges, 1 fitting and associated small-bore piping.
- Single process vessel count comprises of the vessel itself and any nozzles or inspection openings.

- Single pump / compressor / heat exchanger / cooler count comprises of the equipment itself only.
- Single filter count comprises of the filter body itself and any nozzles or inspection openings.
- For closed valves at the active / non-active boundary, count 1 flange and 1 valve
- For automatic pressure relief valves and blowdown valves, all fittings up to and including the valve will be counted (i.e. 1 valve, 1 flange).
- Reducers are assumed to be typically welded and are not included other than as part of a pipe system (unless shown on the P&ID as flanged).
- DNV [58] notes that application of failure rate per unit length of piping results in a very high contribution compared to other equipment, and this is believed to be through an underestimation of overall exposure data. The reference recommends a parts count be completed for all other components and leaks attributable to pipework defined such that they represent 25% of the total release frequency. This approach has been adopted within this FHA.
- The P&IDs represent the mode of operation, i.e. valves are closed as indicated on the P&IDs.

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

- 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. This remains valid for the high demand case (refer Section 3.1.1, Table 3-1).
- Jet fires and flash fires within the cargo machinery room are assumed to remain within the room and therefore do not contribute to offsite risk. The cargo machinery room is of steel frame and plate construction with F&G detection, ESD and fire suppression systems (refer Section 3.7.1).
- 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 for the base case model and 1 day every week in the high demand case (refer Section 3.1.1, Table 3-1). LNGC leak frequencies are adjusted based on their time in Port Kembla.
- For ‘Segment 1.’ of the PKP a leak frequency for an onshore gas pipeline between 17” – 23” is specified as 0.091 per 1000km pa and used in this FHA. This is consistent with the pipeline leak frequency in the Jemena pipeline FHA [12].

A summary of the overall leak frequencies and contributions calculated from the different area / facilities associated with the PKGT Project is presented in Table 7-1. Note that the presented leak frequencies exclude ship collision incidents which are calculated separately in Section 7.2. The PKGT FHA parts count sheets used are provided in Appendix H. Noting the QRA parts count sheets are broken into smaller sub-sections/scenarios than those presented in Section 6.2 primarily due to the location of equipment. These scenarios and subsequent frequency data are input to the DNV SAFTEI software combined with the operating conditions defined in Table 6-2 in order to calculate risk. QRA scenarios with the same operating conditions and inventories will have the same consequence results. Detailed frequency analysis of these sections as outputs of the DNV SAFETI software is provided in Appendix I.

Table 7-1: PKGT Base Case Leak Frequency Summary

Facility	Equipment	10mm	25mm	50mm	100mm	Rupture	Leak Freq. by Equipment (pa)	Leak Freq. by Facility (pa)
FSRU	Cargo Tanks (x4)	1.10E-02	1.20E-03	6.13E-04	1.24E-04	9.14E-05	1.30E-02	2.34E-01
	Cargo Machinery Room	7.69E-02	7.77E-03	3.27E-03	2.04E-03	9.32E-04	9.09E-02	
	LNG Loading Manifold	1.19E-03	9.90E-05	3.82E-05	2.79E-05	3.70E-06	1.36E-03	
	Suction Drum Module	8.99E-03	1.01E-03	5.17E-04	2.74E-04	8.56E-05	1.09E-02	
	Regasification Modules (x2)	8.78E-02	8.00E-03	2.40E-03	1.70E-03	6.88E-04	1.01E-01	
	Headers	9.41E-03	1.08E-03	3.96E-04	3.23E-04	1.09E-04	1.13E-02	
	HP Unloading Manifold	4.71E-03	6.49E-04	6.16E-05	3.96E-05	3.70E-05	5.50E-03	
LNGC	Cargo Tanks (x4)	1.10E-02	1.20E-03	6.13E-04	1.24E-04	9.14E-05	1.30E-02	1.10E-01
	LNG Unloading Manifold	7.69E-02	7.77E-03	3.27E-03	2.04E-03	9.32E-04	9.09E-02	
	Headers	4.78E-03	5.54E-04	1.64E-04	1.63E-04	3.10E-05	5.69E-03	
Ship-to-ship	Transfer Hose(s)	7.41E-04	8.55E-05	1.42E-04	0.00E+00	1.78E-06	9.70E-04	9.70E-04
ORF	MLA, NG pipework & odourant	1.97E-02	4.46E-03	3.61E-04	2.65E-04	1.08E-04	2.49E-02	2.49E-02
PKP	Segment 1.1	2.74E-04 Note 1		5.87E-05	1.96E-05	3.91E-05	3.91E-04	3.91E-04
Total Frequency		3.13E-01	3.41E-02	1.18E-02	7.15E-03	3.15E-03	3.69E-01	
Leak Distribution		85%	9%	3%	2%	1%		

Note 1: Pipeline "small" releases modelled as 20mm.

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 Ship Collision / Grounding Frequencies

LNGC transit risk (specifically collisions in a port area) were included in an Addendum to the PHA [17] and has been included in the FHA. Berth 101 is located in the Port Kembla Inner Harbour area between the existing PKCT coal berth (B102) to the north, and “The Cut” shipping channel to the south. Figure 7-2 presents the Port Kembla passage plan which indicates the transit route that will be taken by the LNGC and other vessels entering / exiting Port Kembla.

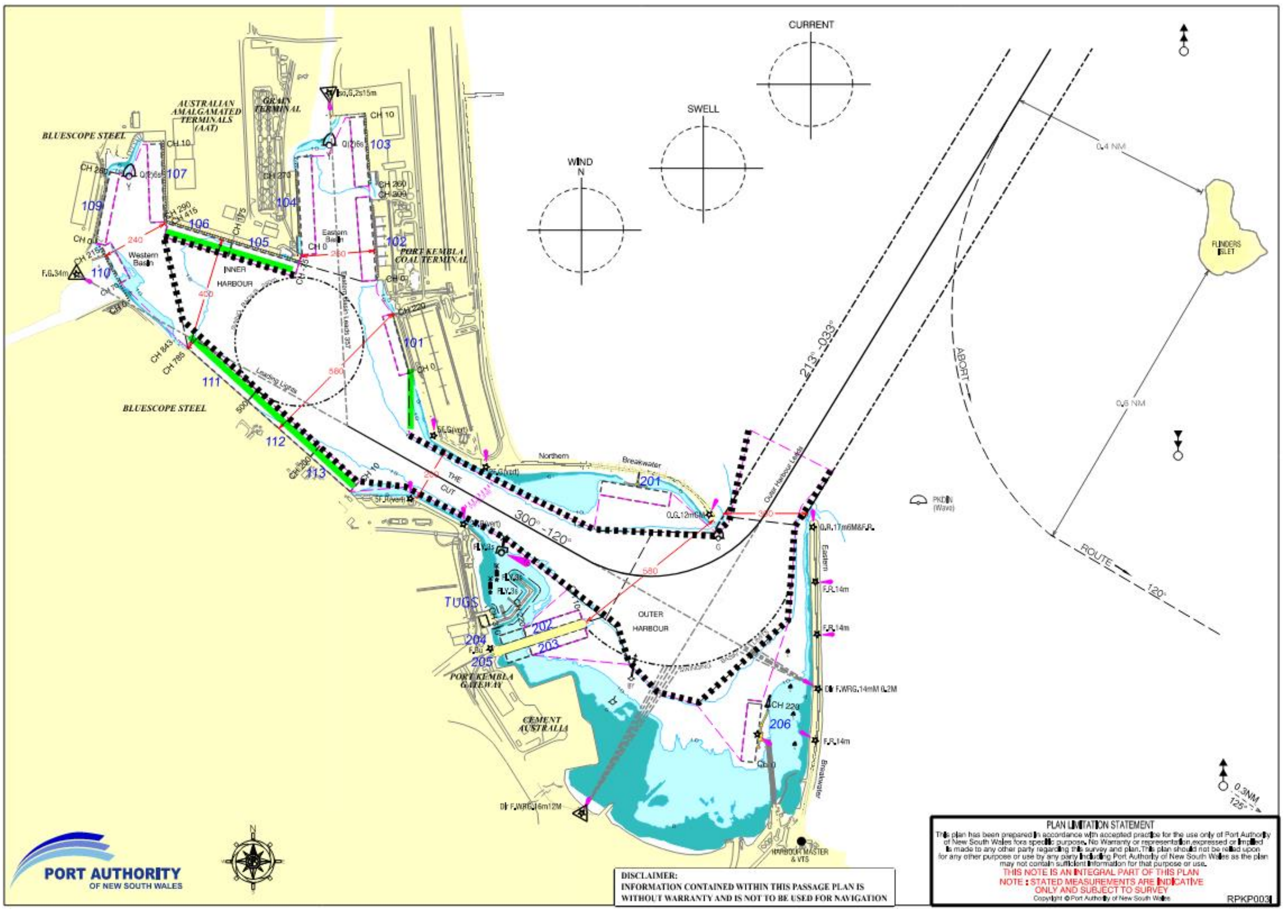

Figure 7-2: Port Kembla Passage Plan

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 bulk vessel entries and exits from the 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 (RoRo) car carrying vessels have a dry weight mass of 35,000 tonnes and entry and exit speeds of 6-7 knots.

Based on guidance developed by Sandia National Laboratories for U.S. Department of Energy to quantify potential threats to an LNG ship [59], the estimated minimum kinetic energy required to puncture a LNG tank within a double hulled tanker is approximately 1.0E08 Nm. The heaviest vessel weighing 205,000 tonnes travelling at 2.5 knots would generate a kinetic energy of 1.7E08 Nm and 2.3E08 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).

Data published for Port Kembla [60] indicates that 54% of vessel movements in the harbour are tugs or pilot vessels, and 25% are tankers or cargo vessels. The remaining percentage are high speed vessels and other smaller boats. As detailed above, only the tankers and cargo vessels are considered to have the potential generate sufficient energy for a puncture of the FSRU or LNGC double hull. For the ship collision frequency analysis, it is conservatively assumed 50% of all ships entering and exiting the harbour have sufficient kinetic energy to puncture an LNG tank within the FSRU or LNGC. LNGC visiting frequency is also included in the vessel collision analysis.

Potential LNG storage tank rupture due to ship collision including grounding are also included in the FHA modelling. The following scenarios are modelled:

- Incoming LNGC / passing vessels collision with the stationary FSRU leading to LNG storage tank rupture.
- Passing vessels collision with the stationery LNGC leading to LNG storage tank rupture.
- Passing vessels collision with the in transit LNGC leading to LNG storage tank rupture.
- In transit LNGC grounding or collision with land within Port Kembla inner and outer harbour leading to LNG storage tank rupture (marked-up in BLACK in Figure 7-2).
- In transit LNGC collision with moored ship (including the FSRU) leading to LNG storage tank rupture (marked-up in GREEN in Figure 7-2).

Ship to ship / ship to land collision leading to hull puncture consequence and risk modelling in the FHA is based on the calculation method presented in the "A Quantitative Risk Analysis Approach to Port Hydrocarbon Logistics" technical paper and TNO Purple Book [51, 61]. The paper is based on the Barcelona Port, for which the port movement distance is approximated to be 3.8 km with inclusion of 7 piers. Note the collision frequencies calculated would be no different from any other vessel exiting or entering the harbour. The risk associated with vessel movement within a port area is not specific to LNGC vessels. Vessel movements are under the control of PANSW. This control is vessel traffic management, which includes speed limits, and the use of tugs and piloted vessels. There are no recorded ship collision events that have occurred at Port Kembla.

For vessel collision incidents with the FSRU / LNGC leading to spillage are broken down to minor and major, where minor is limited to spillage up to 32 m^3 over 30 minutes and major is 126 m^3 over 30 minutes [51, 61]. The incident frequency (f_b) of a major / minor spill from the stationary FSRU or LNGC due to a ship collision is calculated using the following equations and inputs [51]:

$$f_b \text{ (minor)} = F_b \times T \times Dt \times p_m$$

$$f_b \text{ (major)} = F_b \times T \times Dt \times p_M$$

Table 7-2: Ship to Stationary Ship Collision

Parameter	Definition	Base Case		High Season	
		FSRU	LNGC	FSRU	LNGC
F_b	Frequency of a ship collision with stationary vessel (i.e. FSRU / LNGC)	4.00E-06 pa per ship			
T	Shipping traffic in Port Kembla	1216 Note 1	1190	1242 Note 1	1190
D_t	Duration of exposure to collision Note 2	0.88	0.12	0.86	0.14

Parameter	Definition	Base Case		High Season	
		FSRU	LNGC	FSRU	LNGC
P_m	Probability of minor spill	2.5E-02			
P_M	Probability of major spill	1.2E-04			
f_b (minor)	Calculated minor spill frequency (pa)	1.13E-04	8.66E-06	1.07E-04	1.77E-05
f_b (major)	Calculated major spill frequency (pa)	5.42E-07	4.16E-08	5.11E-07	8.49E-08

Note 1: Includes 26 LNGC visits per year (base case) and 52 LNGC visits per year (high demand case).

Note 2: Based on 26 LNGC visits per year (base case) and 52 LNGC visits per year (high demand case).

In addition to a collision while the FSRU or LNGC is berthed, the potential spillage from the LNGC while in transit is also considered for ship to land impacts with the following equations and inputs:

$f_{s/c/d/f}$ (minor) = $F_{s/c/d/f} \times T \times p_m$

$f_{s/c/d/f}$ (major) = $F_{s/c/d/f} \times T \times p_M$

Table 7-3: Ship to Land Collision

Parameter	Definition	LNGC Value [2]			
F_s	Frequency of LNGC collision with ship	2.30E-05 pa per visit			
F_c	Frequency of LNGC collision with land	1.50E-04 pa per visit			
F_d	Frequency of LNGC grounding	3.00E-05 pa per visit			
F_f	Frequency of LNGC collision with moored ship	5.00E-05 pa per visit			
T	Number of LNGC visits per year	29			
Pm	Probability of minor spill	2.5E-02			
PM	Probability of major spill	1.2E-04			
$f_{s/c/d/f}$ (minor)	Calculated minor spill frequency (pa)	fs	fc	fd	ff
		1.67E-05	1.09E-04	2.18E-05	3.63E-05
$f_{s/c/d/f}$ (major)	Calculated major spill frequency (pa)	8.00E-08	5.22E-07	1.04E-07	1.74E-07

The ignition probabilities applied for the shipping collision and LNGC grounding models are per the "A Quantitative Risk Analysis Approach to Port Hydrocarbon Logistics" technical paper [51] and presented in Figure 7-3.

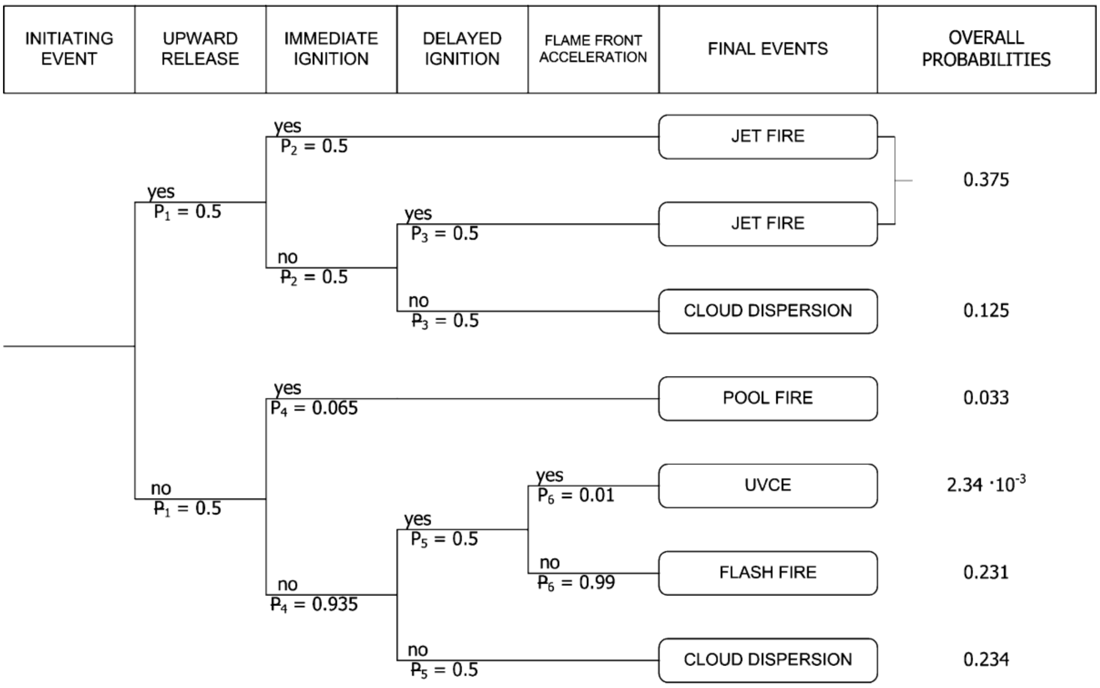

Figure 7-3: Shipping Collision and Grounding Ignition Probabilities

7.3 Risk Reduction Measures

As detailed in Section 3.7, the FSRU has F&G detection, protection and suppression systems installed in compliance with the DNV Rules for Classification DNV-RU-SHIP-Pt5Ch7 [14] and DNV-RU-SHIP-Pt6Ch4 Section 7 (Regasification Plant) [15]. The ORF also has a F&G and ESD system provided. As such, risk reduction provided by these systems has been considered in the FSRU, and ORF models. Risk reduction has conservatively not been considered in the pipeline 'Segment 1.1', LNGC, and LNGC transit (ship collision and grounding) models.

When the ESD systems are activated, hazardous inventories will be isolated, and pressure sources (i.e. pumps) are tripped. As ESD occurs, the leak release rate decreases over time as the inventory available is limited (via isolation through ESD valves) and the system pressure drops (via depressurisation of the isolatable section). Additional emergency depressuring of the regasification plant (trains, suction drum) and HP gas export area (including HIPPS, metering skid, and HP gas export manifold) on board the FSRU via blowdown can be automatically (confirmed fire) or manually (operator) initiated. The ORF with its small inventory is similar to pipeline infrastructure including metering stations and pigging facilities which are not normally provided with automatic emergency depressuring as the above ground inventories are relatively small and escalation risks are low. The risks at the ORF without blowdown have been assessed in the PKGT ORF SFAIRP Technical Note [11] and shown to be SFAIRP.

The effects of risk reduction and mitigation are incorporated into the FSRU and ORF models as follows:

- Using isolatable inventories (refer Table 6-2, Section 6.2); and
- Reducing pressure for the LNG release scenarios where the pressure source of the liquid is from pumps. As liquid is typically incompressible, once the pumps trip, the inventory pressure will drop to approximately ambient pressure which would significantly reduce the release rate and subsequent jet fire impact distances.

To account for the frequency of detection and isolation, the following assumptions have been made:

- F&G detection and trip systems on board the FSRU are expected to be at least as reliable as a Basic Process Control System (BPCS) function with a Probability of Failure on Demand (PFD) of 0.1, i.e., 90% of time the release / fire event is detected and the remaining 10% of the time, it is not detected. Note DNV Rules for Classification do not require minimum SIL requirements on the FSRU. Note according to failure data from the Exida Safety Equipment Reliability Handbook [62], a conservative PFD for a F&G detection and isolation system is 0.02 with yearly maintenance. Therefore, PFD of 0.1 is considered to be conservative. This assumption will also be applied to the ORF.

- ESD can be manually (operator) initiated. PFD of 0.1 is also taken for operator intervention under stress [63], i.e., 90% of fire / gas event are actioned by an operator with appropriate executive action implemented and the remaining 10% of the time, no executive action taken.

Therefore, is it conservatively assumed the release rates from FSRU and ORF are based on the initial process condition for 10% of the time (i.e. assumed either automatic F&G detection and trip systems fails or operator intervention fails) and at the mitigated (i.e. tripped and/or isolated) condition for 90% of the time.

7.4 Ignition Probability

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

- Material state (liquid or gas);
- Release rate;
- 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. With exception of the shipping collision and LNGC grounding models (refer Section Figure 7-3, Section 7.2) the ignition probabilities used in this FHA are based on the United Kingdom Offshore Operators Association (UKOOA) overall ignition correlations [64] 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 (IP) models selected for the FHA are:

- Model 24 - Offshore FPSO Gas (Gas release from typical offshore FPSO process module) for LNGC and FSRU;
- Model 5 - Small Plant Gas LPG (Gas or LPG release from small onshore plant) for ORF; and
- Model 3 - Pipe Gas LPG Industrial (Gas or LPG release from onshore pipeline in an industrial area) for PKP ‘Segment 1.1’.

The PKGT PHA [18] considered UKOOA IP Model for a Large Plant Gas LPG (Gas or LPG release from large onshore plant). The updated IP models for the FHA model are considered a better representation of the configuration of the PKGT project. Figure 7-4 presents the overall ignition probability curves for the selected UKOOA IP models.

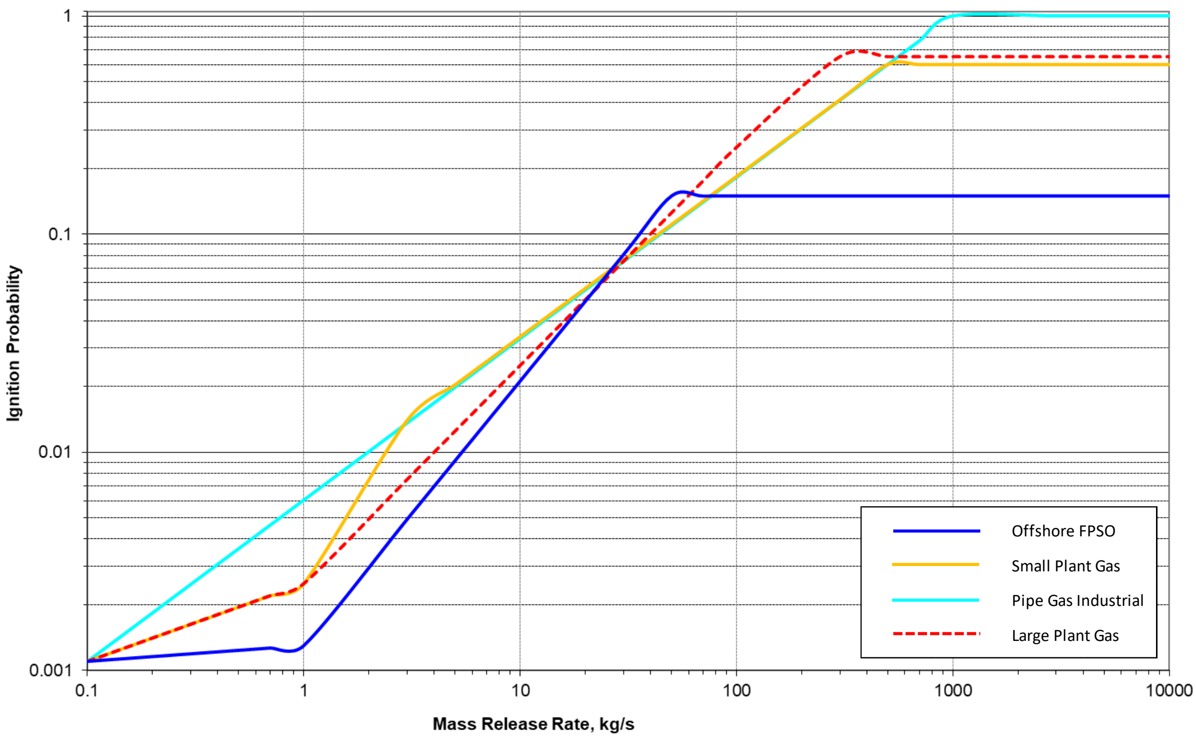

Figure 7-4: UKOOA IP Models

7.4.1 Immediate and Delayed Ignition Probabilities

The overall ignition probability curve from the UKOOA IP model does not distinguish between immediate and delayed ignition. The ignition probability determined using the UKOOA ignition correlations were split between immediate and delayed ignition based on Cox, Lees and Ang [50] as per Table 7-4 with the exception of the PKP which has been aligned with the Jemena FHA [12] and current practice for onshore pipelines which considers 30% of releases are immediately ignited.

Table 7-4: 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).

Detailed ignition frequency analysis of these sections are provided in Appendix I.

8. Risk Analysis

8.1 Risk Assessment Criteria

8.1.1 Individual Risk Criteria

Location Specific Individual Risk (LSIR) in a study is the geographical variation of LSIR that may be represented by iso-risk contour plots and used for land planning or to assess the risk to vulnerable populations. It is the risk of fatality and/or injury at a point in space to a hypothetical individual at a location for 365 days per annum (pa), 24 hours a day, unprotected and assumed to be present at the time of the hazardous event. For this project the overall offsite fatality and injury risk criteria are based on HIPAP4 [9] as presented in Table 8-1 and Table 8-2.

Table 8-1: Individual Fatality Risk Criteria [9]

Risk (pa)	Land Use
5E-07	Hospitals, schools, child-care facilities, old age housing
1E-06	Residential, hotels, motels, tourist resorts
5E-06	Commercial developments including retail centres, offices and entertainment centres
1E-05	Sporting complexes and active open space
5E-05	Industrial

Table 8-2: Individual Injury Risk Criteria [9]

Risk (pa)	Land Use
5E-05	Incident heat flux radiation at residential and sensitive use areas should not exceed 4.7 kW/m^2 at a frequency of more than 50 chances in a million per year.
5E-05	Incident explosion overpressure at residential and sensitive use areas should not exceed 7 kPa at frequency of more than 50 chances in a million per year.
5E-05	Toxic concentrations in residential and sensitive use areas should not cause irritation to eyes or throat, coughing or other acute physiological responses in sensitive members of the community over a maximum frequency of 50 in a million per year
1E-05	Toxic concentrations in residential and sensitive use areas should not exceed a level which would be seriously injuries to sensitive members of the community following a relatively short period of exposure at a maximum frequency of 10 in a million per year.

In line with HIPAP4 [9], the siting of a hazardous installation must account for the potential of an accident at the installation causing damage to buildings and propagating to a neighbouring industrial operation, and hence initiating further hazardous incidents - the so-called ‘domino effect’.

Heat radiation levels of 23 kW/m^2 as the result of fire incidents at a hazardous plant may affect a neighbouring installation to the extent that unprotected steel can suffer thermal stress that may cause structural failure. This may trigger a hazardous event unless protection measures are adopted. Explosion overpressure levels of 14 kPa as the result of explosions at a hazardous plant may damage piping and (low-pressure) equipment at a neighbouring plant.

Table 8-3 presents the probabilistic criteria for 23 kW/m^2 and 14 kPa propagation damage to a neighbouring industrial operation.

Table 8-3: Property Damage and Accident Propagation Risk Criteria [9]

Risk (pa)	Land Use
5E-05	Incident heat flux radiation at neighbouring industrial operations should not exceed 23 kW/m^2 at a frequency of more than 50 chances in a million per year.
5E-05	Incident explosion overpressure at neighbouring industrial operations should not exceed 14 kPa at frequency of more than 50 chances in a million per year.

8.1.2 Societal Risk Criteria

Societal risk (in the form of an FN curve) is used to present the relationship between frequency, f, and the number of people, N, suffering from a specified level of harm in a given population from the realisation of specified hazards. Figure 8-1 presents the offsite societal risk / FN curve criteria based on those presented in HIPAP4 [9]. The suggested criteria take into account the fact that society is particularly intolerant of accidents, which though infrequent, have a potential to result in multiple fatalities. Noting it should be emphasised that the societal risk criteria presented are indicative. and do not represent a firm requirement in NSW

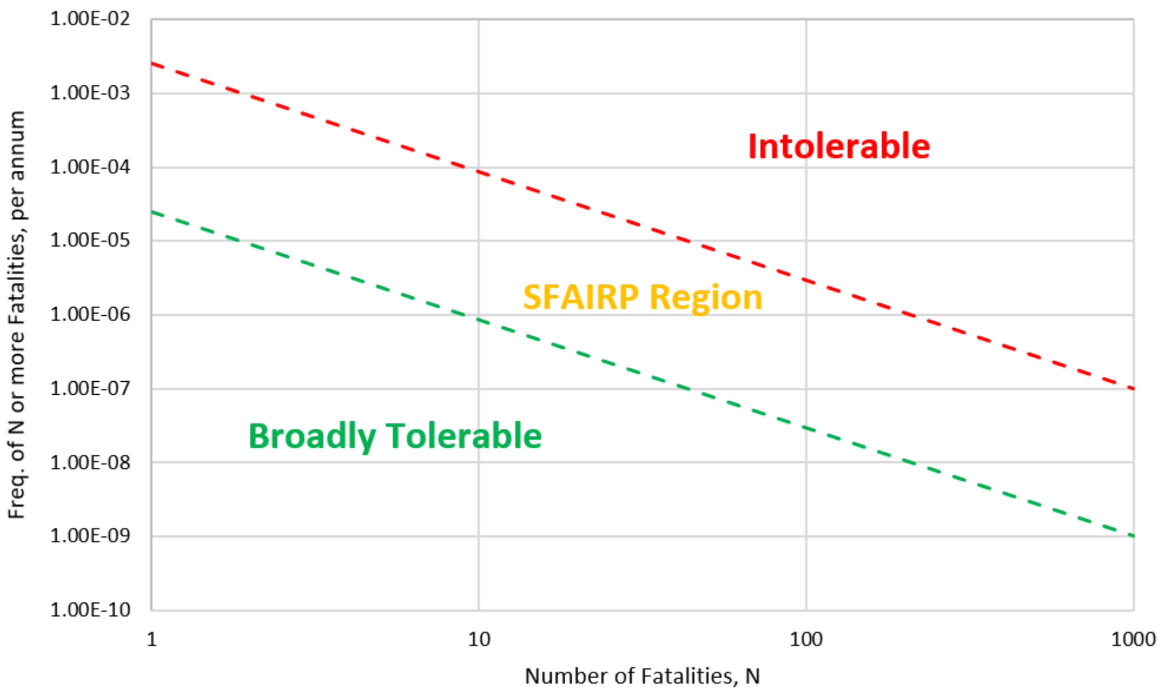

Figure 8-1: Societal Risk Criteria

Within the 'Broadly Tolerable' region, provided other individual criteria are met, societal risk is not considered significant. Above the 'Intolerable' region, an activity is considered undesirable, even if individual risk criteria are met. Within the 'SFAIRP' region, the emphasis is on reducing risks as far as reasonably practicable towards the 'Broadly Tolerable' region. Provided other quantitative and qualitative criteria of HIPAP4 [9] are met, the risks from the activity would be considered tolerable in the 'SFAIRP' region.

8.2 Individual fatality Risk

The overall findings from the 'base case' average seasonal demand risk modelling presented as LSIR contours for the three operational modes i.e. FSRU only, FSRU with LNGC ship-to-ship loading and FSRU with LNGC transit occurring are provided in Figure 8-2, Figure 8-3 and Figure 8-4 respectively. The 'base case' assumes an averaged flat demand profile of 309 TJ/day throughout the year based on the seasonal demands. On average, it is assumed 29 LNGC deliveries are required per year as presented in Table 3-1.

Figure 8-2: PKGT Base Case Fatality Risk Contours – FSRU Only

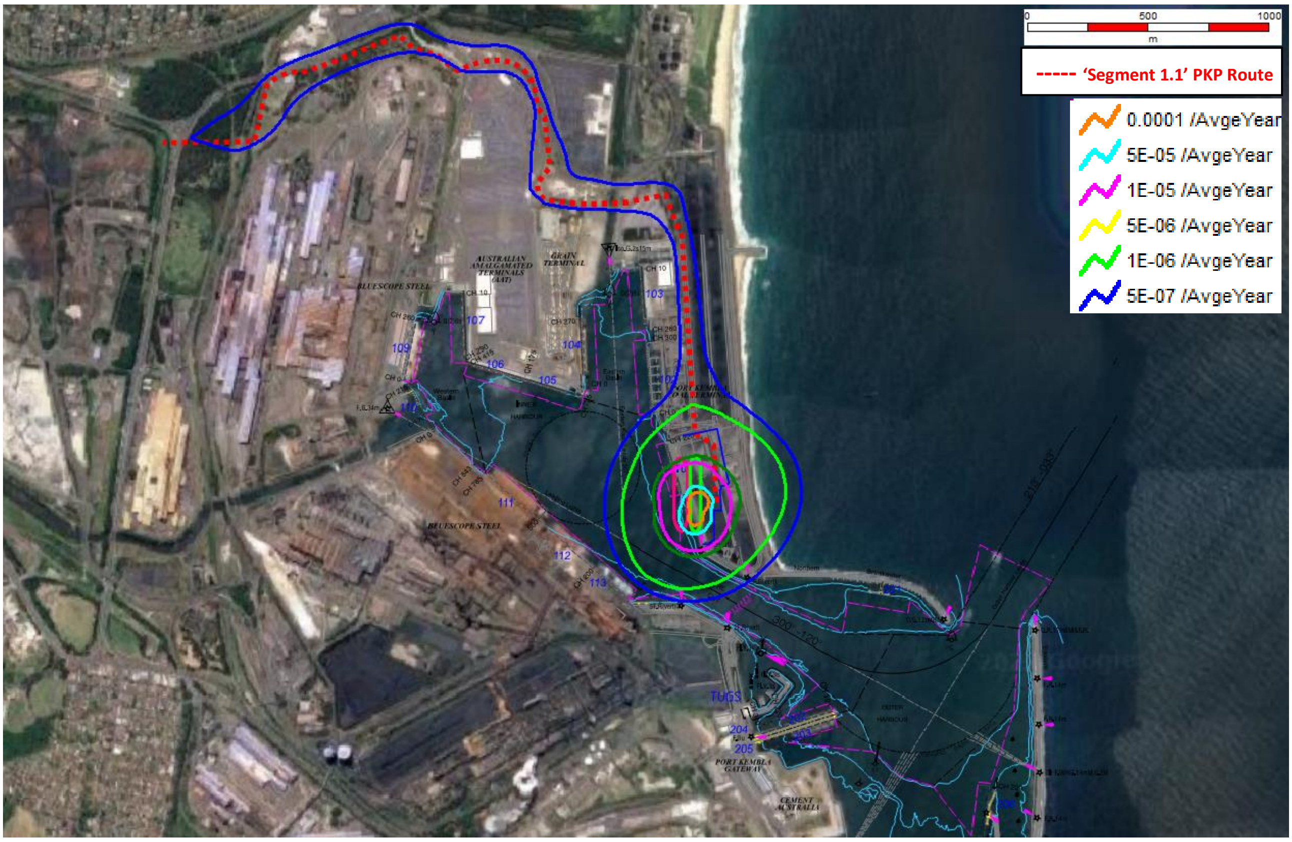

Figure 8-3: PKGT Base Case Fatality Risk Contours – FSRU with LNGC Ship-to-ship Loading

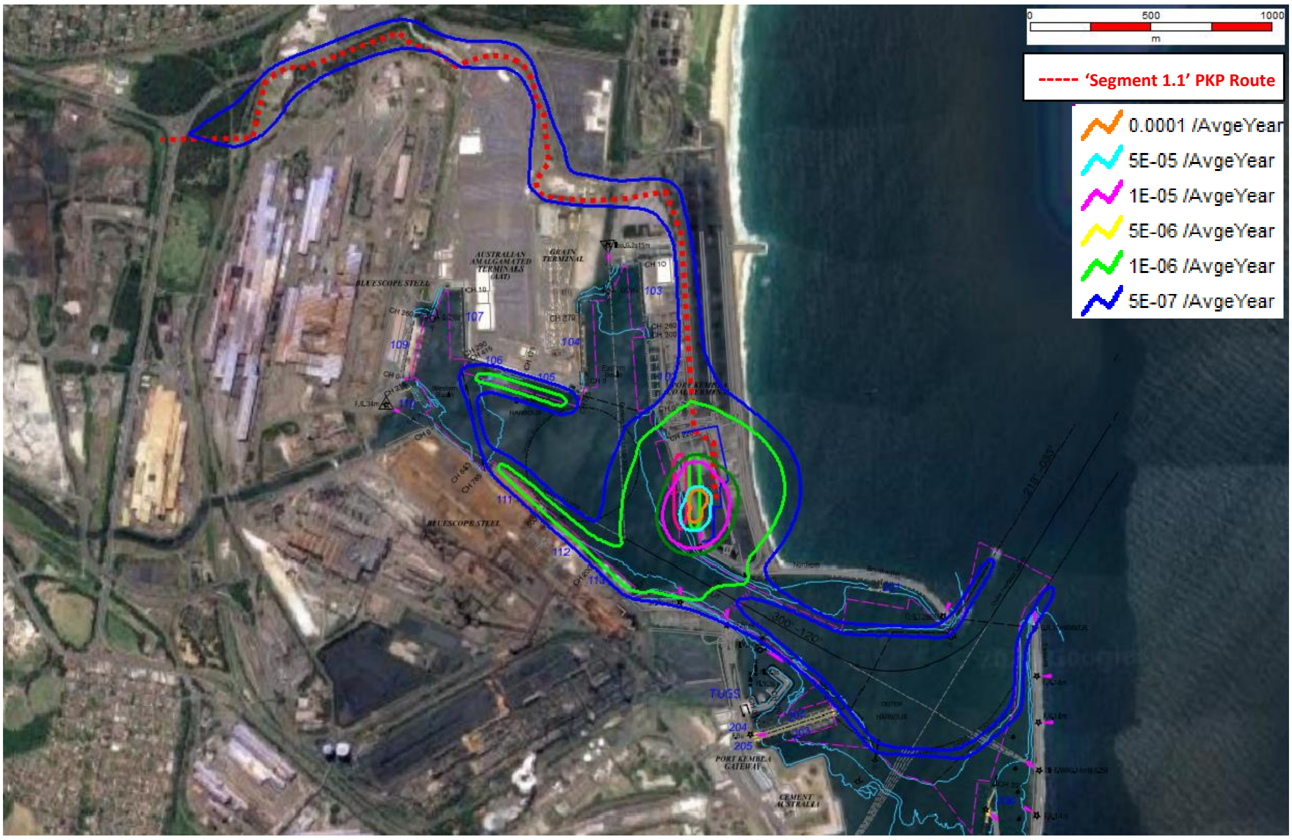

Figure 8-4: PKGT Base Case Fatality Risk Contours – FSRU with LNGC Transit Occurring

The LSIR result assessed against the HIPAP4 fatality criteria are provided in Table 8-4. Note as previously detailed, LSIR is the risk of fatality and/or injury at a point in space to a hypothetical unprotected individual at a location for 365 days per annum (pa), 24 hours a day. Where hazards ae not continually present i.e. those associated with LNGC movements, the LSIR shown are an average over a year. For individuals to be exposed to risk they need to be present at a location at the time a hazardous event occurs.

Table 8-4: PKGT Base Case LSIR Results as Assessed against the HIPAP4 Fatality Risk Criteria

Risk (pa)		Land Use	Criteria Met
5E-07	(blue)	Hospitals, schools, child-care facilities, old age housing	Yes There are no hospitals, schools, child-care facilities, or old age housing within the contour area.
1E-06	(green)	Residential, hotels, motels, tourist resorts	Yes There are no residential developments, hotels, motels, tourist resorts within the contour area.
5E-06	(yellow)	Commercial developments including retail centres, offices and entertainment centres	Yes There are no commercial developments including retail centres, offices and entertainment centres within the contour area. The BlueScope Steel visitors centre located in the vicinity of 'Segment 1.1' has been considered to be equivalent of a commercial development and is outside the associated risk contour.
1E-05	(magenta)	Sporting complexes and active open space	Yes The 1E-05 pa risk contour does not reach any active open spaces (i.e. Seawall Road)
5E-05	(cyan)	Industrial	Yes The 5E-05 pa risk contour remains within the site boundary

The results show that on average throughout the year, with the risk reduction measures included in the PKGT design, the overall offsite fatality risk associated with the project meets all of the criteria specified in HIPAP4 [9].

Figure 8-4 shows that the risk associated with a LNGC movements within Port Kembla. The risk is predominantly a result of the following two scenarios:

- In transit LNGC grounding or collision with land within Port Kembla inner and outer harbour leading to LNG storage tank rupture (marked-up in BLACK in Figure 7-2).
- In transit LNGC collision with moored ship (including the FSRU itself) leading to LNG storage tank rupture (marked-up in GREEN in Figure 7-2).

However, the collision frequencies calculated for these scenarios would be no different from any other vessel exiting or entering the harbour. The collision frequencies associated with vessel movement within a port area is not specific to LNGC vessels. Vessel movements are under the control of PANSW. This control is vessel traffic management, which includes speed limits, and the use of tugs and piloted vessels. There are no recorded ship collision events that have occurred at Port Kembla.

Although there are no permanent residential developments, hotels, motels, tourist resorts, located within the within the contour areas presented in Figure 8-2, Figure 8-3 and Figure 8-4, it is noted that in the past on occasion, cruise ships (considered as a temporary tourist resort) have occupied berth 106. There are no scheduled cruise ships for the next two years. However, it is possible that in the future, cruise ships will return to Port Kembla. This population is included in the societal risk assessment detailed in Section 8.5.

8.2.1 Key Risk Contributors

Locations of interest (generally occupied areas) in proximity to berth 101 are shown in Figure 8-5. The risk at these locations has been analysed to determine the hazardous events that provide significant contribution to the risk at each location.

Figure 8-5: Risk Ranking Point Position in PKGT Base Case SAFETI Model

Note the key risk contributors at berth 113 are expected to be similar to the berth 112 location and has not been assessed separately. Similarly, the key risk contributors at the northern breakwater are expected to be the same as Seawall road. A summary of the key risk contributors is provided below.

1. Berth 112 is used by BlueScope steel. Risk at this location is primarily associated with a flash fire impacts resulting from an LNGC collision with either land or a moored vessel (>94% risk contribution). The collision frequencies calculated for these scenarios would be no different from any other bulk carrier vessel exiting or entering the harbour. Vessel movements are under the control of PANSW. This location may also experience risk associated with flash fire impacts resulting from full-bore failure of one of the MLAs at the ORF. Note that the extent of the flammable gas dispersion modelled in the DNV software for this scenario is conservative and does not take into account the the FSRU itself and the impact it may have on a release blown in the direction of berth 112. Full-bore failure of a MLA is only likely to happen

during excessive FSRU vessel movements. Each of the MLAs have a position switch with pre alarm, ESD 1 (Isolation + blowdown) and ESD 2 (Disconnection) functionality. ESD1 and ESD2 activation on one MLA will trigger the same on the other MLA.

2. Berth 111 is also used by BlueScope steel. Risk at this location is associated with a flash fire impacts resulting from an LNGC collision with either land or a moored vessel (>99% risk contribution).
3. Berth 106 is used by Australian Amalgamated Terminals. In the past, on occasion cruise ships have occupied berth 106. Risk at this location is associated with a flash fire impacts resulting from an LNGC collision with either land or a moored vessel (>99% risk contribution). This population is included in the societal risk assessment detailed in Section 8.5.
4. Berth 105 is also used by Australian Amalgamated Terminals. Risk at this location is associated with a flash fire impacts resulting from an LNGC collision with either land or a moored vessel (>99% risk contribution).
5. PKCT is a coal exporting facility adjacent to the ORF. Risk at this location is predominantly associated with the ORF (~64% risk contribution) and the PKP (~31% risk contribution). The lead contributing event from the ORF with the potential to impact this location is a jet fire resulting from full-bore failure of one of the MLAs. As detailed above, full-bore failure of a MLA is only likely to happen during excessive FSRU vessel movements. Each of the MLAs have a position switch with pre alarm, ESD 1 (Isolation + blowdown) and ESD 2 (Disconnection) functionality. In addition, the ORF has infrared (IR) flame detection provided with supplementary elevated IR flame detectors provided specifically for the MLAs. This fire event was considered in the PKGT ORF Passive Fire Protection Requirement Assessment [46] and ORF SFAIRP Technical Note [11]. On confirmed fire, the MLA inventory will be isolated and rapidly consumed. The lead contributing event from the PKP with the potential to impact this location is a jet fire or jet fire from full-bore failure of the buried PKP. It should also be highlighted that while full-bore failure events are the key risk contributors for this location, a release of this type (i.e. rupture) only contributes up to 1% of the overall leak frequency (refer Table 7-1, Section 7.1). These types of events are highly unlikely. The PKP will be a licenced pipeline operated by Jemena. The Pipeline Safety Management Study concluded that no unusual threats that cannot be controlled through the current design process were identified and has been reviewed by NSW Department of Planning and Environment and confirmed the study was conducted appropriately by all relevant stakeholders, in line with the requirements of AS 2885 [8].
6. Seawall road may be used by surfers, rock fishers and occasional on-lookers. Risk at this location is predominantly associated with the ORF (~73% risk contribution) and the FSRU (~23% risk contribution). The lead contributing event from the ORF with the potential to impact this location is a jet fire resulting from full-bore failure of one of the MLAs. The same controls apply as detailed above. The lead contributing event from the FSRU with the potential to impact this location is a jet fire resulting from a 100mm hole size release in the LNG booster pump discharge section. The fire detection and prevention strategy for a release of LNG from the regasification booster pumps is provided in detail in the PKGT FSS [4]. However, confirmed fire (via fusible melt links and/or IR flame detectors) in the regasification plant area will isolate the inventory, stop the booster pumps, initiate a TPSD and automatically blowdown the regasification plant and high pressure export pipework. Jet fire impacts will significantly reduce such that they will not impact offsite areas. It should also be highlighted that similar to full-bore failure events, releases from the 100mm hole size only contributes up to 2% of the overall leak frequency (refer Table 7-1, Section 7.1).

As LNGC’s are only expected to be in the harbour for a one day period every two weeks (or one day every week during ‘high season’) and they do not have much process equipment as the FSRU, they do not significantly impact the risk contours. Whilst the stored inventory is the same as the FSRU this inventory is at low pressure which results in short consequence distances.

8.3 Propagation and Injury Risk

8.3.1 Injury Risk

Injury risk due to heat radiation levels in excess of 4.7 kW/m^2, explosion overpressure levels greater than 7 kPa and toxic exposure has been determined at the 'base case' average seasonal demand operating conditions. The injury risk assessment considers the entire project scope including the LNGC, FSRU, ORF and 'Segment 1.1' of the PKP.

Overall, no residential and sensitive land users in the vicinity of the PKGT will be exposed to injury risks greater than the criteria in HIPAP4 [9] (refer Table 8-2, Section 8.1). The injury risk modelling results are presented below.

Figure 8-6 shows the 5E-05 pa frequency of heat radiation levels of 4.7 kW/m^2 which have the potential to cause injury extends marginally outside of the fence line. However, there are no sensitive or residential areas within this area.

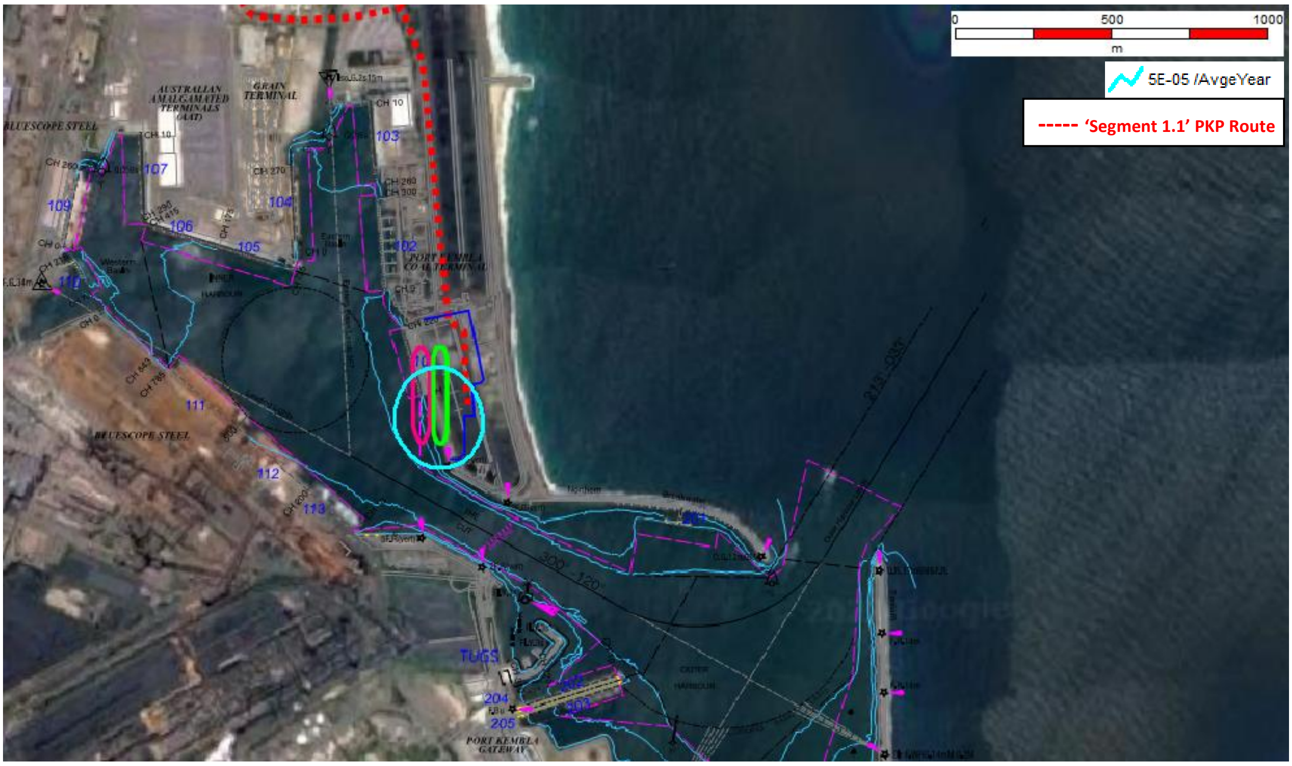

Figure 8-6: Injury Risk (5E-05 pa) from 4.7 kW/m^2 Thermal Radiation Exposure

Figure 8-7 shows the 5E-05 pa frequency of explosion overpressure levels of 7 kPa 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.

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energy | chemicals | resources

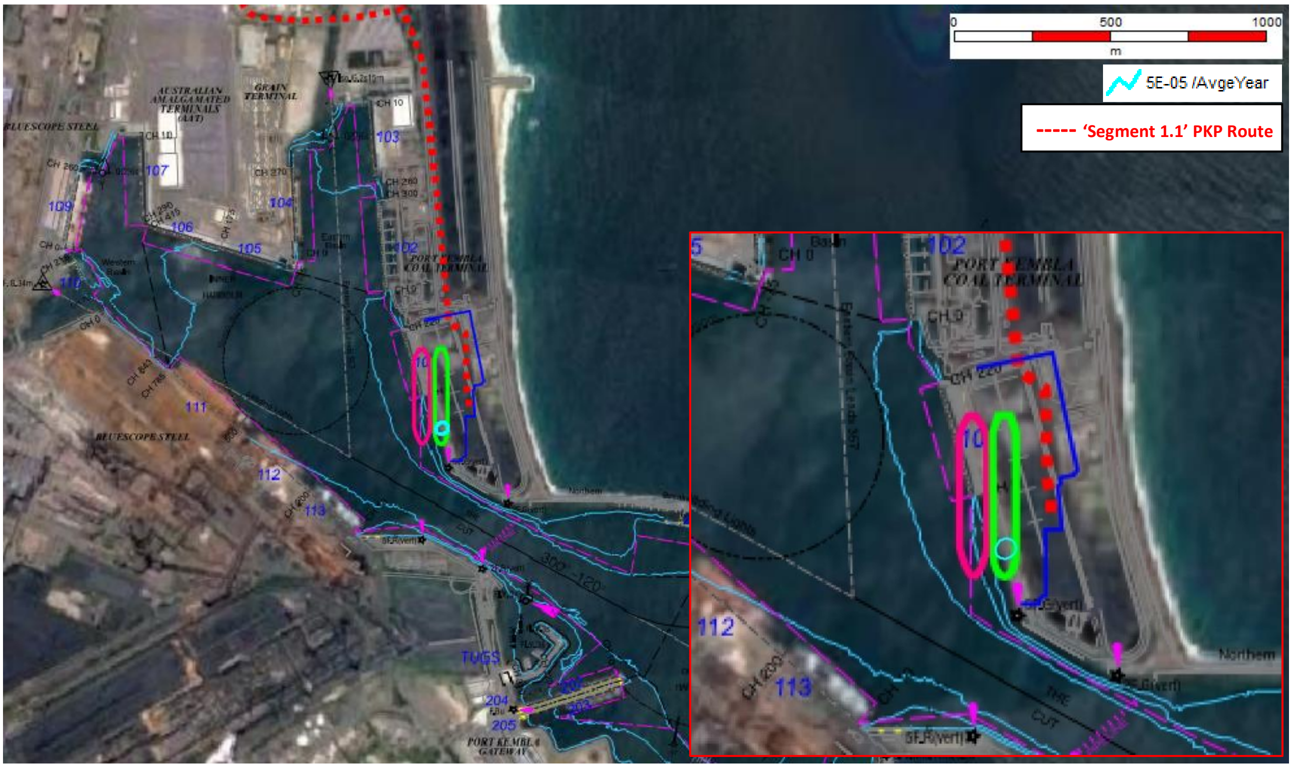

Figure 8-7: Injury Risk (5E-05 pa) from 7 kPa Explosion Overpressure Levels

Figure 8-8 shows the 5E-05 pa frequency of toxic exposure resulting in minor irritation extends outside of the PKGT fence line. However, there are no sensitive or residential areas within this area. Figure 8-9 shows the 1E-06 pa frequency of toxic exposure which has the potential to cause serious injury is localised to the odourant storage and injection shipping container. It does not impact any sensitive or residential areas.

Figure 8-8: Injury Risk (5E-05 pa) – Minor injury due to toxic exposure (AEGL 1, 30 min)

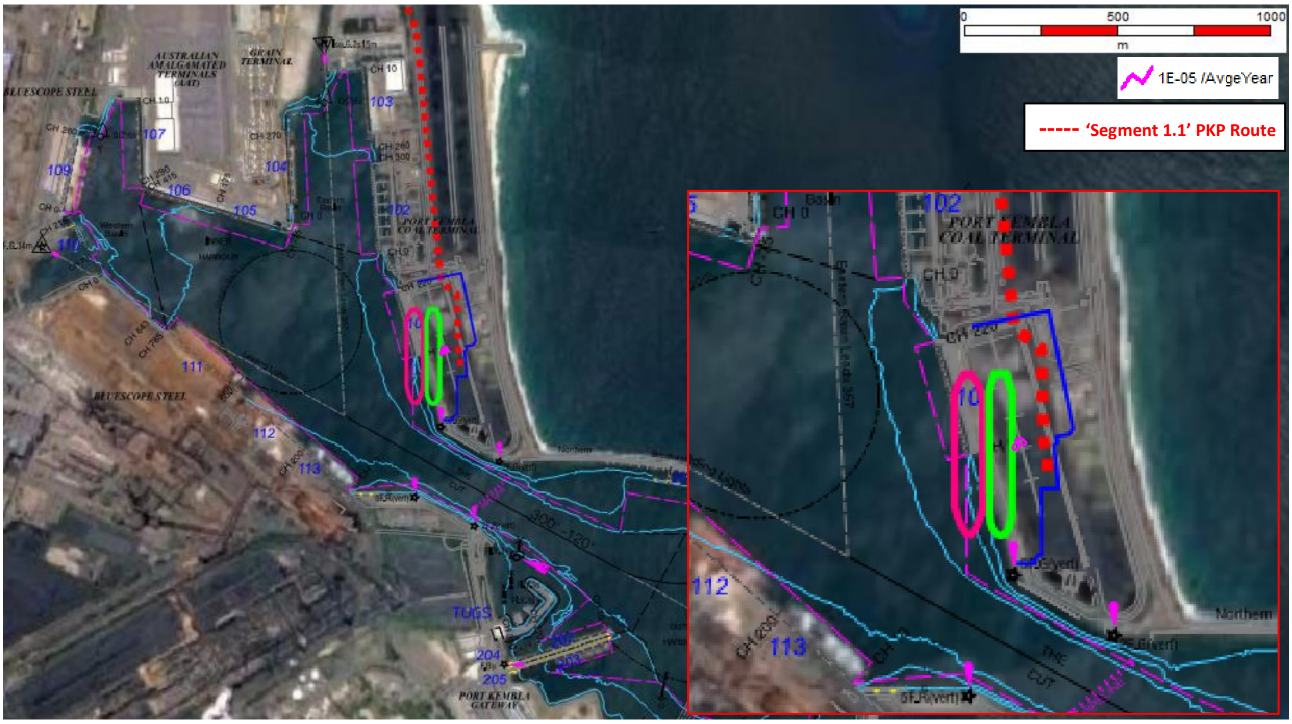

Figure 8-9: Injury Risk (1E-05 pa) - Serious injury due to toxic exposure (AEGL 2, 30 min)

Risk of toxic exposure is only likely to occur during changeout of a Spotleak 1005 SBC. During normal operation, a LOC will occur within the shipping container which is provided with an activated carbon filter system. A release of odourant within the shipping container it is stored is more likely to result in an explosion and was considered as an obstructed region in the risk modelling (refer Section 6.3). A LOC of the odourant from the injection pipework at the odourant injection conditions (i.e. dosing) are either very localised or not produced due to the low flow rates as limited by the injection pump as determined in the PKGT FSS [4].

8.3.2 Accident Propagation Risk

Accident propagation risk due to heat radiation levels in excess of 23 kW/m^2 and explosion overpressure levels greater than 14 kPa have also been determined at the 'base case' average seasonal demand operating conditions. The accident propagation risk assessment considers the entire project scope including the LNGC, FSRU, ORF and 'Segment 1.1' of the PKP.

Overall, the risk of damage or accident propagation to the surrounding industrial facilities is not greater than the criteria in HIPAP4 [9] (refer Table 8-2, Section 8.1). The accident propagation risk modelling results are presented below.

Figure 8-10 shows the 5E-05 pa frequency of heat radiation levels of 23 kW/m^2 which have the potential to cause damage and escalation at neighbouring facilities remains on the FSRU, in the vicinity of the regasification module. There is no risk of damage or propagation at the surrounding industrial facilities due to exposure to high heat radiation levels. This is considered to be a result of the risk reduction measures incorporated into the PKGT design (i.e. F&G, isolation and ESD).

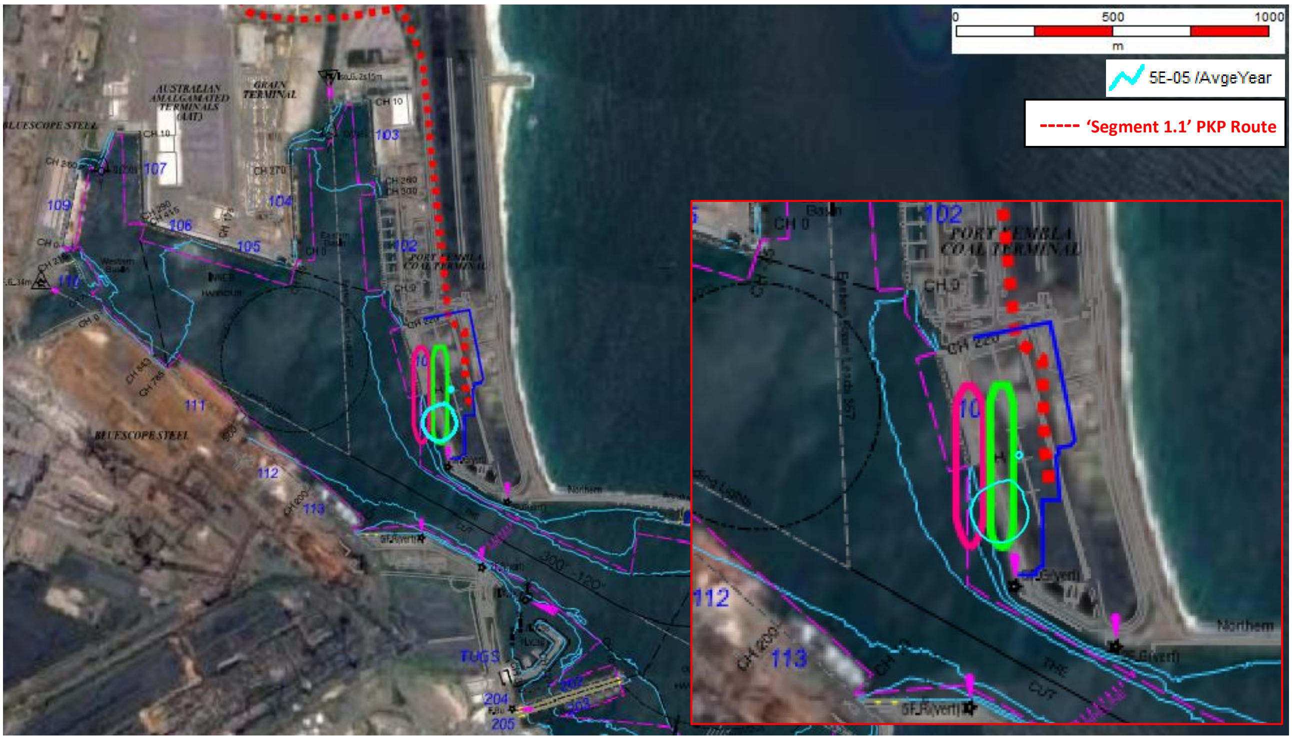

Figure 8-10: Property Damage (5E-05 pa) from 23 kW/m2 Thermal Radiation Exposure

Figure 8-11 shows the 5E-05 pa frequency contour for explosion overpressure levels of 14 kPa which have the potential to cause damage and escalation at neighbouring facilities, in the vicinity of the regasification module. There is no risk of damage or propagation at the surrounding industrial facilities due to explosion at the berth.

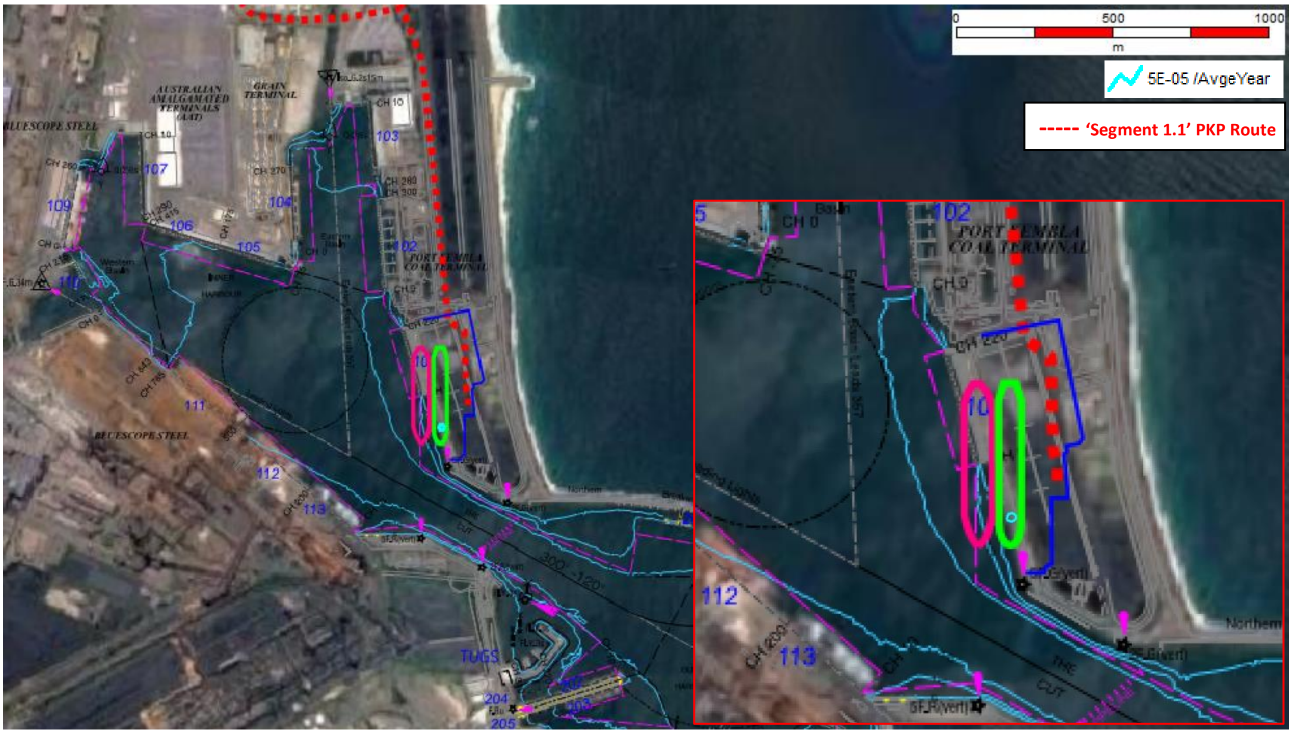

Figure 8-11: Property Damage (5E-05 pa) from 14 kPa Explosion Overpressure Levels

8.4 Sensitivity Cases

8.4.1 Base Case with No Risk Reduction Considered (Unmitigated)

An additional risk model for the FSRU only operational mode 'base case' average seasonal demand without the risk reductions detailed in Section 7.3 has been considered in this FHA in order to present the impact of mitigation measures in place. This risk model is based on unlimited inventories (i.e. no isolation) and sustained peak release rates which will indicate the worst LSIR from the PKGT. Note figures for the FSRU with LNGC ship-to-ship loading and FSRU with LNGC transit occurring operational modes are not shown as risk reduction measures were conservatively not considered in the LNGC, and LNGC transit (ship collision and grounding) models.

The overall findings from the unmitigated FSRU only operational mode 'base case' average seasonal demand sensitivity risk modelling presented as LSIR contours is provided in Figure 8-12.

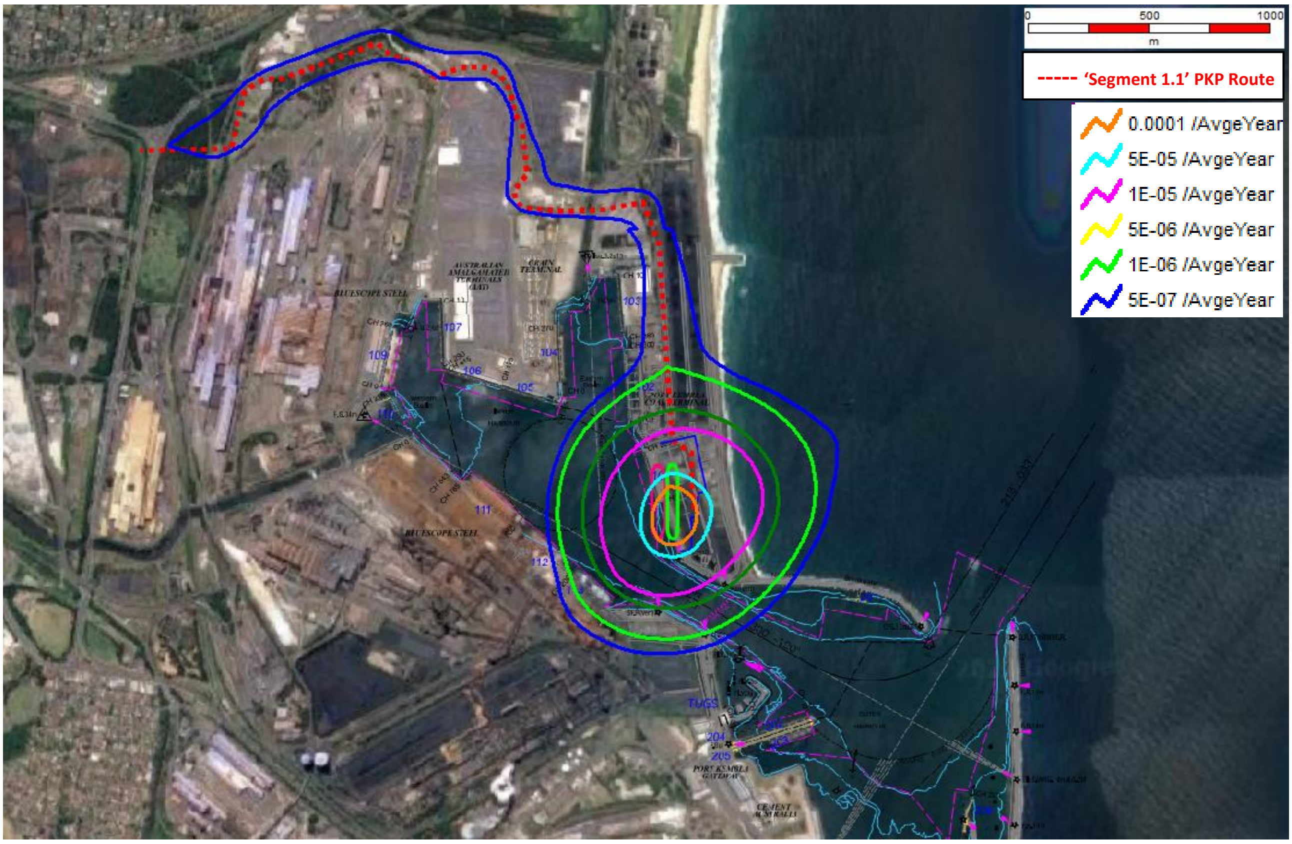

Figure 8-12: PKGT Base Case Fatality Risk Contours – FSRU Only – No Risk Reduction Sensitivity

The HIPAP4 [9] criteria states that the 5E-05 pa risk contour, as a target, should be contained within the boundaries of the industrial site where applicable. This risk contour is largely within the site boundary. However, it slightly extends beyond the ORF fence line at the south-east.

The 1E-05 pa risk contour for active open spaces also extends beyond the ORF fence line, across Seawall Road and extends into the harbour. Seawall Road to the east of berth 101 is a public road managed by NSW Ports. PHA Addendum 1 [17] addressed access via Seawall Road which is opened to the public during daylight hours only and regularly closed for poor weather and/or other operational needs, including bulk haulage, construction / maintenance, etc. The road can be closed and secured at these times via security fencing and lockable gates. Access restrictions can be implemented and enforced by NSW Ports as required. Exposure for public users of Seawall Road is likely to be for short durations and numbers are limited as indicated by NSW Ports:

"The road tends to be used by surfers, rock fishers and occasional on-lookers for unusual events, such as the arrival of a large cruise ship. However, numbers of users are in the dozens, not the 100's, with the largest crowds seen there for the arrival of the Port's first cruise ship. Subsequent cruise ship arrivals have seen the crowd numbers dwindle."

Vessel entry into the Port Kembla Inner Harbour is controlled by PANSW and unauthorised entry is prohibited and enforced. Exposure of the public in this area is therefore expected to be low. Based on the above access restriction controls and the risk reduction measures incorporated in the PKGT design (refer Section 7.3) the risk to surrounding land users and the public is reduced.

8.4.2 High Demand Case with Risk Reduction Considered (Mitigated)

As detailed in PHA Addendum 2 [18] the 'high demand' case may operate for up to six months from April through to September and will continue to operate with two LNG trains. However, the high demand case will operate with one additional LNG booster pump to achieve higher gas output. To accommodate the increased production, it is conservatively assumed 52 LNGC deliveries are required per year.

The overall findings from the 'high season' demand risk modelling presented as LSIR contours for the three operational modes i.e. FSRU only, FSRU with LNGC ship-to-ship loading and FSRU with LNGC transit occurring are provided in Figure 8-13.

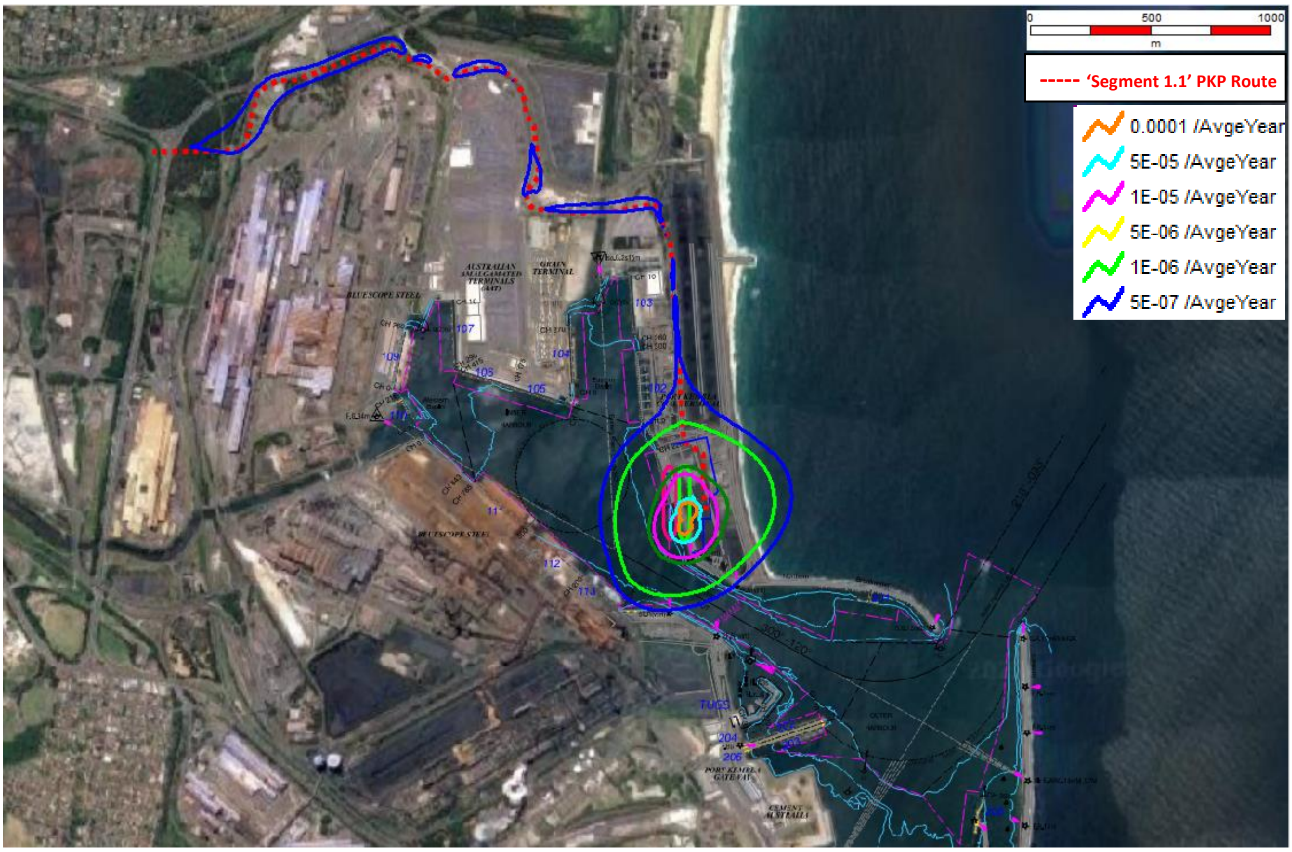

Figure 8-13: PKGT 'High Season' Demand Risk Contours – FSRU Only

Figure 8-14: PKGT 'High Season' Demand Risk Contours – FSRU with LNGC Ship-to-ship Loading

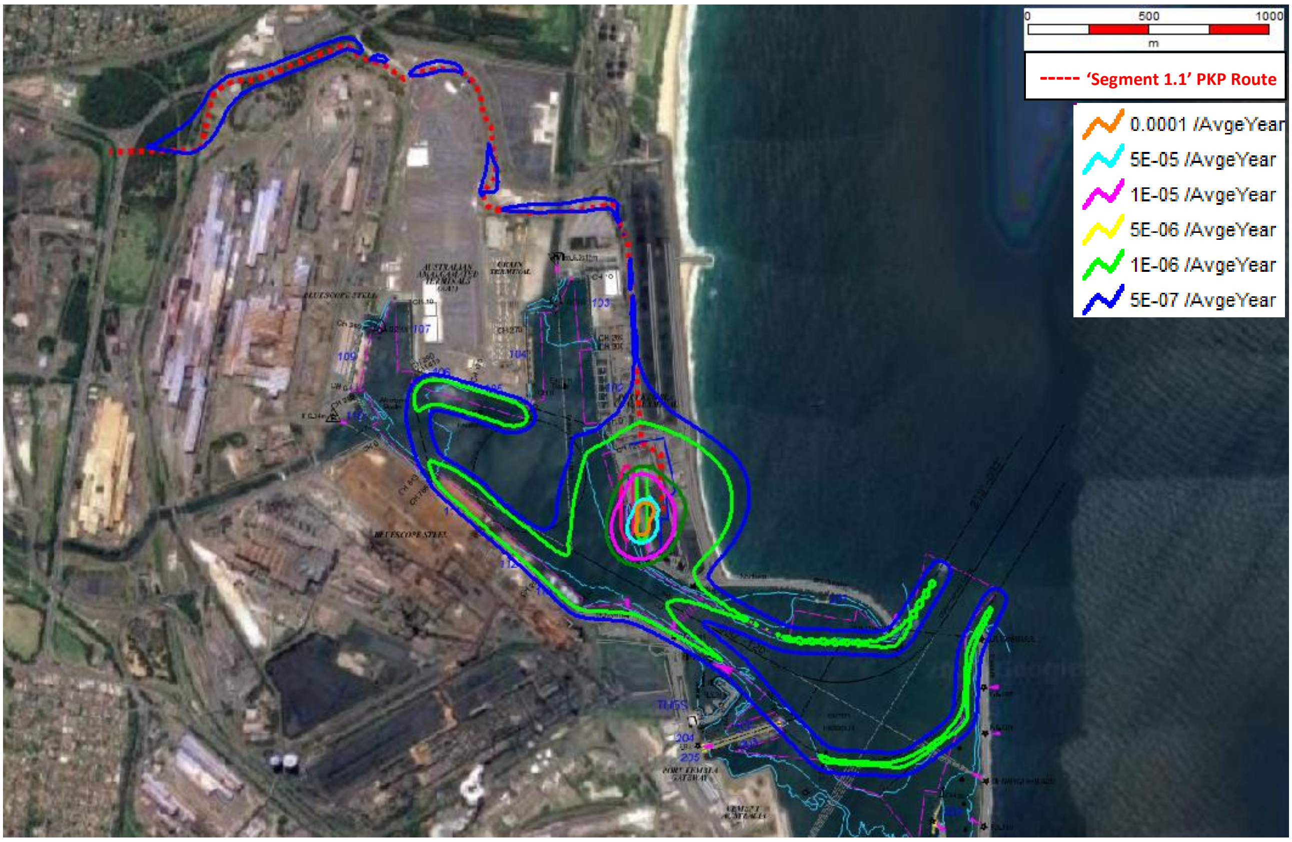

Figure 8-15: PKGT 'High Season' Demand Risk Contours – FSRU with LNGC Transit Occurring

The results show that even when the FSRU is operating with a greater throughput, with the risk reduction measures identified included in the PKGT design, the 5E-05 pa risk contour for industrial areas and 1E-05 pa risk contour for active open spaces remain within the ORF fence line and the project meets all of the criteria specified in HIPAP4 [9]. This is considered to be a result of the risk reduction measures incorporated into the PKGT design (i.e. F&G, isolation and ESD).

The reduction of risk along the pipeline route presented in Figure 8-16 and Figure 8-17 is due to the reduction in the operating pressure during the 'high season'. During 'high season', the throughput of the regasification plant is higher and the resulting discharge pressure from the FSRU reduces to 100 barg. This is due to the performance characteristics of the pumps in the regasification plant. The absence of contours in some locations along the pipeline route is due to pipeline route itself and the weather conditions. Flammable gas dispersion is strongly influenced by the wind conditions and direction.

The increased quantity of LNGC deliveries has extended the 1E-06 pa and 5E-07 pa risk contours along the identified LNGC grounding and collision with land or moored vessel locations within the harbour. Note the collision frequencies calculated would be no different from any other vessel exiting or entering the harbour. The risk associated with vessel movement within a port area is not specific to LNGC vessels.

8.5 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. The population data presented in Appendix C was included in the risk modelling using DNV SAFETI software to calculate societal risk. Note the following additional assumptions were also made:

- When cruise ships visit Port Kembla, they will be located at berth 106. Therefore, a RoRo vessel will be unable to be berthed at the same location;
- In the event on an LNGC collision during transit with either land or a moored vessel (i.e. located at berth 105, 106, 111, 112 or 113) there is potential for a liquid LNG pool to form on the surface of the water. Flashing will occur resulting in the generation of flammable gas. For a major spill (as defined in Section 7.2) the flammable gas dispersion does not reach greater than 4m above sea level. Therefore, the populations on board a RoRo vessel, bulk carrier or cruise ship vessel in these berths will not be vulnerable to the potential hazardous consequence and are excluded from the societal risk calculation.

The resulting societal risk of a fatality (in the form of an FN curve) to the populations identified in Section 3.4 for the three operational modes i.e. FSRU only, FSRU with LNGC ship-to-ship loading and FSRU with LNGC transit occurring are provided in Figure 8-16, Figure 8-17 and Figure 8-18 respectively. As previously detailed in Section 8.1.2, the societal risk criteria presented are indicative and do not represent a firm requirement in NSW.

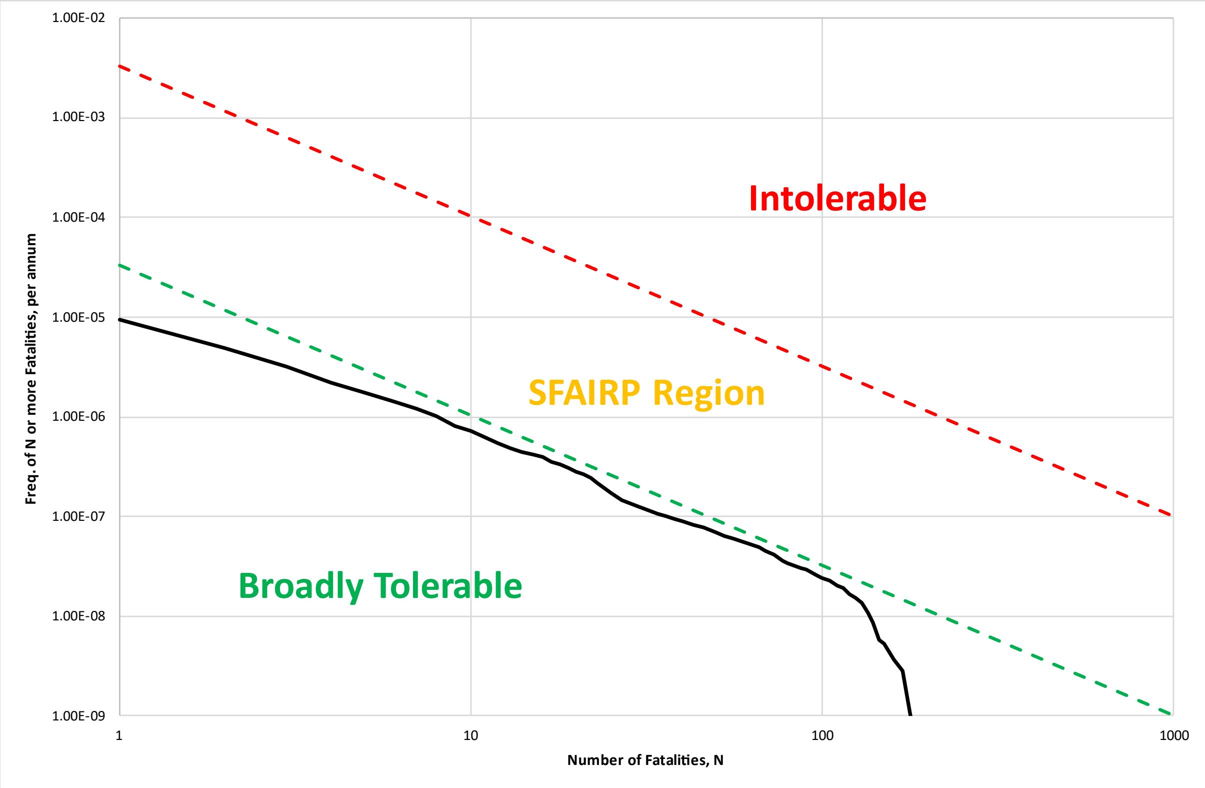

Figure 8-16: PKGT Base Societal Risk Curve – FSRU Only

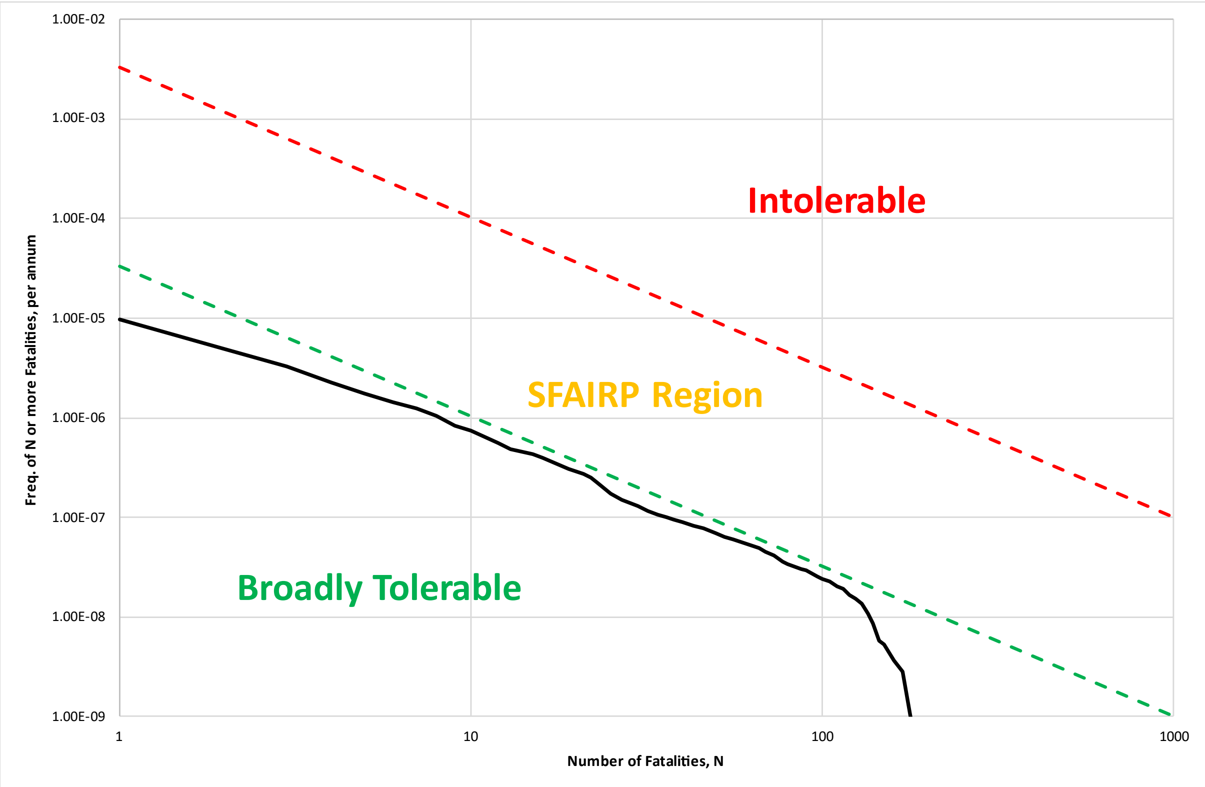

Figure 8-17: PKGT Base Societal Risk Curve – FSRU with LNGC Ship-to-ship Loading

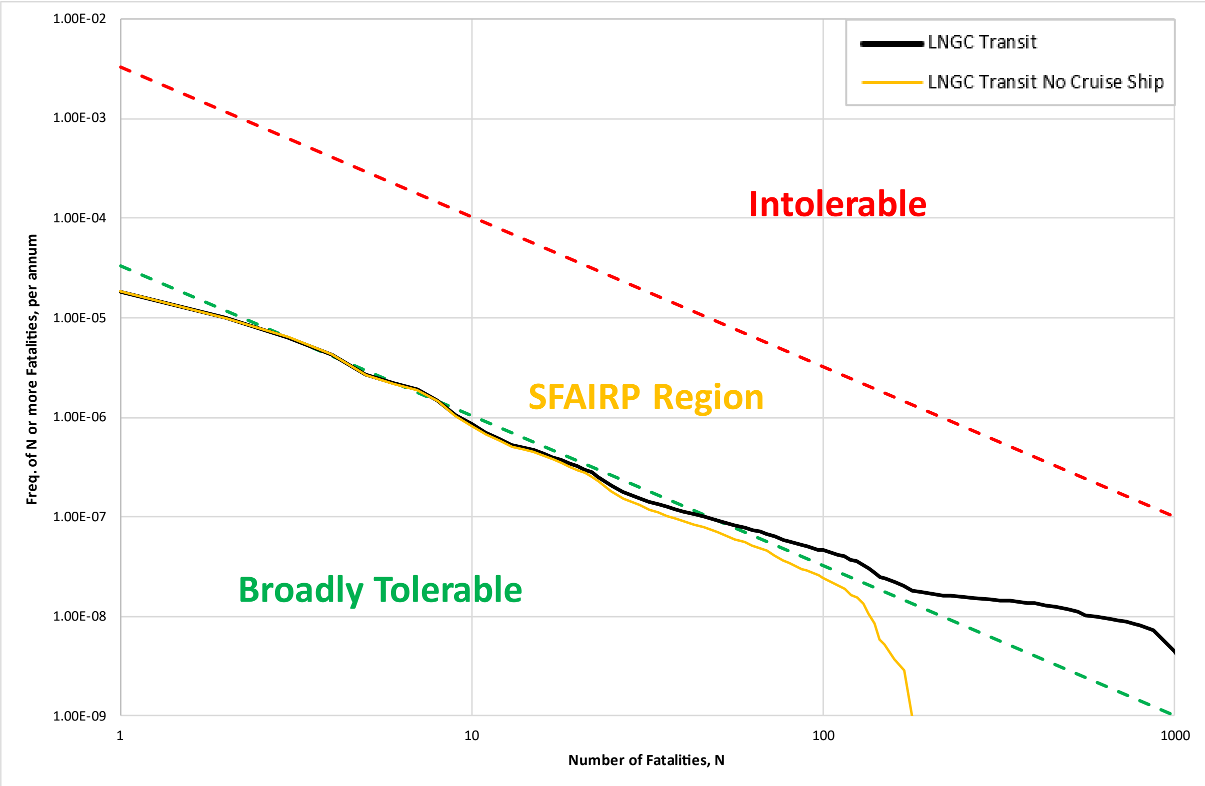

Figure 8-18: PKGT Base Societal Risk Curve – FSRU with LNGC Transit Occurring

The societal risk results show that when the FSRU is in operation the likelihood of multiple fatalities is in the 'Broadly Acceptable' region. The presence of a LNGC moored alongside unloading its LNG cargo has negligible impact on the societal risk which remains in the 'Broadly Acceptable' region. This is expected due to the frequency at which a LNGC will be moored in Port Kembla combined with lower operating conditions (compared with the regasification process) which has small consequence distances [4].

It is only when the LNGC vessel movements within the harbour is included in the societal risk calculation that the societal risk curve is in the 'Tolerable if SFAIRP' region. Note the calculations consider a cruise ship may be present in the berth 106 location a fraction of the year. When this population is excluded from the societal risk calculation (i.e. a cruise ship is not present when LNGC transit is occurring) the societal risk is in the 'Broadly Acceptable' region as presented in Figure 8-18.

The key risk contributors identified for the berth 105, 106, 111, and 112 locations in Section 8.2.1 indicate that an LNGC collision with either land or a moored vessel dominates the risk at these locations. The LNGC transit risk is generally proportional to the number of LNGC deliveries and the collision frequencies calculated for these scenarios would be no different from any other bulk carrier vessel exiting or entering the harbour. Vessel movements are under the control of PANSW. This includes vessel traffic management, speed limits, and the use of tugs and piloted vessels. There are no recorded ship collision events that have occurred at Port Kembla.

The following recommendation is made in line with inherent safety and SFAIRP principals.

Recommendation 1: PANSW to manage LNC vessel movements such that an LNGC shall not enter or leave the port while a cruise vessel is at berth 106.

8.6 Risk to the Biophysical Environment

Risk to the biophysical environment from accidental releases of hazardous inventories has been minimised throughout the design and will be managed via operation and maintenance processes for the facility. Gaseous releases are not expected to impact the biophysical environment. Impacts on the biophysical environment were considered in the EIS prepared for the project [1] which subsequently received approval from the Minister for Planning and Public Spaces on the 24th of April 2019.

Onboard the FRSU, drains to direct liquid releases are provided to ensure cryogenic liquids are collected and vapourised. Drip trays are locally mounted at flanged connections in low pressure LNG lines and a stainless steel drip tray is also installed beneath regasification trains with drains to reduce potential for LNG pooling (pool fire). As detailed in Section 5.2.4, Section 5.2.6, and Section 5.2.7, glycol, hydraulic oils and other chemicals are not stored above deck or remain contained within equipment rooms. Spills below the deck (i.e. engine room) or for the accommodation decks will be collected in the bilge tanks.

On the ORF, diesel for the fire water pumps and the odourant are the only liquid chemicals stored. Diesel will be stored in double skinned day tanks in compliance with AS 1940 and the odourant will be stored in SBC's located within a shipping container.

9. Stakeholder Consultation

The previous revision (Revision 0) of this report was issued to NSW Ports and SafeWork NSW for consultation. Separate meetings have been held via Microsoft Teams on the 5th May 2023 (attended by representatives from NSW Ports, Sherpa Consulting, AIE and Worley) and 9th June 2023 (attended by representatives from SafeWork NSW, NSW Department of Planning and Environment, FRNSW, AIE and Worley) to clarify comments which have subsequently been addressed in this revision of the report. Noting consultation with stakeholders will be ongoing in order to uphold stakeholder engagement and to develop the facility's emergency response arrangements per the requirements of Infrastructure Approval [19] Schedule 3, Condition 23(a).

10. Key Findings and Conclusions

A FHA for the PKGT has been conducted in compliance with requirements of Condition 21(c) of the Infrastructure Approval SS 9471 [2] and in line with HIPAP6 [3] to develop a comprehensive understanding of the hazards and risks associated with operation of the PKGT and of the adequacy of safeguards. The FHA includes consideration of all relevant LOC of hazardous process related substances and associated escalation events emanating from the FSRU (or LNGC) and onshore receiving facilities including the above ground section of the Port Kembla Pipeline tie-in (up to the boundary isolation valve MLV-064011) located at the berth and the 4.3km 'Segment 1.1' of the PKP up to KP4.3.

The project has carried out a number of hazard studies including HAZID and HAZOP [29, 30, 31, 32, 33, 34, 35] over various phases. Based on the findings of these studies, additional studies and analysis have been conducted and include the following:

- SIL determination study for which four SIFs were reviewed with three assigned a SIL-0 rating, and one (HP manifold LL temperature) assigned a SIL-1 requirement. An action was raised in the SIL Determination report to ensure that the HP manifold LL temperature function meets is able to achieve the risk reduction / integrity level of a SIL-1 function. This action remains open and will be tracked to closure by the project.
- FSS [4] which details the fire prevention, mitigation, protection and suppression (i.e. risk reduction) strategies for the potential hazardous scenarios identified for the project. This study was completed for the PKGT as required by Condition 21(a) of the Infrastructure Approval SSI 9471 [2] and in line with HIPAP2 [5] and has been issued for consultation with Safework NSW, PANSW and FRNSW. It has subsequently been approved by FRNSW.
- EMERA [6] for the ORF to ensure adequate arrangements for EMER have been provided by the project.

A Pipeline Safety Management Study was carried out for the Jemena PKP [7] by others in accordance with the Australian Standard for Pipelines – Gas and Liquid Petroleum (AS 2885) and concluded that no unusual threats that cannot be controlled through the current design process were identified. The scope of the Pipeline Safety Management Study covers the entirety of the new lateral pipeline route from the PKGT to the existing EGP (i.e. 'Segment 1.1' up to KP4.3). The Pipeline Safety Management Study has been reviewed by NSW Department of Planning and Environment and confirmed the study was conducted appropriately by all relevant stakeholders, in line with the requirements of AS 2885 [8].

The frequency analysis determined the FSRU contains the majority of leak sources followed by the LNGC, and then the ORF. It is noted however, that the LNGC will only be berthed alongside the FSRU a fraction of the time which is factored into the risk modelling. Approximately 90% of the leaks are associated with the smaller leak sizes of 25mm and less. These also contribute the least to offsite risk due to their reduced consequence distances.

Risk modelling using DNV SAFETI software was conducted to determine the LSIR contours (offsite risk) associated with the PKGT. The results show that on average throughout the year, with the risk reduction measures identified included in the PKGT design, the overall offsite fatality risk associated with the project meets all of the criteria specified in HIPAP4 [9].

Additional risk models (sensitivities) were considered in this FHA and include the following:

- ‘Base case’ average seasonal demand without the risk reductions applied; and
- ‘High season’ demand when the FSRU is operating with a greater throughput and receiving increased LNGC deliveries.

The results of the unmitigated ‘base case’ sensitivity demonstrate the impact of risk reduction measures identified and included in the PKGT design. Without the implementation of the risk reduction measures, members of the public accessing Seawall Road may be exposed to unacceptable levels of risk. It is noted that the credit taken to account for risk reduction in the FHA is considered conservative. PKGT has multiple layers of protection including BPCS trips to indicate when the process deviates from a normal operating condition which may result in a LOC event (i.e. high pressure and low temperature).

The results of the ‘high season’ demand case indicates the incremental risk associated with operating the FSRU with a greater throughput and receiving additional LNGC deliveries. The increased LNGC deliveries has extended the 1E-06 pa and 5E-07 pa risk contours along the ship route through the harbour. However, there are no permanent residential developments, hotels, motels, tourist resorts, located within the within the contour area. Risk from the ORF does not increase. Overall, for the ‘high season’ demand case, with the risk reduction measures identified included in the PKGT design, the offsite fatality risk associated with the project meets all of the criteria specified in HIPAP4 [9].

Societal risk (in the form of an FN curve) has also been assessed. Noting the criteria provided in HIPAP4 [9] are indicative and do not represent a firm requirement in NSW. Societal risk for the project is generally in the ‘Broadly Acceptable’ region except when a population from a berthed cruise ship is included in the calculations the FN curve moves into the SFAIRP region. Therefore, in Revision 2 of this report, the following recommendation is made to reduce the coincidence of a cruise ship in berth and LNGC vessel movements.

Recommendation 1: PANSW to manage LNC vessel movements such that an LNGC shall not enter or leave the port while a cruise vessel is at berth 106.

Following the issue of the previous revision of this report, Port Authority NSW (PANSW) has confirmed [10] the following:

“Port Authority manages vessel movements under our port safety functions in accordance with the risk profile of Port Kembla. This includes management of Liquid Natural Gas and cruise vessel movements to ensure that they are performed in a safe manner that is consistent with relevant legislation and standards. In the unlikely event that a cruise vessel is at berth 106 during the visit of an LNGC vessel at berth 101, such a movement will be managed to ensure safe access and egress, including delaying an LNGC vessel to berth while the cruise vessel is at berth 106”.

Overall, it is considered the FHA demonstrates that LOC of hazardous process related substances associated with the PKGT are well understood, a number of hazard studies have been conducted to identify controls and safeguards included in the design and risk associated with the PKGT meet the criteria defined in HIPAP4 [9].

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Appendix A. Hazard Identification

Facility / Event	Cause	Preventative Controls	Possible Consequence	Mitigation Measures
LOC of LNG or NG on FSRU	• Small (10mm) ◦ Corrosion ◦ Fatigue or defective material ◦ Flange leak • Medium (25mm) ◦ Leak from small-bore fitting • Medium – Large (50mm) ◦ Ship to ship loading hose failure ◦ Overpressure ◦ Dropped object or other impact • Large (100mm) ◦ Dropped object or other impact • Ship collision	• Engineering design to relevant codes and standards including: ◦ DNV Rules of Classification – Part 5, Chapter 7 Liquified Gas Tankers (DNV-RU-SHIP-Pt5Ch7) ◦ DNV Rules of Classification – Part 6, Chapter 4 Cargo Operations (DNV-RU-SHIP-Pt6Ch4) • Inspection and maintenance • Operating procedures and permit to work • Overpressure protection on FSRU including HIPPS on HP export header (overpressure) • Water Spray Curtain during ship-to-ship transfer (ship-to-ship loading – hull protection) • Harbour exclusion zone (ship collision) • Warning protocols & procedures (ship collision) • Tug support (ship collision) • Piloted vessels(ship collision)	• Unignited liquid or gas release	• Drip trays locally mounted at flanged connections in low pressure LNG lines (ensure cryogenic liquids are collected and vapourise in drip tray) • In line with the Blowdown, ESD AND PSD Philosophy (EF00109 Rev 0) fixed gas detection is installed in the following process areas: ◦ Regasification plant (including regas module and suction drum module) ◦ Vent mast for the regasification plant (alarm only) ◦ HP export manifold ◦ Gas Metering unit ◦ Cargo Machinery Room • Fixed gas detection is also installed in the following non-hazardous areas: ◦ Engine room (various spaces and air intakes) ◦ Accommodation (various entrances and air intakes) • On confirmed gas, blowdown of the regasification plant can be manually initiated. • Höegh Fire Contingency Plans (emergency response) which covers LOC events
			• Immediate ignition of gas release resulting in flash fire, jet fire or delayed ignition of liquid release resulting in pool fire	• Refer gas detection for unignited release. • Stainless steel drip tray installed beneath regasification trains with drains to reduce potential for LNG pooling (pool fire) • Ignition controls including hazardous area classification in line with Höegh Galleon Hazardous Area & Zone Plan (DF00620 Rev 0). • In line with the Blowdown, ESD AND PSD Philosophy (EF00109 Rev 0) IR flame detectors AND electric thermal fuse type fusible melt links is fitted for the following hazardous process areas: ◦ Regasification Plant including suction drum ◦ HP export manifold ◦ Gas Metering unit ◦ Cargo Machinery room ◦ Electric Motor room • Fusible melt links of electric thermal fuse type ONLY are be provided in the following hazardous process areas: ◦ Loading manifold areas ◦ At each liquid dome (tank outer structure) ◦ At each gas dome (tank outer structure) • On confirmed fire, ESDH is implemented (refer Section 3.7.1). • Active fire protection including water spray and independent hydrant system, dry powder and CO_2 extinguishing systems. • Höegh Fire Contingency Plans (emergency response) which covers (but is not limited to) fires in the cargo machinery room or motor room, machinery spaces, the cargo deck, fires on the jetty, and fires on either the LNGC or FSRU during ship-to-ship transfer
			• Delayed ignition of gas release resulting in explosion. Potential congested or confined areas with the potential for explosion include: ◦ Piping directly above each LNG cargo tank ◦ Cargo machinery room ◦ Suction drum module ◦ Regasification module	• Refer gas detection for unignited release. • Ignition controls including hazardous area classification in line with Höegh Galleon Hazardous Area & Zone Plan (DF00620 Rev 0). • Cargo machinery has CO_2 extinguishing system.
LOC of glycol on FSRU (Electric Motor Room)	• Small (10mm) ◦ Corrosion ◦ Fatigue or defective material ◦ Flange leak • Medium (25mm) ◦ Leak from small-bore fitting • Medium – Large (50mm) ◦ Dropped object or other impact	• Engineering design to relevant codes and standards including: ◦ DNV Rules of Classification – Part 5, Chapter 7 Liquified Gas Tankers (DNV-RU-SHIP-Pt5Ch7) ◦ DNV Rules of Classification – Part 6, Chapter 4 Cargo Operations (DNV-RU-SHIP-Pt6Ch4) • Welded pipe system, flange connections minimised • Inspection and maintenance • Operating procedures and permit to work	• Unignited liquid release (environmental incident)	• Glycol storage spill will be contained by electric motor room boundary wall coaming / specific coaming for storage areas. • Spill containment kit
			• Ignited release resulting in pool fire (flash point of the glycol is ~111°C i.e. not classed as flammable material per AS 1940, the storage and process conditions are below this)	• Ignition controls including hazardous area classification in line with Höegh Galleon Hazardous Area & Zone Plan (DF00620 Rev 0). • In line with the Blowdown, ESD AND PSD Philosophy (EF00109 Rev 0) IR flame detectors AND electric thermal fuse type fusible melt links are fitted in the Electric Motor Room • Smoke and heat detection • Electric motor room has CO_2 extinguishing system.

Facility / Event	Cause	Preventative Controls	Possible Consequence	Mitigation Measures

LOC of marine / hydraulic oils on FSRU (Cargo Machinery Room, Engine Room, Forward Pump room)	• Small (10mm)
	  ◦ Corrosion
	  ◦ Fatigue or defective material
	  ◦ Flange leak
	• Medium (25mm)
	  ◦ Leak from small-bore fitting
	• Medium – Large (50mm)
	  ◦ Overpressure
	  ◦ Dropped object or other impact
	• Large (100mm)
	  ◦ Dropped object or other impact
		• Engineering design to relevant codes and standards including:
		  ◦ DNV Rules of Classification – Part 5, Chapter 7 Liquified Gas Tankers (DNV-RU-SHIP-Pt5Ch7)
		  ◦ DNV Rules of Classification – Part 6, Chapter 4 Cargo Operations (DNV-RU-SHIP-Pt6Ch4)
		• Inspection and maintenance
		• Operating procedures and permit to work
		• Overpressure protection
			• Unignited liquid release (environmental incident)	• Oil spill will be contained by boundary wall coaming / specific coaming for storage areas.
				• Drip trays installed under oil systems
				• Spill containment kit

			• Ignited release resulting in pool fire (marine / hydraulic oil is not classed as flammable material per AS 1940, the storage and process conditions are below this)	• Ignition controls including hazardous area classification in line with Höegh Galleon Hazardous Area & Zone Plan (DF00620 Rev 0). • In line with the Blowdown, ESD AND PSD Philosophy (EF00109 Rev 0) IR flame detectors AND electric thermal fuse type fusible melt links is fitted in the Electric Motor Room • Smoke and heat detection • Cargo machinery room and forward pump room has CO_2 extinguishing system. • Engine room has high expansion foam system
LOC on LNGC	• Refer LOC on FSRU. Only approved vessels in accordance with DNV Rules for Classification [14] shall be selected for ship-to-ship transfer to the FSRU. When a LNGC vessel is tethered alongside the FSRU while they transfer their LNG cargo, a ship-to-ship link shall be established (i.e. via electrical connection and/or fibre optic connection).			

LOC of NG at MLA	• Small (10mm)
	  ◦ Corrosion
	  ◦ Fatigue or defective material
	  ◦ Flange leak
	• Medium (25mm)
	  ◦ Leak from small-bore fitting
	• Medium – Large (50mm)
	  ◦ Overpressure
	  ◦ Dropped object or other impact
	• Large (100mm)
	  ◦ Dropped object or other impact
	  ◦ Excessive vessel movement
		• Engineering design to relevant codes and standards
		• Inspection and maintenance
		• Operating procedures and permit to work
		• Overpressure protection on FSRU including HIPPS on HP export header (overpressure)
		• Mooring system designed for site conditions with ongoing mooring line load monitoring and maintenance (excessive vessel movement)
		• Position switch on MLA with pre alarm, ESD 1 (Isolation + blowdown), ESD 2 (Disconnection) functionality. ESD 1 & 2 on one MLA will trigger the same on the other MLA (excessive vessel movement)
			• Unignited gas release	• Point gas detector installed at MLAs (PKGT-LOG-ORF-SAF-LAD-0001).

			• Immediate ignition of gas release resulting in flash fire or jet fire	• Refer gas detection for unignited release. • Ignition controls including hazardous area classification and certified equipment • Elevated IR flame detectors are installed at MLAs (PKGT-LOG-ORF-SAF-LAD-0001). • Active fire protection including tower mounted fire water monitors and hydrant system. Noting, FRNSW is the statutory firefighting authority for the PKGT ORF.

LOC of NG at ORF and PKP tie-in	• Small (10mm)
	  ◦ Corrosion
	  ◦ Fatigue or defective material
	  ◦ Flange leak
	• Medium (25mm)
	  ◦ Leak from small-bore fitting
	• Medium – Large (50mm)
	  ◦ Overpressure
	  ◦ Dropped object or other impact
	• Large (100mm)
	  ◦ Dropped object or other impact (vehicle collision)
		• Engineering design to relevant codes and standards
		• Inspection and maintenance
		• Operating procedures and permit to work
		• Overpressure protection on FSRU including HIPPS on HP export header (overpressure)
		• Security Fencing and Signage
		• Access Controls
		• Passive fire protection provided to above ground section of PKP
			• Unignited gas release	• Acoustic, line-of-sight (open path) and point gas detectors installed (PKGT-LOG-ORF-SAF-LAD-0001).

			• Immediate ignition of gas release resulting in flash fire or jet fire	• Refer gas detection for unignited release. • Ignition controls including hazardous area classification and certified equipment • Elevated IR flame detectors are installed at MLAs (PKGT-LOG-ORF-SAF-LAD-0001). • Active fire protection including tower mounted fire water monitors and hydrant system. Noting, FRNSW is the statutory firefighting authority for the PKGT ORF.

LOC of Spotleak1005 at Odourant Storage and Injection	• Small (10mm)
	  ◦ Corrosion
	  ◦ Fatigue or defective material
	  ◦ Flange leak
	• Medium (25mm)
	  ◦ Leak from small-bore fitting
	  ◦ Tubing failure
		• Engineering design to relevant codes and standards
		• Inspection and maintenance
		• Operating procedures and permit to work for SBC changeout
		• Injection system expansion provided with overpressure protection (PSVs)
		• Spills contained within shipping container
		• Security Fencing and Signage
		• Access Controls
			• Unignited gas release and toxic dispersion (during normal operations)	• Activated carbon filter system
				• Operating procedures for container entry
				• Emergency response procedures and provision of breathing apparatus

			• Unignited gas release and toxic dispersion (during tank loading while container doors opened)	• Operating procedures forcontainer entry Emergency response procedures and provision of breathing apparatus available
			• Immediate ignition of release resulting in flash fire, jet/spray fire or delayed ignition of liquid release resulting in pool fire	• Activated carbon filter system • Ignition controls – all equipment including control panel will be ExD rated suitable for Zone 1 • Heat detection cable installed inside container and supplied by vendor with alarm
			• Delayed ignition of odourant release within container resulting in explosion	• Activated carbon filter system • Ignition controls – all equipment including control panel will be ExD rated suitable for Zone 1

LOC of diesel at ORF	• Small (10mm)
	  ◦ Corrosion
	  ◦ Fatigue or defective material
	  ◦ Flange leak
	• Medium (25mm)
	  ◦ Leak from small-bore fitting
		• Engineering design to relevant codes and standards (i.e. AS 1940)
		• Double skinned diesel day tanks
		• Inspection and maintenance
			• Unignited liquid release (environmental incident) or immediate ignition of diesel (above its flash point) resulting in spray fire or delayed ignition of liquid release resulting in pool fire. Diesel is not a flammable material per AS 1940, the storage and process conditions are below this.	• Diesel storage and fie water pumps are segregated from main process area
				• Ignition controls including hazardous area classification and certified equipment

LOC of NG from PKP Segment 1.1	• Small (20mm)
	  ◦ Corrosion or erosion
	  ◦ Fatigue or defective material
	  ◦ Stress cracking
	• Medium (50mm) or Large (100mm)
	  ◦ Auger or excavation activities
		• Engineering design to relevant codes and standards (incl. materials of construction, coatings and depth of cover)
		• Inspection and maintenance
		• Pipeline patrolling
		• "Dial before you dig" registered pipeline
			• Unignited gas release	• Jemena Pipeline Safety Management Study concluded that no unusual threats that cannot be controlled through the current design process were identified. The Pipeline Safety Management Study has been reviewed by NSW Department of Planning and Environment and confirmed the study was conducted appropriately by all relevant stakeholders, in line with the requirements of AS 2885.

			• Immediate ignition of gas release resulting in flash fire or jet fire	

Facility / Event	Cause	Preventative Controls	Possible Consequence	Mitigation Measures
Weather / natural events	• Extreme weather (storms, high winds, rain or fog) • Lightning • Earthquake	• Vessels and ORF Engineering design to relevant codes and standards • FSRU mooring design for weather and tidal movements in Port Kembla • Warning protocols and ship movement procedures • Navigational aids • Tug support and piloted vessels • Position switch on MLA with pre alarm, ESD 1 (Isolation + blowdown), ESD 2 (Disconnection) functionality. ESD 1 & 2 on one MLA will trigger the same on the other MLA (excessive vessel movement) • Lightning protection including earthing / grounding • Surge protection on MLA electrical equipment and instruments • Stormwater drainage system	• Injury to ship crew and operators • Reduced visibility during LNGC transit causing ship collision and LOC of LNG (refer consequence above) • LOC of hazardous materials (refer consequence above)	• Ignition controls including hazardous area classification and certified equipment • Emergency response plans

Appendix B. Hazard Analysis Team

Andrew Fergusson, Managing Consultant Safety & Risk ANZ

Andrew has over twenty years of engineering experience in process safety, process design, process plant operation and commissioning in the onshore gas processing and liquification, hydrogen, steelmaking, mining, minerals processing, pulp and paper and waste water treatment industries. This experience includes technical and supervisory roles. As the Managing Consultant Safety and Risk ANZ, Andrew, manages the ANZ Safety and Risk team and provides consulting services to projects. His in-depth knowledge of flammable and toxic hazards, the associated consequences and industry best practice safeguards ensure risks are reduced to ALARP. Andrew is an accomplished workshop facilitator with formal qualifications in HAZOP and SIL Determination.

Donald Law, Principal Consultant Safety & Risk

Donald has more than fifteen years of experience in safety and risk and reliability engineering for offshore and onshore hydrogen, mineral, oil and gas industries. Engineering experience includes fire and gas consequence analysis, quantitative risk assessment, production availability assessment, ALARP demonstration and safety case development. Donald's attention to detail and in-depth knowledge of modelling applications provides accurate and efficient outcomes.

Alice Stembridge, Consultant Safety & Risk

Alice has over seven years of safety and risk engineering experience as well as additional various subsurface, process and operations experience within the New Zealand and Australian oil, gas and energy sectors. She is proficient in identifying and quantifying impacts associated with flammable and toxic hazards including (but not limited to) gas, condensates, liquid fuels, LNG, hydrogen, methanol, H_2S, ammonia and chlorine as well as providing assessment of protection and mitigation systems to ensure safer design and that risks identified are ALARP.

Appendix C. Surrounding Land Users Population Data

Key surrounding land users are presented in Figure C-1.

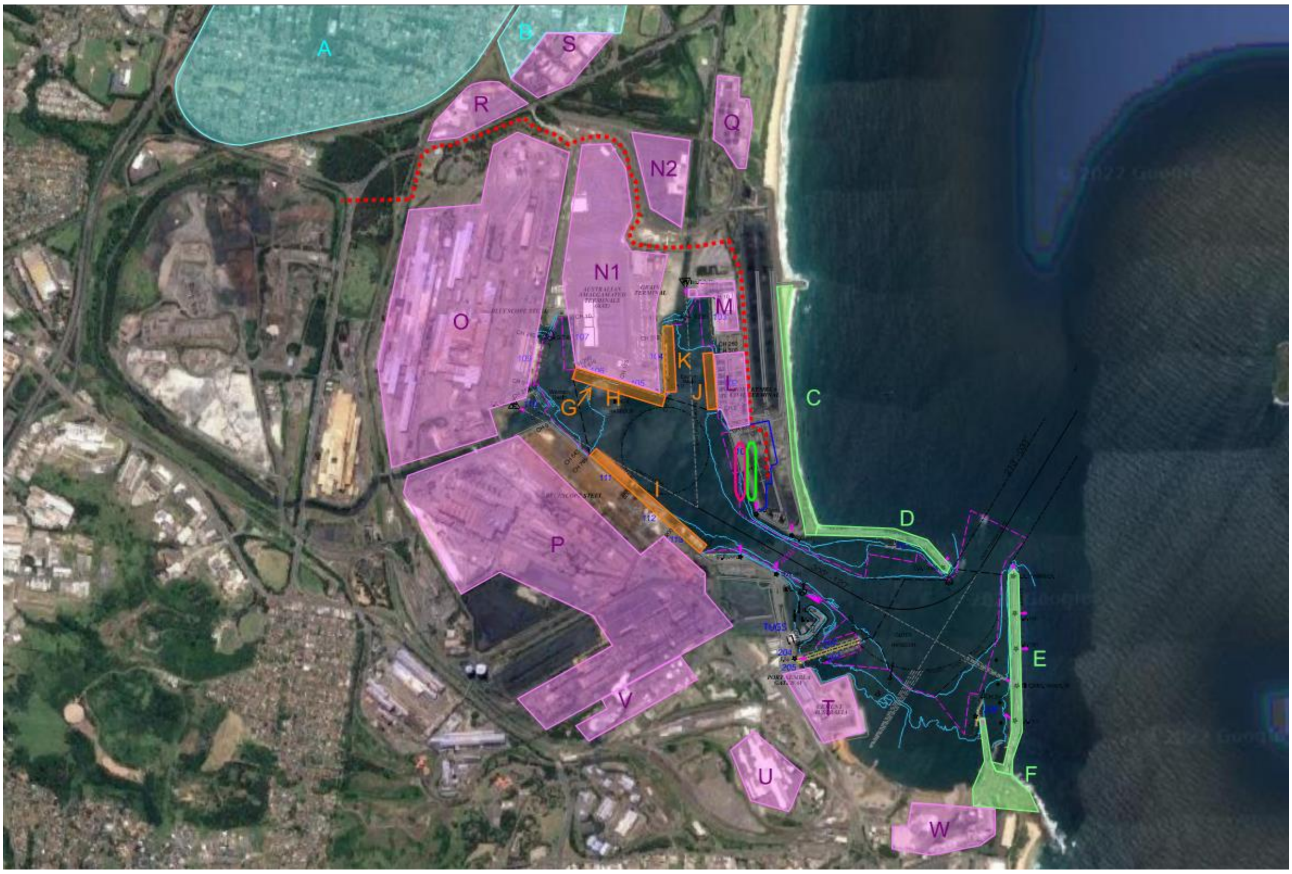


Figure C-1: PKGT Surrounding Land Users

Where available, population data has been sourced specifically for that location. However, in the absence of this data, the following assumptions have been made:

- For industrial sites guidance from the TNO 'Green Book' [65] has been applied. In particular, the 'low density industrial' population density of 5 people per hectare.
- Roll-on Roll-off (RoRo) carriers are assumed to have a maximum crew size of 40 people [66].
- All other bulk carriers are assumed to have a maximum crew size of 25 people [67].
- BlueScope steel (i.e. locations O and P) are known to employee in excess of 3000 people in the Illawarra region [68]. Therefore, the number of industrial workers for these locations estimated using the TNO 'Green Book' [65] have been increased.
- Populations for recreational areas have been estimated based on the specific to the type of activities being carried out per the guidance from the TNO 'Green Book' [65].

In most cases guidance from the TNO 'purple book' [61] has been applied to determine the fraction of the population that will be indoors during a given time. However, for the various Port Kembla berths and associated industrial facilities, assumptions based on the type of activity undertaken has been applied. It is assumed 80% of the population will be indoors. The societal risk calculations consider that persons located indoors (located in buildings or vehicles) may be afforded protection from loss of containment events.

Table C-1: PKGT Surrounding Land Users Population Data

Name / Description		Daytime		Night-time		Source
		No. People	Fraction indoors	No. People	Fraction indoors	
A	Wollongong – West Note 1	11586	0.93	16551	0.99	[69]
B	Wollongong - East Note 1	11214	0.93	16020	0.99	[69]
C	Seawall Road	10	0	0	0	-
D	Northern Breakwater	10	0	0	0	-
E	Eastern Breakwater	10	0	0	0	-
F	Boat Ramp Area	70	0	0	0	-
G	Berth 106 (Cruise Ship)	5000	0.8	5000	0.9	[21]
H	Berths 105&106 (RoRo)	80	0.93	80	0.99	[65]
I	Berths 111&112&113 (Steel Carrier)	75	0.93	75	0.99	[67]
J	Berth 102 (Coal Carrier)	25	0.93	25	0.99	[67]
K	Berth 104 (Grain Carrier)	25	0.93	25	0.99	[67]
L	Port Kembla Coal Terminal	60	0.8	12	0.8	[20]
M	Koch Fertiliser Terminal	20	0.8	4	0.8	[65]
N1	Australian Amalgamated Terminals + GrainCorp Terminal	376	0.8	75	0.8	[65]
N2	Australian Amalgamated Terminals	30	0.8	6	0.8	[65]
O	BlueScope Steel North River	1000	0.8	200	0.8	[65]
P	BlueScope Steel South River	1000	0.8	200	0.8	[65]
Q	Wollongong Water Recycling Facility	8	0.8	2	0.8	[70]
R	Various Industrial Buildings	35	0.93	0	0	[65]
S	Various Industrial Buildings	55	0.93	0	0	[65]
T	Cement Australia + Port Kembla Gateway	50	0.8	14	0.8	[65]
U	BlueScope Commonwealth Rolling Mills (CRM)	60	0.8	0	0	[65]
V	Various Industrial Buildings	25	0.93	0	0	[65]
W	Various Industrial Buildings	35	0.93	0	0	[65]

Appendix D. AIE Risk Matrix

AIE Risk Matrix

	Minor	Moderate	Severe	Major	Catastrophic
Almost Certain	Significant	High	Extreme	Extreme	Extreme
Likely	Moderate	Significant	High	Extreme	Extreme
Possible	Moderate	Moderate	Significant	High	Extreme
Unlikely	Low	Moderate	Moderate	Significant	High
Rare	Low	Low	Moderate	Moderate	Significant

Almost Certain	>1E-02 per annum
Likely	<1E-02 to 1E-03 per annum
Possible	<1E-03 to 1E-04 per annum
Unlikely	<1E-04 to 1E-05 per annum
Rare	<1E-05 per annum

Consequence Description	**Minor**	**Moderate**	**Severe**	**Major**	**Catastrophic**
Injury / Illness	First Air case or less	Minor injury requiring medical attention	Work related illness of injury with lost time OR restricted work >7 days	Single fatality Permanent disabling injury Irreversible health effect from work related illness	Multiple fatalities
Environment	Minimal impact localised to point source. Immediate recovery	Impact within site boundary. Recovery within 1 month.	Impact with site boundary with possible wider effect. Recovery within 1 year.	Significant harm with off-site impact. Recovery >1 year	Significant harm with off-site impact with limited prospect of full recovery.
Financial	<$100k	$100k - <$1M	$1M - <$10M	$10M - <$50M	$50M plus
Project Delivery / Schedule	<2 week delay	2 weeks - 1 month delay	1 month = 3 month delay	3 month - 6 month delay	>6 month delay
Reputation / Brand / Product Quality	Negligible impact	Issue identified and managed locally. <5 customers /community members affected	Widespread complaints with local impact. >5 customers / community members affected	Widespread complaints with state-wide impact	Community outrage, government action, "parent company" impact
Operations	Flow rate decreased for <24 hours	Flow rate decreased for <48 hours	Flow rate decreased for <72 hours	No flow for <1 day	No flow for >1 day
Regulatory and Compliance	Regulatory interest resolved through normal business processes. No PIN.	PIN issued or breach with litigation, prosecution, fines per financial category	Breach with litigation, prosecution, fines per financial category	Breach with litigation, prosecution, fines per financial category	Breach with litigation, prosecution, fines per financial category

Appendix E. Extract from HAZID Study

Extracts from PKGT Project HAZID Study Report (Doc No. PKGT-WOR-ORF-SAF-RPT-0003) - Top 5 'High' Risk Ranked Hazards

Node 2: LNGC Unloading

Hazard Category & Guideword	Hazardous Event Description	Potential Consequences	Effective Safeguards	Consequence	Likelihood	Risk	Actions	Comments
2. Process Hazards - Ignited Release / Fire / Smoke	1. LNG release during transfer	1. Release of low pressure LNG with potential for pool fire, or flash fire	1. Fire & gas systems (line of sight gas detection and IR flame detection 2. Ignition Controls - Hazardous Area Classification and certified equipment 3. Fire Protection on FSRU and LNGC 4. ESD systems, with ESD link between LNGC and FSRU, tested prior to each transfer.	Catastrophic	Unlikely	**High**		1. Reference: PKGT FEED HAZID 1.14.1
	5. Vessel movement during transfer.	1. Excessive stressing of hoses, leading to failure, and LOC	1. Weather window for transfer operations. 2. Load monitoring on mooring lines, with tension indication and local alarm on both FSRU and LNGC side. 3. Proximity sensors for ship position, with emergency disconnect function (double ball valve).	Catastrophic	Unlikely	**High**		
3. Process Hazards - Explosions / Pressurised Release	1. Mixing of dissimilar cargoes in tanks during transfer if required	1. Rollover/ excessive vapourisation leading to overpressurisation of cargo tanks and LOC	1. Procedures 2. Cargo tank, temperature and density monitoring throughout tank 3. Ability to transfer old cargo to cargo tank 1 which can be top and bottom filled to suppress vapour generation 4. Relief valves on cargo tanks	Catastrophic	Unlikely	**High**		

Node 5: Gas Unloading (FRSU to Shore via MLA)

Hazard Category & Guideword	Hazardous Event Description	Potential Consequences	Effective Safeguards	Consequence	Likelihood	Risk	Actions	Comments
22. Working Environment / Operational Hazards - Dropped Objects	1. Cranes for maintenance of the MLAs	1. Potential crane boom impact with MLA, or dropped object on process leading to LOC	1. Crane access from north and south to prevent need to lift over live equipment 2. Permit to work 3. Trained crane operators and riggers 4. Certified lifting equipment	Catastrophic	Unlikely	**High**		
	2. Crane lifts for FSRU maintenance (north of MLAs near fire water monitor)	1. Potential crane boom impact with MLA, or dropped object on process leading to LOC	1. Certified lifting equipment 2. Trained crane operators and riggers 3. Permit to work 4. Cranes can slew across fire water monitor away from MLA area	Catastrophic	Unlikely	**High**		

Worley energy | chemicals | resources

Extracts from PKGT Project HAZID Study Report (Doc No. PKGT-WOR-ORF-SAF-RPT-0003) - Top 5 'Significant' Risk Ranked Hazards

Node 1: LNGC Passage through Outer and Inner Harbour, Berthing and De-berthing

Hazard Category & Guideword	Hazardous Event Description	Potential Consequences	Effective Safeguards	Consequence	Likelihood	Risk	Actions	Comments
2. Process Hazards - Ignited Release / Fire / Smoke	1. Vessel collision (including collision with FSRU during berthing). Note, tight turning circle in inner harbour. Note, Port Kembla harbour already operates with vessels of similar size to the LNGC, refer Harbour Master Directions.	1. Breach of hull / cargo tank with release of LNG to water with potential for ignition	1. Only 1 vessel traversing the inner harbour at a time	Catastrophic	Rare	**Significant**	2. Develop emergency response plan for LNGC vessel collision in harbour which may result in release of LNG or diesel	
			2. Speed limits within harbour limit impact energy below that which could cause breach					
			3. Vessel traffic control (pilot and tugs, with specific training for management of LNGC)					
			4. Vessel design as per standards and class body (ballast tank outboard of LNG cargo tanks)					
			5. Full bridge simulation of LNGC entering, turning and berthing					
			6. Tugs fitted with FW facilities					
			7. Vessel movements through harbour during daylight hours					
28. Natural Hazards - Extreme weather (Temperature, Wind, Waves)	2. Fog	1. Reduced visibility causing collision with other ships leading to LOC fire / explosion	1. SOPs (visibility requirements under direction of Harbour Master)	Catastrophic	Rare	**Significant**		1. Reference: PKGT FEED HAZID 1.1.2 & 2.1.2
			2. Navigational aids					2. Initially there will be two pilots per vessel and more stringent weather restrictions implemented. Subject to review once operations commence.
			3. Collision avoidance systems					
			4. Warning protocols & ship movement procedures					
			5. Tug support					
			6. Piloted vessels					
			7. Exclusion zone					

Node 3: FSRU Process Operations (Storage, Regassification and Sendout)

Hazard Category & Guideword	Hazardous Event Description	Potential Consequences	Effective Safeguards	Consequence	Likelihood	Risk	Actions	Comments
2. Process Hazards - Ignited Release / Fire / Smoke	1. LNG or NG release (generic)	1. Potential fire leading to injury or fatality	1. Regular maintenance and inspection	Major	Unlikely	**Significant**		
			2. Fire and gas detection with automatic shutdown / isolation					
			3. Firefighting system (dry chemical powder, water spray and fire hydrant system)					
			4. Shore based monitor system can provide cooling to exposed equipment on FSRU					
			5. Emergency procedures					
			6. PPE					
			7. Cryogenic spill protection					
			8. Hazardous area rating and control of ignition sources					
3. Process Hazards - Explosions / Pressurised Release	1. LNG or natural gas leakage close to air intakes (e.g. forward pump room and bosun store)	1. Potential for flammable gas ingress to non-hazardous area. Potential for explosion due to confinement.	1. Gas detection on air intakes will close air inlet dampers	Catastrophic	Rare	**Significant**		1. Reference: Regassification System HAZID 2.5.1.4
								2. Note Regassification System HAZID risk ranked (L:S:R = 2:5:M) using a different risk matrix
								3. Action "Complete hazardous area drawings considering requirements

Node 3: FSRU Process Operations (Storage, Regassification and Sendout)

Hazard Category & Guideword	Hazardous Event Description	Potential Consequences	Effective Safeguards	Consequence	Likelihood	Risk	Actions	Comments
								for safe distance between hazardous area and air intake" raised in the Regasification System HAZID
	3. Ignition of flammable vapour in regas module area	1. Potential vapour cloud explosion due to area congestion	1. Open, well ventilated area 2. Grating of intermediate decks within module 3. Physical separation between regas modules and accommodation / bridge area	Catastrophic	Rare	**Significant**		
	4. Flammable release within cargo machinery room	1. Explosion	1. Zone 1 hazardous area rating within compressor room 2. High rate of mechanical ventilation	Catastrophic	Rare	**Significant**	25. Confirm gas detection provisions for FSRU compressor room (e.g. in room and in air intakes) and required system response (e.g. shutdown of air handling system or increase of ventilation rate)	

Appendix F. Consequence Results Summary

F.1 Release Rate Modelling and Flash Fire

Table F - 1 presents initial release rates, and the release rate after five minutes after detection and isolation for the operating conditions presented in Table 6-2 of Section 6. Five minutes is selected as this is the time to fail a steel beam, pipe or process vessel by direct jet fire impingement [40]. The total release duration is estimated based on the release rate at five minutes post release taking account of process response time of 60 seconds. Both on board the FSRU and at the ORF, response times for F&G detection devices will be short (i.e. typically less than 10 seconds). The total time for detection, isolation, and initiation of depressurisation (where provided) is expected to be completed within 60 seconds. This time is dominated by the time for valves reach their safe state i.e. closed for isolation valve and open for blowdown valves.

Worst case maximum downwind distances for flammable dispersion at the LFL concentration are reported at 1 m above grade at ORF or sea level and also at 14 m above grade at FSRU. Noting worst case results are selected from all release directions (vertical up, vertical down, and horizontal) and weather conditions modelled. In the table, where an isolatable inventory is expected to deplete in less than five minutes, this is indicated by "-". Where downwind effects are not reached at the reporting height, they are documented as "NR" ("Not Reached").

Table F - 1: Release Rate and Flammable Dispersion (Flash Fire) Results

Release Scenario	Hole Size (mm)	Release Rate (kg/s)		Release Duration (s) after isolation	Max Downwind Dist. to LFL (m)	
		Initial	5 Minutes		ORF / Sea	FSRU
Scenario 1: BOG from cargo tanks via vapour header to cargo machinery room (compressor suction conditions)	10mm	0.01	0.01	1608	NR	3.2
	25mm	0.06	0.01	257	NR	6.3
	50mm	0.25	-	64	NR	10.2
	100mm	1.01	-	16	NR	16.0
	FB	16.18	-	1	NR	45.5
Scenario 2: LNG from cargo tank via liquid header to regasification plant (including cargo spray main, and LNG loading headers)	10mm	1.1	0.1	>3600	NR	12.7
	25mm	6.8	0.5	>3600	62.0	18.9
	50mm	27.0	1.8	>3600	247.7	20.2
	100mm	72.0 Note 1	6.6	1607	398.0 Note 3	33.3
	FB	72.0 Note 1	13.7	402	270.0 Note 3	NR
Scenario 3: BOG from LD compressors in cargo machinery room for fuel gas or to BOG cooler for reliquefication (compressor discharge conditions)	10mm	0.1	0.1	>3600	NR	4.4
	25mm	0.5	0.3	979	NR	9.9
	50mm	1.9	0.02	245	NR	17.7
	100mm	7.7	-	61	NR	30.9
	FB	30.9	-	15	NR	52.2

Release Scenario	Hole Size (mm)	Release Rate (kg/s)		Release Duration (s) after isolation	Max Downwind Dist. to LFL (m)	
		Initial	5 Minutes		ORF / Sea	FSRU
Scenario 4: LNG from regasification booster pumps	10mm	5.1	0.03	>3600	NR	25.1
	25mm	31.6	0.2	1640.0	118.8	52.0
	50mm	72.0 Note 1	0.7	410.0	450.6	60.4
	100mm	72.0 Note 1	2.7	102.5	397.8 Note 3	33.2
	FB	72.0 Note 1	10.9	25.6	270.2 Note 3	NR
Scenario 5: NG from regasification plant to FSRU ESD Valve	10mm	2.1	0.7	900 Note 6	30.7	13.9
	25mm	13.2	3.6	900 Note 6	107.0	32.7
	50mm	52.8	7.1	682 Note 6	244.5	63.9
	100mm	211.3	1.7	269 Note 6	474.4	129.5
	FB	7605.0	-	38 Note 6	406.4	324.1
Scenario 6: NG from FSRU ESD Valve to ORF (up to SDV-064001 / SDV-064002) including MLA	10mm	2.1	1.0	2801	111.2	NR
	25mm	13.2	0.7	448	113.5	3.2
	50mm	52.8	-	112	178.5	5.1
	100mm	211.3	-	28	208.0	3.8
	FB	7605.0	-	1	185.6	3.7
Scenario 7: NG from ORF Pipework (from SDV-064001 / SDV-064002 to SDV-064007)	10mm	2.1	0.9	2310	111.2	NR
	25mm	13.2	0.4	370	101.0	3.2
	50mm	52.8	-	92	171.4	5.1
	100mm	211.3	-	23	193.7	3.8
	FB	3380.0	-	1	174.3	3.6
Scenario 8: NG from PKP (from SDV-064007 to MLV-064011) (~300m)	10mm	2.1	1.9	>3600	111.2	NR
	25mm	13.2	7.3	>3600	243.4	3.2
	50mm	52.8	8.7	963	245.5	5.1
	100mm	211.3	0.1	241	370.6	3.8
	FB	4278.0	-	12	395.7	359.0
Scenario 9a: Odourant storage & pipework Note 2	10mm	1.1	1.1	2323.0	6.9	NR
	25mm	6.7	6.4	372.7	10.4	NR
Scenario 10: LNG from Ship Collision	Minor Spill	8.6	NA Note 4	NA Note 4	81.7	NR
	Major Spill	33.7	NA Note 4	NA Note 4	266.1	NR

Release Scenario	Hole Size (mm)	Release Rate (kg/s)		Release Duration (s) after isolation	Max Downwind Dist. to LFL (m)	
		Initial	5 Minutes		ORF / Sea	FSRU
Scenario 11: LNG from Ship to Ship Loading Hose Failure	10mm	0.7	NA Note 5	NA Note 5	NR	1.4
	25mm	4.5	NA Note 5	NA Note 5	34.0	1.6
	50mm	17.8	NA Note 5	NA Note 5	128.5	1.6
	100mm	71.4	NA Note 5	NA Note 5	597.0	NR
	FB	446.0	NA Note 5	NA Note 5	1984.0	NR

Notes:

1. The liquid initial release rate has been limited by the pumped-in rate of 72 kg/s.
2. Scenario is only applicable during odourant SBC changeout (i.e. shipping container side fully open and accessible). During normal operation, LOC will occur within the shipping container which is provided with an activated carbon filter system. Results at the odourant injection conditions (i.e. Scenario 9b) are either very localised or not produced due to the low flow rates limited by the injection pump.
3. Same mass released through a larger hole size generates a gas plume with lower velocity thus lower momentum and shorter distance to reach its steady state.
4. Not applicable as there will be no isolation during a ship collision and subsequent LOC incident therefore release will continue until the tanker is emptied.
5. Liquid release from the system would stop instantaneously once loading hose emergency release couplings activated to isolate the inventory. Therefore release after five minutes is not considered in this study.
6. This inventory will be subject to blowdown once ESD has been activated. Blowdown is designed to take 15 minutes. However, depending on the hole size the inventory may be depleted via the leak hole itself in less time than the time to depressure the inventory.

F.2 Jet Fires

Table F - 2 presents the worst case maximum potential jet fire radiant heat impact distances at 1 m above grade at ORF or sea level while Table F - 3 presents worst case maximum potential jet fire radiant heat impact distances at 14 m above grade at FSRU Noting worst case results are selected from all release directions (vertical up, vertical down, and horizontal) and weather conditions modelled. Impacts based on initial release rate and the release rate after 5 minutes are shown. Jet fires emanating from the FSRU are not expected to directly impinge on any of the berth infrastructure. However, equipment and structures may initially be exposed to radiant heat levels of 23 kW/m^2. In the table, where an isolatable inventory is expected to deplete in less than five minutes, this is indicated by "-". Thermal radiation levels not reached at the reporting height are indicated by "NR".

Table F - 2: Worst Case Jet Fire Results reported at 1m above ORF grade level or sea level

Release Scenario	Hole Size	Initial Downwind Impact Distance (m)				5 Min Downwind Impact Distance (m)			
		Flame Length (m)	3 kW/m^2	4.7 kW/m^2	23 kW/m^2	Flame Length (m)	3 kW/m^2	4.7 kW/m^2	23 kW/m^2
Scenario 1: BOG from cargo tanks via vapour	10mm	2.4	NR	NR	NR	2.3	NR	NR	NR
	25mm	5.4	NR	NR	NR	3.0	NR	NR	NR

Release Scenario	Hole Size	Initial Downwind Impact Distance (m)				5 Min Downwind Impact Distance (m)			
		Flame Length (m)	3 kW/m²	4.7 kW/m²	23 kW/m²	Flame Length (m)	3 kW/m²	4.7 kW/m²	23 kW/m²
header to cargo machinery room (compressor suction conditions)	50mm	9.8	NR	NR	NR	-	-	-	-
	100mm	17.7	22.9	15.6	NR	-	-	-	-
	FB	57.7	101.9	91.5	63.9	-	-	-	-
Scenario 2: LNG from cargo tank via liquid header to regasification plant (including cargo spray main, and LNG loading headers)	10mm	19.9	26.5	18.9	NR	8.1	NR	NR	NR
	25mm	43.1	72.5	64.4	41.2	17.1	9.8	NR	NR
	50mm	76.9	139.5	125.5	89.6	29.9	41.9	35.9	NR
	100mm	119.5	220.6	197.6	138.2	34.5	50.1	44.0	NR
	FB	59.8	130.6	110.3	64.6	46.3	69.6	62.5	33.5
Scenario 3: BOG from LD compressors in cargo machinery room for fuel gas or to BOG cooler for reliquefication (compressor discharge conditions)	10mm	4.0	NR	NR	NR	3.9	NR	NR	NR
	25mm	10.2	NR	NR	NR	7.9	NR	NR	NR
	50mm	19.5	20.3	NR	NR	4.8	NR	NR	NR
	100mm	35.7	55.3	48.9	NR	-	-	-	-
	FB	59.8	105.9	93.8	61.7	-	-	-	-
Scenario 4: LNG from Regasification Booster Pumps	10mm	31.2	50.9	45.0	NR	5.6	NR	NR	NR
	25mm	68.8	122.5	110.6	79.9	11.2	NR	NR	NR
	50mm	105.3	194.6	175.6	128.9	11.2	NR	NR	NR
	100mm	119.4	220.5	197.5	138.1	11.6	NR	NR	NR
	FB	59.9	131.2	110.8	64.8	22.0	20.9	11.2	NR
Scenario 5: NG from regasification plant to FSRU ESD Valve	10mm	22.8	26.5	19.7	11.1	14.7	NR	NR	NR
	25mm	44.4	72.2	63.4	40.6	28.3	37.7	32.4	NR
	50mm	74.2	139.6	119.7	85.3	35.6	58.9	52.6	29.1
	100mm	129.3	267.2	228.5	159.9	21.2	31.0	25.1	NR
	FB	570.9	1392.0	1199.0	790.8	-	-	-	-
Scenario 6: NG from FSRU ESD Valve to ORF (up to SDV-064001 / SDV-064002) including MLA	10mm	22.8	35.1	31.4	25.0	16.5	20.9	20.0	17.8
	25mm	45.5	79.5	70.8	51.3	12.6	21.0	19.2	15.0
	50mm	81.3	147.4	131.0	91.0	-	-	-	-
	100mm	145.1	273.0	241.7	167.0	-	-	-	-
	FB	642.1	1394.0	1199.0	793.3	-	-	-	-

Release Scenario	Hole Size	Initial Downwind Impact Distance (m)				5 Min Downwind Impact Distance (m)			
		Flame Length (m)	3 kW/m²	4.7 kW/m²	23 kW/m²	Flame Length (m)	3 kW/m²	4.7 kW/m²	23 kW/m²
Scenario 7: NG from ORF Pipework (from SDV-064001 / SDV-064002 to SDV-064007)	10mm	22.8	35.1	31.4	25.0	15.6	19.7	18.8	16.8
	25mm	45.5	79.5	70.8	51.3	9.9	16.4	15.1	11.9
	50mm	81.3	147.4	131.0	91.0	-	-	-	-
	100mm	145.1	273.0	241.7	167.0	-	-	-	-
	FB	459.1	963.9	823.3	558.7	-	-	-	-
Scenario 8: NG from PKP (from SDV-064007 to MLV-064011) (~300m)	10mm	22.8	35.1	31.4	25.0	21.9	28.9	27.4	23.9
	25mm	45.5	79.5	70.8	51.3	36.1	55.4	48.9	41.2
	50mm	81.3	147.4	131.0	91.0	39.0	67.5	61.3	46.3
	100mm	145.1	273.0	241.7	167.0	9.3	14.1	12.9	10.3
	FB	506.2	1073.0	917.8	618.7	-	-	-	-
Scenario 9: Odourant storage & pipework Note 1	10mm	11.4	23.4	19.7	12.0	9.0	15.7	14.2	10.6
	25mm	24.5	54.4	45.1	24.9	16.6	29.8	26.8	19.5
Scenario 10: Ship Collision	Minor	51.9	88.5	79.4	56.3	No isolation during a ship collision and LoC incident therefore LoC incident will continue until the tanker is emptied.			
	Major	91.1	160.7	143.8	99.7				
Scenario 11: Ship to Ship Loading Hose Failure	10mm	17.5	8.7	NR	NR	-	-	-	-
	25mm	37.6	34.6	26.8	2.5	-	-	-	-
	50mm	67.0	69.8	56.4	27.9	-	-	-	-
	100mm	119.0	134.7	108.4	62.7	-	-	-	-
	1 x FB	173.3	320.2	255.8	130.8	-	-	-	-
	6 x FB	232.1	386.4	308.7	155.9	-	-	-	-

Table F - 3: Worst Case Jet Fire Results reported at FSRU level

Release Scenario	Hole Size	Initial Downwind Impact Distance (m)				5 Min Downwind Impact Distance (m)			
		Flame Length (m)	3 kW/m²	4.7 kW/m²	23 kW/m²	Flame Length (m)	3 kW/m²	4.7 kW/m²	23 kW/m²
Scenario 1: BOG from cargo tanks via vapour header to cargo machinery room (compressor suction conditions)	10mm	2.4	3.7	3.4	2.7	2.3	3.6	3.3	2.6
	25mm	5.4	8.6	7.9	6.2	3.0	4.3	4.0	2.6
	50mm	9.8	16.1	14.8	11.6	-	-	-	-
	100mm	17.7	30.2	27.6	21.5	-	-	-	-
	FB	57.7	105.0	95.5	73.2	-	-	-	-

Release Scenario	Hole Size	Initial Downwind Impact Distance (m)				5 Min Downwind Impact Distance (m)			
		Flame Length (m)	3 kW/m²	4.7 kW/m²	23 kW/m²	Flame Length (m)	3 kW/m²	4.7 kW/m²	23 kW/m²
Scenario 2: LNG from cargo tank via liquid header to regasification plant (including cargo spray main, and LNG loading headers)	10mm	19.9	33.9	31.0	23.8	17.1	26.6	24.5	18.9
	25mm	43.1	76.9	69.9	53.2	29.9	48.3	44.3	34.3
	50mm	76.9	142.5	129.2	97.6	34.5	56.0	51.4	39.8
	100mm	119.5	224.6	202.7	150.6	46.3	74.5	68.6	54.0
	FB	59.8	129.8	110.5	70.5	3.9	4.5	4.3	2.7
Scenario 3: BOG from LD compressors in cargo machinery room for fuel gas or to BOG cooler for reliquefication (compressor discharge conditions)	10mm	4.0	4.8	4.5	3.3	7.9	9.4	8.9	7.9
	25mm	10.2	12.7	12.0	10.5	4.8	5.3	5.3	NR
	50mm	19.5	26.8	25.1	21.2	10.6	11.6	11.6	11.6
	100mm	35.7	54.8	50.0	40.6	-	-	-	-
	FB	59.8	106.1	93.1	71.3	-	-	-	-
Scenario 4: LNG from Regasification Booster Pumps	10mm	31.2	54.7	49.9	38.9	5.6	7.7	7.2	4.9
	25mm	68.8	125.2	113.9	87.9	11.2	16.2	15.1	12.2
	50mm	105.3	197.4	179.0	136.4	11.2	15.9	14.8	12.2
	100mm	119.4	224.5	202.6	150.5	11.6	16.0	15.0	12.6
	FB	59.9	130.4	111.0	70.6	22.0	31.7	29.5	23.8
Scenario 5: NG from regasification plant to FSRU ESD Valve	10mm	22.8	30.4	28.8	25.0	35.6	62.6	57.1	44.5
	25mm	44.4	73.2	64.2	51.3	21.2	36.4	33.3	25.9
	50mm	74.2	140.2	121.4	87.8	72.8	134.5	121.9	92.4
	100mm	129.3	267.9	230.3	162.3	43.2	70.4	61.7	49.4
	FB	570.9	1394.0	1199.0	799.6	-	-	-	-
Scenario 6: NG from FSRU ESD Valve to ORF (up to SDV-064001 / SDV-064002) including MLA	10mm	22.8	32.0	27.5	10.7	16.5	14.3	NR	NR
	25mm	45.5	80.9	72.3	51.5	12.6	9.1	NR	NR
	50mm	81.3	150.1	134.2	97.5	-	-	-	-
	100mm	145.1	275.5	245.2	175.6	-	-	-	-
	FB	642.1	1395.0	1199.0	800.9	-	-	-	-
Scenario 7: NG from ORF Pipework (from SDV-064001 / SDV-064002 to SDV-064007)	10mm	22.8	32.0	27.5	10.7	15.6	11.0	NR	NR
	25mm	45.5	80.9	72.3	51.5	9.9	NR	NR	NR
	50mm	81.3	150.1	134.2	97.5	-	-	-	-
	100mm	145.1	275.5	245.2	175.6	-	-	-	-
	FB	459.1	964.9	825.0	566.4	-	-	-	-

Release Scenario	Hole Size	Initial Downwind Impact Distance (m)				5 Min Downwind Impact Distance (m)			
		Flame Length (m)	3 kW/m²	4.7 kW/m²	23 kW/m²	Flame Length (m)	3 kW/m²	4.7 kW/m²	23 kW/m²
Scenario 8: NG from PKP (from SDV-064007 to MLV-064011) (~300m)	10mm	22.8	32.0	27.5	10.7	21.9	25.6	21.8	NR
	25mm	45.5	80.9	72.3	51.5	36.1	52.6	48.0	34.8
	50mm	81.3	150.1	134.2	97.5	39.0	67.1	60.5	42.5
	100mm	145.1	275.5	245.2	175.6	9.3	NR	NR	NR
	FB	506.2	1075.0	918.4	626.4	-	-	-	-
Scenario 9: Odourant storage & pipework [Note 1]	10mm	11.4	21.8	17.9	10.1	9.0	NR	NR	NR
	25mm	24.5	54.1	45.2	26.2	16.6	25.2	20.3	NR
Scenario 10: Ship Collision	Minor	51.9	91.6	83.2	62.1	No isolation during a shop collision and LoC incident therefore LoC incident will continue until the tanker is emptied.			
	Major	91.1	165.1	149.3	111.6				
Scenario 11: Ship to Ship Loading Hose Failure	10mm	17.5	15.0	13.7	10.5	-	-	-	-
	25mm	37.6	35.1	30.8	23.0	-	-	-	-
	50mm	67.0	68.6	57.1	42.1	-	-	-	-
	100mm	119.0	133.7	107.1	75.9	-	-	-	-
	1 x FB	173.3	320.4	256.7	134.6	-	-	-	-
	6 x FB	232.1	386.8	310.3	159.5	-	-	-	-

Notes:

1. Scenario is only applicable during odourant SBC changeout (i.e. shipping container side fully open and accessible). During normal operation, LOC will occur within the shipping container. Results at the odourant injection conditions (i.e. Scenario 9b) are either very localised or not produced due to the low flow rates limited by the injection pump. In these circumstances, LOC likely to be high pressure natural gas (i.e. Scenario 7)

F.3 Pool Fires

Table F - 4 presents the worst case maximum potential pool fire radiant heat impact distances at 1m above grade at ORF or sea level while Table F - 5 presents worst case maximum potential pool fire radiant heat impact distances at 14 m above grade at FSRU. Noting worst case results are selected from all release directions (vertical up, vertical down, and horizontal) and weather conditions modelled. Thermal radiation levels not reached at the reporting height are indicated by "NR".

Table F - 4: Worst Case Pool Fire Results reported at 1m ORF grade level or sea level

Release Scenario	Hole Size	Downwind Impact Distance (m)			
		Pool Diameter (m)	3 kW/m²	4.7 kW/m²	23 kW/m²
Scenario 2: LNG from cargo tank via liquid header to regasification plant	10mm	2.3	NR	NR	NR
	25mm	8.4	46.7	37.8	NR
	50mm	17.9	103.8	86.4	41.2
	100mm	30.3	158.3	137.1	70.3
	FB	30.6	159.8	138.4	71.1
Scenario 4: LNG from Regasification Booster Pumps	10mm	Pool not formed			
	25mm				
	50mm				
	100mm	30.2	158.3	137.1	70.3
	FB	30.6	160.0	138.6	71.2
Scenario 9: Odourant storage & pipework Note 1	10mm	4.5	21.7	18.9	12.0
	25mm	11.3	49.8	42.4	25.3
Scenario 10: Ship Collision	Minor	6.8	48.8	42.1	25.3
	Major	13.4	102.5	87.7	51.1
Scenario 11: Ship to Ship Loading Hose Failure	10mm	Pool not formed			
	25mm				
	50mm	0.96	15.1	14.7	13.5
	100mm	15.6	126.1	106.2	54.3
	1 x FB	46.2	295.4	248.4	137.0

Table F - 5: Worst Case Pool Fire Results reported at FSRU level

Release Scenario	Hole Size	Downwind Impact Distance (m)			
		Pool Diameter (m)	3 kW/m²	4.7 kW/m²	23 kW/m²
Scenario 2: LNG from cargo tank via liquid header to regasification plant	10mm	2.3	8.6	7.4	4.4
	25mm	8.4	45.9	38.7	22.5
	50mm	17.9	99.6	83.5	47.6
	100mm	30.3	156.8	131.7	74.2
	FB	30.6	158.2	132.9	74.9
Scenario 4: LNG from Regasification Booster Pumps	10mm	Pool not formed			
	25mm				
	50mm				
	100mm	30.2	156.7	131.6	74.2
	FB	30.6	158.4	133.1	75.0
Scenario 9: Odourant storage & pipework Note 1	10mm	4.5	15.0	10.9	NR
	25mm	11.3	46.1	38.0	23.8
Scenario 10: Ship Collision	Minor	3.6	26.5	24.9	NR
	Major	10.2	90.5	77.9	51.0
Scenario 11: Ship to Ship Loading Hose Failure	10mm	Pool not formed			
	25mm				
	50mm	1.0	NR	NR	NR
	100mm	15.6	126.4	106.5	61.3
	1 x FB	46.2	295.0	248.8	140.4

Notes:

1. Scenario is only applicable during odourant SBC changeout (i.e. shipping container side fully open and accessible). During normal operation, LOC will occur within the shipping container. Results at the odourant injection conditions (i.e. dosing) are either very localised or not produced due to the low flow rates limited by the injection pump. In these circumstances, LOC likely to be high pressure natural gas (i.e. Scenario 7).

F.4 VCE Results

Table F - 6 presents the worst case VCE overpressure impacts reported at the level of the explosion.

Table F - 6: Worst Case VCE Overpressure Results

Area	Peak Overpressure (kPa)	Distance to Overpressure Level (m)				
		7 kPa	14 kPa	21 kPa	35 kPa	70 kPa
LNG Cargo Tank 1-4 Piping	51	52.7	28.9	20.8	12.9	-
Cargo Machinery Room	203	163.5	93.6	70.3	51.0	35.2
Suction Drum Module	51	83.5	45.7	32.9	20.4	-
Regasification Module – Bottom Half	101	138.5	79.3	59.6	43.3	26.3
Regasification Module – Top Half	51	176.2	96.6	69.4	43.1	-
Odourant Package Shipping Container	20	25.7	12.7	-	-	-

F.5 Odourant Toxic Dispersion

Table F - 7 shows the worst case toxic dispersion modelling results for a release of Spotleak1005 during SBC changeout of a Spotleak 1005 SBC. Noting worst case results are selected from all release directions (vertical up, vertical down, and horizontal) and weather conditions modelled. During normal operation, a LOC will occur within the shipping container which is provided with an activated carbon filter system and toxic dispersion is not expected. In addition, results at the odourant injection conditions (i.e. dosing) are either very localised or not produced due to the low flow rates as limited by the injection pump. Downwind distances were modelled at the assumed AEGL 1 (6 ppm) and AEGL 2 (900 ppm) concentrations for TBM. Toxic concentration levels not reached at the reporting height are indicated by "NR".

Table F - 7: Worst Case Toxic Dispersion Results

Release Scenario	Hole Size	Distance downwind to concentration (m) at ORF / sea level		Distance downwind to concentration (m) at FSRU level	
		6 ppm (AEGL 1)	900 ppm (AEGL 2)	6 ppm (AEGL 1)	900 ppm (AEGL 2)
Scenario 9: Odourant storage & pipework	10mm	2480.0	54.4	1561.0	NR
	25mm	2485.0	89.6	1530.0	NR

Appendix G. Port Kembla Wind Rose

The daytime and nighttime weather probability distributions are summarised in Table G - 1, Table G - 2, and Table G - 3 presents the weighted average distribution based on average night and daytime durations which were taken as 14 hours/day and 10 hours/day, respectively. Resultant wind roses are provided below.

Table G - 1: PKGT Daytime Weather Probability Distribution (fraction)

Weather ID	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NWW	Total
Calm	0.0153	0.0225	0.0218	0.0193	0.0188	0.0196	0.0118	0.0123	0.0118	0.0136	0.0146	0.0148	0.0079	0.0047	0.0048	0.0083	**0.2218**
Average	0.0216	0.0705	0.1042	0.0285	0.0109	0.0207	0.0583	0.0432	0.0545	0.0527	0.0457	0.0383	0.0176	0.0072	0.0059	0.0103	**0.5900**
Windy	0.0007	0.0066	0.0522	0.0010	0.0007	0.0020	0.0029	0.0005	0.0016	0.0033	0.0224	0.0179	0.0521	0.0193	0.0035	0.0017	**0.1882**

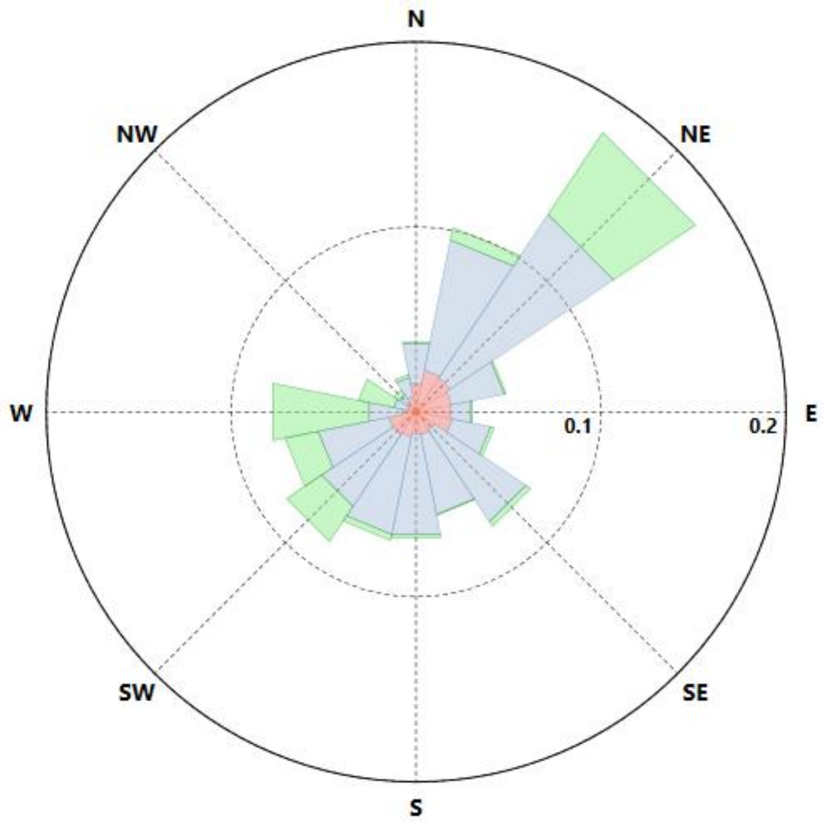
Table G - 2: PKGT Nighttime Weather Probability Distribution (fraction)

Weather ID	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NWW	Total
Calm	0.0293	0.0231	0.0116	0.0087	0.0068	0.0062	0.0070	0.0121	0.0157	0.0180	0.0484	0.1195	0.0299	0.0129	0.0119	0.0229	**0.3840**
Average	0.0385	0.0571	0.0210	0.0070	0.0047	0.0058	0.0126	0.0121	0.0221	0.0290	0.0701	0.0872	0.0643	0.0158	0.0135	0.0279	**0.4887**
Windy	0.0006	0.0082	0.0081	0.0008	0.0008	0.0021	0.0029	0.0010	0.0005	0.0010	0.0136	0.0149	0.0572	0.0127	0.0015	0.0012	**0.1273**

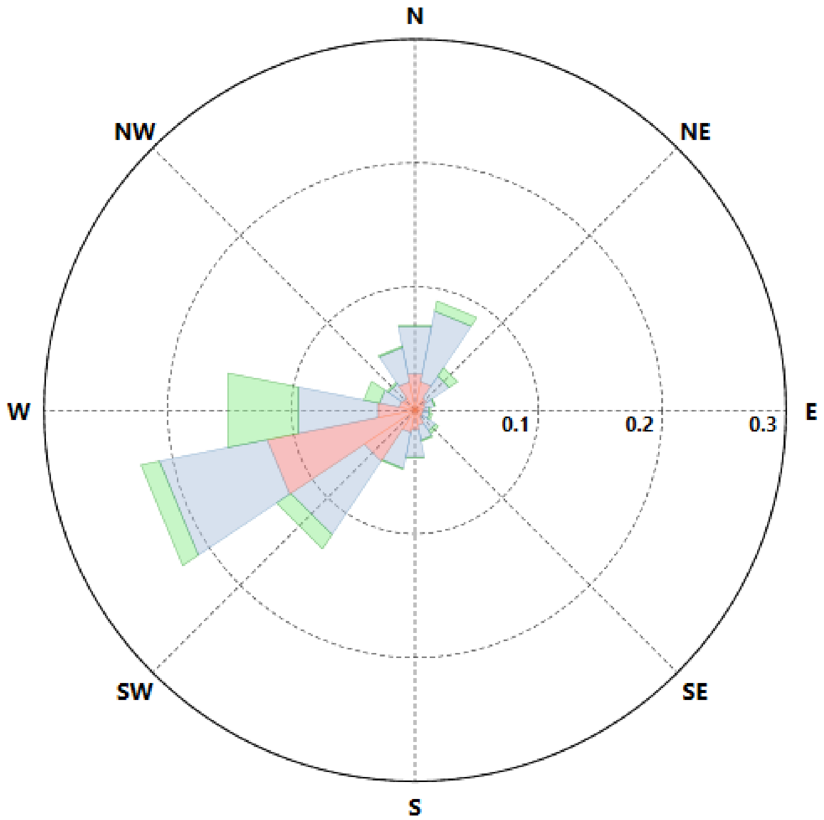
Table G - 3: PKGT Weighted Average Weather Probability Distribution (fraction) – used in FHA model

Weather ID	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NWW	Total
Calm	0.0211	0.0228	0.0176	0.0149	0.0138	0.0140	0.0098	0.0122	0.0134	0.0154	0.0287	0.0584	0.0171	0.0081	0.0078	0.0144	**0.2894**
Average	0.0286	0.0649	0.0695	0.0195	0.0083	0.0145	0.0393	0.0302	0.0410	0.0428	0.0559	0.0587	0.0371	0.0108	0.0091	0.0176	**0.5478**
Windy	0.0007	0.0073	0.0338	0.0009	0.0007	0.0020	0.0029	0.0007	0.0011	0.0023	0.0187	0.0167	0.0542	0.0166	0.0027	0.0015	**0.1628**

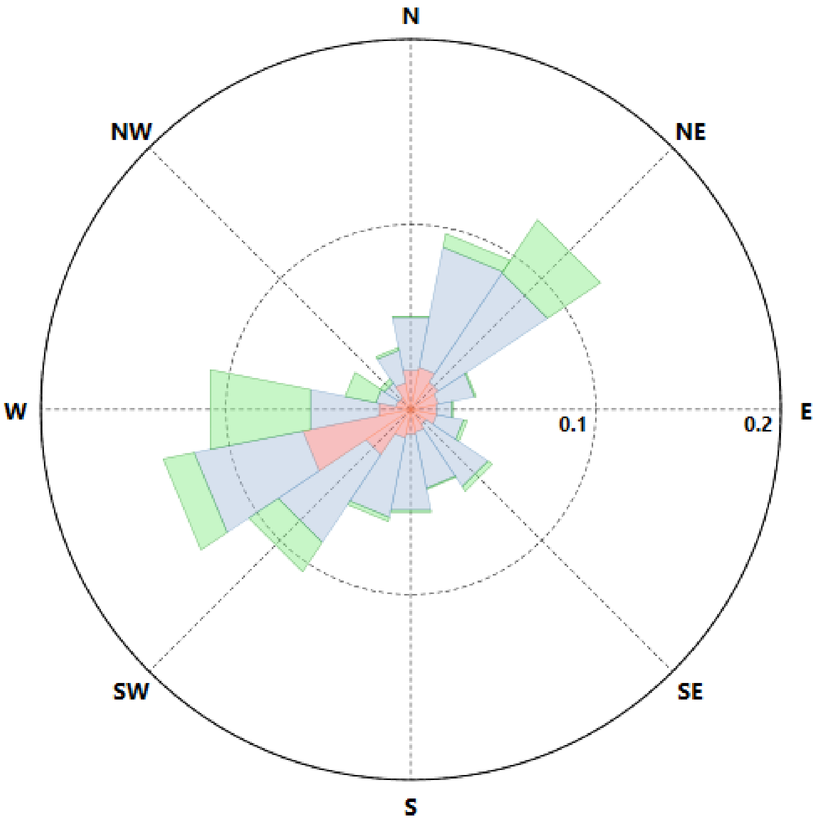
PKGT Daytime Wind Rose



PKGT Nighttime Wind Rose



PKGT Weighted Average Wind Rose



Appendix H. FHA Parts Count Sheets

Port Kembla Gas Terminal Project FHA Parts Count Sheets

QRA-01 No. 4 Tank (Incl tank instr & tank PSVs; Excl tank) [Dark blue]

				10mm	25mm	50mm	100mm	300mm
Component	**Diameter**	**Lookup**	**COUNT**	**1-15**	**15-40**	**40-60**	**60-165**	**RUPTURE**
INST	15	INST15	5	8.61E-04	1.34E-04	0.00E+00	0.00E+00	0.00E+00
FLANGE	25	FLANGE25	16	8.64E-05	8.82E-06	7.50E-06	0.00E+00	0.00E+00
MANVALVE	25	MANVALVE25	10	2.24E-04	3.24E-05	4.54E-05	0.00E+00	0.00E+00
ACTVALVE	250	ACTVALVE250	2	2.09E-04	2.19E-05	8.90E-06	9.02E-06	4.18E-06
MANVALVE	300	MANVALVE300	2	8.72E-05	1.09E-05	4.77E-06	5.64E-06	2.77E-06
FLANGE	300	FLANGE300	6	1.04E-04	8.48E-06	3.08E-06	2.86E-06	6.85E-06
PIPE				5.24E-04	7.23E-05	2.32E-05	5.84E-06	4.60E-06
TOTAL				**2.09E-03**	**2.89E-04**	**9.28E-05**	**2.34E-05**	**1.84E-05**

QRA-02 No. 4 Tank (To LNG Feed Header) [Red]

				10mm	25mm	50mm	100mm	200mm
Component	**Diameter**	**Lookup**	**COUNT**	**1-15**	**15-40**	**40-60**	**60-165**	**RUPTURE**
INST	15	INST15	2	3.44E-04	5.37E-05	0.00E+00	0.00E+00	0.00E+00
FLANGE	25	FLANGE25	6	3.24E-05	3.31E-06	2.81E-06	0.00E+00	0.00E+00
FLANGE	150	FLANGE150	3	3.02E-05	3.03E-06	1.20E-06	9.59E-07	1.67E-06
FLANGE	200	FLANGE200	6	7.35E-05	7.04E-06	2.74E-06	2.45E-06	4.35E-06
ACTVALVE	25	ACTVALVE25	1	2.26E-04	1.75E-05	1.31E-05	0.00E+00	0.00E+00
ACTVALVE	150	ACTVALVE150	1	1.17E-04	1.27E-05	5.20E-06	4.29E-06	3.60E-06
ACTVALVE	200	ACTVALVE200	3	3.04E-04	3.36E-05	1.40E-05	1.35E-05	8.41E-06
MANVALVE	25	MANVALVE25	7	1.57E-04	2.27E-05	3.18E-05	0.00E+00	0.00E+00
MANVALVE	200	MANVALVE200	2	6.06E-05	6.64E-06	2.74E-06	2.63E-06	1.56E-06
PIPE				4.48E-04	5.34E-05	2.45E-05	7.93E-06	6.53E-06
TOTAL				**1.79E-03**	**2.14E-04**	**9.81E-05**	**3.17E-05**	**2.61E-05**

QRA-03 No. 4 Tank (From Cargo Liquid header) [Yellow]

				10mm	25mm	50mm	100mm	400mm
Component	**Diameter**	**Lookup**	**COUNT**	**1-15**	**15-40**	**40-60**	**60-165**	**RUPTURE**
INST	15	INST15	2	3.44E-04	5.37E-05	0.00E+00	0.00E+00	0.00E+00
FLANGE	25	FLANGE25	5	2.70E-05	2.76E-06	2.34E-06	0.00E+00	0.00E+00
FLANGE	50	FLANGE50	1	6.33E-06	6.44E-07	2.58E-07	3.75E-07	0.00E+00
FLANGE	300	FLANGE300	6	1.04E-04	8.48E-06	3.08E-06	2.86E-06	6.85E-06
FLANGE	400	FLANGE400	3	6.77E-05	4.69E-06	1.59E-06	1.42E-06	4.76E-06
ACTVALVE	50	ACTVALVE50	1	2.03E-04	1.68E-05	6.17E-06	7.27E-06	0.00E+00
ACTVALVE	250	ACTVALVE250	4	4.18E-04	4.38E-05	1.78E-05	1.80E-05	8.37E-06
MANVALVE	25	MANVALVE25	8	1.79E-04	2.60E-05	3.63E-05	0.00E+00	0.00E+00
PIPE				4.50E-04	5.23E-05	2.25E-05	9.99E-06	6.66E-06
TOTAL				**1.80E-03**	**2.09E-04**	**9.01E-05**	**4.00E-05**	**2.66E-05**

QRA-04 No. 4 Tank (To Spray Main) [Green]

				10mm	25mm	50mm	65mm
Component	**Diameter**	**Lookup**	**COUNT**	**1-15**	**15-40**	**40-60**	**60-165**
INST	15	INST15	2	3.44E-04	5.37E-05	0.00E+00	0.00E+00
FILTER	40	FILTER40	1	1.67E-03	1.14E-04	7.73E-05	0.00E+00
FLANGE	25	FLANGE25	3	1.62E-05	1.65E-06	1.41E-06	0.00E+00
FLANGE	50	FLANGE50	12	7.60E-05	7.73E-06	3.09E-06	4.50E-06
FLANGE	80	FLANGE80	4	2.98E-05	3.02E-06	1.21E-06	2.11E-06
ACTVALVE	50	ACTVALVE50	4	8.14E-04	6.74E-05	2.47E-05	2.91E-05
ACTVALVE	80	ACTVALVE80	2	3.54E-04	3.18E-05	1.20E-05	1.53E-05
MANVALVE	25	MANVALVE25	4	8.96E-05	1.30E-05	1.82E-05	0.00E+00
MANVALVE	50	MANVALVE50	2	4.60E-05	6.29E-06	2.87E-06	5.35E-06
MANVALVE	80	MANVALVE80	1	2.37E-05	3.02E-06	1.34E-06	2.31E-06
PIPE				1.15E-03	1.00E-04	4.74E-05	1.95E-05
TOTAL				**4.62E-03**	**4.02E-04**	**1.89E-04**	**7.81E-05**

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QRA-05 No. 4 Tank (To Cargo Vapour Header) [Light Purple]

				10mm	25mm	50mm	100mm	400mm
Component	**Diameter**	**Lookup**	**COUNT**	**1-15**	**15-40**	**40-60**	**60-165**	**RUPTURE**
FLANGE	25	FLANGE25	10	5.40E-05	5.51E-06	4.69E-06	0.00E+00	0.00E+00
FLANGE	50	FLANGE50	2	1.27E-05	1.29E-06	5.16E-07	7.50E-07	0.00E+00
FLANGE	300	FLANGE300	1	1.73E-05	1.41E-06	5.13E-07	4.77E-07	1.14E-06
FLANGE	400	FLANGE400	5	1.13E-04	7.82E-06	2.65E-06	2.37E-06	7.94E-06
MANVALVE	25	MANVALVE25	6	1.34E-04	1.95E-05	2.72E-05	0.00E+00	0.00E+00
MANVALVE	50	MANVALVE50	2	4.60E-05	6.29E-06	2.87E-06	5.35E-06	0.00E+00
MANVALVE	300	MANVALVE300	1	4.36E-05	5.44E-06	2.38E-06	2.82E-06	1.39E-06
MANVALVE	400	MANVALVE400	2	1.11E-04	1.57E-05	7.29E-06	1.01E-05	4.67E-06
PIPE				1.77E-04	2.10E-05	1.60E-05	7.28E-06	5.04E-06
TOTAL				**7.09E-04**	**8.39E-05**	**6.42E-05**	**2.91E-05**	**2.02E-05**

QRA-06 Cargo Machinery (HD Comp Inlet) [Light Purple]

				10mm	25mm	50mm	100mm	700mm
Component	**Diameter**	**Lookup**	**COUNT**	**1-15**	**15-40**	**40-60**	**60-165**	**RUPTURE**
INST	15	INST15	6	1.03E-03	1.61E-04	0.00E+00	0.00E+00	0.00E+00
COMP(Centrif)	250	COMP(Centrif)250	1	4.88E-03	4.78E-04	1.88E-04	1.84E-04	7.00E-05
FILTER	300	FILTER300	2	3.34E-03	2.28E-04	7.67E-05	6.47E-05	1.33E-05
FLANGE	25	FLANGE25	8	4.32E-05	4.41E-06	3.75E-06	0.00E+00	0.00E+00
FLANGE	300	FLANGE300	4	6.93E-05	5.65E-06	2.05E-06	1.91E-06	4.57E-06
FLANGE	600	FLANGE600	4	1.13E-04	6.58E-06	2.07E-06	1.75E-06	8.33E-06
ACTVALVE	600	ACTVALVE600	2	2.40E-04	1.90E-05	6.82E-06	6.93E-06	8.02E-07
MANVALVE	25	MANVALVE25	4	8.96E-05	1.30E-05	1.82E-05	0.00E+00	0.00E+00
MANVALVE	400	MANVALVE400	1	5.53E-05	7.85E-06	3.65E-06	5.04E-06	2.33E-06
PIPE				3.29E-03	3.08E-04	1.00E-04	8.80E-05	3.31E-05
TOTAL				**1.32E-02**	**1.23E-03**	**4.02E-04**	**3.52E-04**	**1.32E-04**

QRA-07 Cargo Machinery (LNG Vaporizer Outlet) [Light Purple]

				10mm	25mm	50mm	100mm	600mm
Component	**Diameter**	**Lookup**	**COUNT**	**1-15**	**15-40**	**40-60**	**60-165**	**RUPTURE**
INST	15	INST15	2	3.44E-04	5.37E-05	0.00E+00	0.00E+00	0.00E+00
HX SHELL	400	HX SHELL400	0.5	6.64E-04	7.55E-05	3.17E-05	3.81E-05	1.10E-05
FLANGE	25	FLANGE25	5	2.70E-05	2.76E-06	2.34E-06	0.00E+00	0.00E+00
FLANGE	80	FLANGE80	1	7.45E-06	7.54E-07	3.01E-07	5.27E-07	0.00E+00
FLANGE	250	FLANGE250	1	1.48E-05	1.30E-06	4.91E-07	4.54E-07	9.29E-07
FLANGE	400	FLANGE400	5	1.13E-04	7.82E-06	2.65E-06	2.37E-06	7.94E-06
FLANGE	600	FLANGE600	1	2.84E-05	1.65E-06	5.17E-07	4.37E-07	2.08E-06
ACTVALVE	50	ACTVALVE50	1	2.03E-04	1.68E-05	6.17E-06	7.27E-06	0.00E+00
MANVALVE	25	MANVALVE25	2	4.48E-05	6.49E-06	9.08E-06	0.00E+00	0.00E+00
MANVALVE	400	MANVALVE400	1	5.53E-05	7.85E-06	3.65E-06	5.04E-06	2.33E-06
MANVALVE	600	MANVALVE600	1	6.57E-05	1.07E-05	5.29E-06	8.79E-06	3.73E-06
PIPE				5.23E-04	6.18E-05	2.07E-05	2.10E-05	9.33E-06
TOTAL				**2.09E-03**	**2.47E-04**	**8.30E-05**	**8.39E-05**	**3.73E-05**

QRA-08 Cargo Machinery (Forcing Vaporizer Outlet) [Light Purple]

				10mm	25mm	50mm	100mm	250mm
Component	**Diameter**	**Lookup**	**COUNT**	**1-15**	**15-40**	**40-60**	**60-165**	**RUPTURE**
INST	15	INST15	2	3.44E-04	5.37E-05	0.00E+00	0.00E+00	0.00E+00
HX SHELL	250	HX SHELL250	0.5	6.64E-04	7.55E-05	3.17E-05	3.36E-05	1.54E-05
FLANGE	25	FLANGE25	6	3.24E-05	3.31E-06	2.81E-06	0.00E+00	0.00E+00
FLANGE	250	FLANGE250	6	8.86E-05	7.83E-06	2.95E-06	2.73E-06	5.58E-06
ACTVALVE	25	ACTVALVE25	1	2.26E-04	1.75E-05	1.31E-05	0.00E+00	0.00E+00
MANVALVE	25	MANVALVE25	2	4.48E-05	6.49E-06	9.08E-06	0.00E+00	0.00E+00
MANVALVE	250	MANVALVE250	2	7.43E-05	8.68E-06	3.70E-06	3.98E-06	2.10E-06
PIPE				4.91E-04	5.77E-05	2.11E-05	1.35E-05	7.69E-06
TOTAL				**1.97E-03**	**2.31E-04**	**8.45E-05**	**5.38E-05**	**3.08E-05**

Port Kembla Gas Terminal Project FHA Parts Count Sheets

QRA-09 Cargo Machinery (Heaters Outlet) [Light Purple]

Component	Diameter	Lookup	COUNT	10mm 1-15	25mm 15-40	50mm 40-60	100mm 60-165	600mm RUPTURE
INST	15	INST15	2	3.44E-04	5.37E-05	0.00E+00	0.00E+00	0.00E+00
HX SHELL	400	HX SHELL400	1	1.33E-03	1.51E-04	6.35E-05	7.61E-05	2.19E-05
FLANGE	25	FLANGE25	10	5.40E-05	5.51E-06	4.69E-06	0.00E+00	0.00E+00
FLANGE	250	FLANGE250	4	5.91E-05	5.22E-06	1.96E-06	1.82E-06	3.72E-06
FLANGE	300	FLANGE300	2	3.47E-05	2.83E-06	1.03E-06	9.53E-07	2.28E-06
FLANGE	400	FLANGE400	8	1.81E-04	1.25E-05	4.24E-06	3.79E-06	1.27E-05
FLANGE	600	FLANGE600	1	2.84E-05	1.65E-06	5.17E-07	4.37E-07	2.08E-06
ACTVALVE	400	ACTVALVE400	2	2.28E-04	2.03E-05	7.65E-06	7.91E-06	1.82E-06
MANVALVE	25	MANVALVE25	4	8.96E-05	1.30E-05	1.82E-05	0.00E+00	0.00E+00
MANVALVE	400	MANVALVE400	1	5.53E-05	7.85E-06	3.65E-06	5.04E-06	2.33E-06
PIPE				8.00E-04	9.11E-05	3.51E-05	3.20E-05	1.56E-05
TOTAL				**3.20E-03**	**3.65E-04**	**1.40E-04**	**1.28E-04**	**6.25E-05**

QRA-10 Cargo Machinery (Mist Sep & LD Comp Inlet) [Light Purple]

Component	Diameter	Lookup	COUNT	10mm 1-15	25mm 15-40	50mm 40-60	100mm 60-165	300mm RUPTURE
INST	15	INST15	6	1.03E-03	1.61E-04	0.00E+00	0.00E+00	0.00E+00
COMP(Centrif)	250	COMP(Centrif)250	1	4.88E-03	4.78E-04	1.88E-04	1.84E-04	7.00E-05
VESSEL	300	VESSEL300	0.5	2.54E-04	3.23E-05	1.43E-05	1.70E-05	7.53E-06
FILTER	250	FILTER250	2	3.34E-03	2.28E-04	7.67E-05	6.21E-05	1.59E-05
FILTER	300	FILTER300	1	1.67E-03	1.14E-04	3.83E-05	3.23E-05	6.64E-06
FLANGE	25	FLANGE25	17	9.18E-05	9.37E-06	7.97E-06	0.00E+00	0.00E+00
FLANGE	250	FLANGE250	8	1.18E-04	1.04E-05	3.93E-06	3.63E-06	7.43E-06
FLANGE	300	FLANGE300	4	6.93E-05	5.65E-06	2.05E-06	1.91E-06	4.57E-06
ACTVALVE	25	ACTVALVE25	2	4.51E-04	3.50E-05	2.63E-05	0.00E+00	0.00E+00
ACTVALVE	250	ACTVALVE250	2	2.09E-04	2.19E-05	8.90E-06	9.02E-06	4.18E-06
MANVALVE	25	MANVALVE25	5	1.12E-04	1.62E-05	2.27E-05	0.00E+00	0.00E+00
MANVALVE	25	MANVALVE25		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MANVALVE	400	MANVALVE400		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PIPE				4.08E-03	3.70E-04	1.30E-04	1.03E-04	3.88E-05
TOTAL				**1.63E-02**	**1.48E-03**	**5.19E-04**	**4.13E-04**	**1.55E-04**

QRA-11 Cargo Machinery (HD Comp Outlet) [Orange]

Component	Diameter	Lookup	COUNT	10mm 1-15	25mm 15-40	50mm 40-60	100mm 60-165	600mm RUPTURE
INST	15	INST15	2	3.44E-04	5.37E-05	0.00E+00	0.00E+00	0.00E+00
COMP(Centrif)	250	COMP(Centrif)250	1	4.88E-03	4.78E-04	1.88E-04	1.84E-04	7.00E-05
FLANGE	25	FLANGE25	10	5.40E-05	5.51E-06	4.69E-06	0.00E+00	0.00E+00
FLANGE	250	FLANGE250	2	2.95E-05	2.61E-06	9.82E-07	9.09E-07	1.86E-06
FLANGE	450	FLANGE450	14	3.53E-04	2.26E-05	7.38E-06	6.40E-06	2.54E-05
ACTVALVE	250	ACTVALVE250	1	1.04E-04	1.10E-05	4.45E-06	4.51E-06	2.09E-06
ACTVALVE	300	ACTVALVE300	2	2.15E-04	2.14E-05	8.47E-06	8.78E-06	3.16E-06
MANVALVE	25	MANVALVE25	4	8.96E-05	1.30E-05	1.82E-05	0.00E+00	0.00E+00
MANVALVE	450	MANVALVE450	5	3.02E-04	4.57E-05	2.19E-05	3.24E-05	1.50E-05
MANVALVE	400	MANVALVE400		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PIPE				2.12E-03	2.18E-04	8.47E-05	7.89E-05	3.92E-05
TOTAL				**8.50E-03**	**8.71E-04**	**3.39E-04**	**3.16E-04**	**1.57E-04**

QRA-12 Cargo Machinery (Heaters Inlet) [Orange]

Component	Diameter	Lookup	COUNT	10mm 1-15	25mm 15-40	50mm 40-60	100mm 60-165	500mm RUPTURE
INST	15	INST15	2	3.44E-04	5.37E-05	0.00E+00	0.00E+00	0.00E+00
HX SHELL	250	HX SHELL250	1	1.33E-03	1.51E-04	6.35E-05	6.73E-05	3.08E-05
FLANGE	25	FLANGE25	8	4.32E-05	4.41E-06	3.75E-06	0.00E+00	0.00E+00
FLANGE	250	FLANGE250	2	2.95E-05	2.61E-06	9.82E-07	9.09E-07	1.86E-06
FLANGE	300	FLANGE300	10	1.73E-04	1.41E-05	5.13E-06	4.77E-06	1.14E-05
ACTVALVE	250	ACTVALVE250	2	2.09E-04	2.19E-05	8.90E-06	9.02E-06	4.18E-06
ACTVALVE	300	ACTVALVE300	4	4.30E-04	4.28E-05	1.69E-05	1.76E-05	6.33E-06
MANVALVE	25	MANVALVE25	4	8.96E-05	1.30E-05	1.82E-05	0.00E+00	0.00E+00
PIPE				8.82E-04	1.01E-04	3.91E-05	3.32E-05	1.82E-05
TOTAL				**3.53E-03**	**4.05E-04**	**1.56E-04**	**1.33E-04**	**7.28E-05**

Port Kembla Gas Terminal Project FHA Parts Count Sheets

QRA-13 Cargo Machinery (LD Comp Outlet to Aftercoolers) [Light Blue]

				10mm	25mm	50mm	100mm	200mm
Component	**Diameter**	**Lookup**	**COUNT**	**1-15**	**15-40**	**40-60**	**60-165**	**RUPTURE**
INST	15	INST15	6	1.03E-03	1.61E-04	0.00E+00	0.00E+00	0.00E+00
COMP(Centrif)	200	COMP(Centrif)200	1	4.88E-03	4.78E-04	1.88E-04	1.70E-04	8.37E-05
HX SHELL	200	HX SHELL200	1	1.33E-03	1.51E-04	6.35E-05	6.19E-05	3.61E-05
FLANGE	25	FLANGE25	22	1.19E-04	1.21E-05	1.03E-05	0.00E+00	0.00E+00
FLANGE	80	FLANGE80	9	6.70E-05	6.79E-06	2.71E-06	4.74E-06	0.00E+00
FLANGE	100	FLANGE100	2	1.64E-05	1.65E-06	6.60E-07	1.26E-06	0.00E+00
FLANGE	200	FLANGE200	12	1.47E-04	1.41E-05	5.49E-06	4.90E-06	8.70E-06
ACTVALVE	80	ACTVALVE80	2	3.54E-04	3.18E-05	1.20E-05	1.53E-05	0.00E+00
MANVALVE	25	MANVALVE25	12	2.69E-04	3.89E-05	5.45E-05	0.00E+00	0.00E+00
MANVALVE	80	MANVALVE80	2	4.73E-05	6.04E-06	2.67E-06	4.63E-06	0.00E+00
MANVALVE	100	MANVALVE100	1	2.41E-05	2.93E-06	1.27E-06	2.10E-06	0.00E+00
MANVALVE	200	MANVALVE200	6	1.82E-04	1.99E-05	8.23E-06	7.88E-06	4.67E-06
PIPE				2.82E-03	3.08E-04	1.16E-04	9.09E-05	4.44E-05
TOTAL				**1.13E-02**	**1.23E-03**	**4.66E-04**	**3.64E-04**	**1.78E-04**

QRA-14 Cargo Machinery (Aftercoolers to Engines) [Light Blue]

				10mm	25mm	50mm	100mm	300mm
Component	**Diameter**	**Lookup**	**COUNT**	**1-15**	**15-40**	**40-60**	**60-165**	**RUPTURE**
INST	15	INST15	4	6.89E-04	1.07E-04	0.00E+00	0.00E+00	0.00E+00
HX SHELL	250	HX SHELL250	1	1.33E-03	1.51E-04	6.35E-05	6.73E-05	3.08E-05
FLANGE	25	FLANGE25	17	9.18E-05	9.37E-06	7.97E-06	0.00E+00	0.00E+00
FLANGE	80	FLANGE80	5	3.72E-05	3.77E-06	1.51E-06	2.64E-06	0.00E+00
FLANGE	200	FLANGE200	18	2.21E-04	2.11E-05	8.23E-06	7.36E-06	1.30E-05
FLANGE	250	FLANGE250	4	5.91E-05	5.22E-06	1.96E-06	1.82E-06	3.72E-06
FLANGE	300	FLANGE300	4	6.93E-05	5.65E-06	2.05E-06	1.91E-06	4.57E-06
ACTVALVE	80	ACTVALVE80	2	3.54E-04	3.18E-05	1.20E-05	1.53E-05	0.00E+00
ACTVALVE	200	ACTVALVE200	6	6.08E-04	6.73E-05	2.80E-05	2.69E-05	1.68E-05
ACTVALVE	250	ACTVALVE250	4	4.18E-04	4.38E-05	1.78E-05	1.80E-05	8.37E-06
ACTVALVE	300	ACTVALVE300	1	1.08E-04	1.07E-05	4.24E-06	4.39E-06	1.58E-06
MANVALVE	25	MANVALVE25	8	1.79E-04	2.60E-05	3.63E-05	0.00E+00	0.00E+00
MANVALVE	80	MANVALVE80	1	2.37E-05	3.02E-06	1.34E-06	2.31E-06	0.00E+00
MANVALVE	200	MANVALVE200	2	6.06E-05	6.64E-06	2.74E-06	2.63E-06	1.56E-06
PIPE				1.41E-03	1.64E-04	6.25E-05	5.02E-05	2.68E-05
TOTAL				**5.66E-03**	**6.57E-04**	**2.50E-04**	**2.01E-04**	**1.07E-04**

QRA-15 Cargo Machinery (Spray to Vaporizers & Mist Sep) [Green]

				10mm	25mm	50mm	80mm
Component	**Diameter**	**Lookup**	**COUNT**	**1-15**	**15-40**	**40-60**	**RUPTURE**
INST	15	INST15	4	6.89E-04	1.07E-04	0.00E+00	0.00E+00
HX SHELL	40	HX SHELL40	1	1.33E-03	1.51E-04	1.62E-04	0.00E+00
FILTER	80	FILTER80	2	3.34E-03	2.28E-04	7.67E-05	7.80E-05
VESSEL	80	VESSEL80	0.5	2.54E-04	3.23E-05	1.43E-05	2.46E-05
FLANGE	25	FLANGE25	23	1.24E-04	1.27E-05	1.08E-05	0.00E+00
FLANGE	50	FLANGE50	21	1.33E-04	1.35E-05	5.42E-06	7.88E-06
ACTVALVE	25	ACTVALVE25	3	6.77E-04	5.25E-05	3.94E-05	0.00E+00
ACTVALVE	50	ACTVALVE50	6	1.22E-03	1.01E-04	3.70E-05	4.36E-05
MANVALVE	25	MANVALVE25	18	4.03E-04	5.84E-05	8.17E-05	0.00E+00
MANVALVE	50	MANVALVE50	5	1.15E-04	1.57E-05	7.18E-06	1.34E-05
MANVALVE	80	MANVALVE80	6	1.42E-04	1.81E-05	8.02E-06	1.39E-05
MANVALVE	400	MANVALVE400		0.00E+00	0.00E+00	0.00E+00	0.00E+00
PIPE				2.81E-03	2.63E-04	1.47E-04	6.04E-05
TOTAL				**1.12E-02**	**1.05E-03**	**5.89E-04**	**2.42E-04**

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QRA-16 Loading Arms (Gas Return) [Orange]

				10mm	25mm	50mm	100mm	400mm
Component	**Diameter**	**Lookup**	**COUNT**	**1-15**	**15-40**	**40-60**	**60-165**	**RUPTURE**
INST	15	INST15	1	1.72E-04	2.68E-05	0.00E+00	0.00E+00	0.00E+00
FILTER	400	FILTER400	1	1.67E-03	1.14E-04	3.83E-05	3.40E-05	5.00E-06
FLANGE	25	FLANGE25	8	4.32E-05	4.41E-06	3.75E-06	0.00E+00	0.00E+00
ACTVALVE	400	ACTVALVE400	1	1.14E-04	1.01E-05	3.83E-06	3.96E-06	9.09E-07
MANVALVE	25	MANVALVE25	5	1.12E-04	1.62E-05	2.27E-05	0.00E+00	0.00E+00
PIPE				7.03E-04	5.72E-05	2.29E-05	1.26E-05	1.97E-06
TOTAL				**2.81E-03**	**2.29E-04**	**9.15E-05**	**5.06E-05**	**7.87E-06**

QRA-17 Loading Arms (Cargo Liquid) [Yellow]

				10mm	25mm	50mm	100mm	450mm
Component	**Diameter**	**Lookup**	**COUNT**	**1-15**	**15-40**	**40-60**	**60-165**	**RUPTURE**
INST	15	INST15	4	6.89E-04	1.07E-04	0.00E+00	0.00E+00	0.00E+00
FILTER	400	FILTER400	4	6.68E-03	4.56E-04	1.53E-04	1.36E-04	2.00E-05
FLANGE	25	FLANGE25	4	2.16E-05	2.21E-06	1.87E-06	0.00E+00	0.00E+00
FLANGE	50	FLANGE50	8	5.06E-05	5.15E-06	2.06E-06	3.00E-06	0.00E+00
ACTVALVE	50	ACTVALVE50	8	1.63E-03	1.35E-04	4.93E-05	5.82E-05	0.00E+00
ACTVALVE	400	ACTVALVE400	4	4.55E-04	4.05E-05	1.53E-05	1.58E-05	3.63E-06
MANVALVE	50	MANVALVE50	8	1.84E-04	2.52E-05	1.15E-05	2.14E-05	0.00E+00
MANVALVE	400	MANVALVE400	4	2.21E-04	3.14E-05	1.46E-05	2.02E-05	9.33E-06
PIPE				3.31E-03	2.67E-04	8.27E-05	8.48E-05	1.10E-05
TOTAL				**1.32E-02**	**1.07E-03**	**3.31E-04**	**3.39E-04**	**4.39E-05**

QRA-18 Loading Arms (Spray) [Green]

				10mm	25mm	50mm	80mm
Component	**Diameter**	**Lookup**	**COUNT**	**1-15**	**15-40**	**40-60**	**RUPTURE**
FLANGE	25	FLANGE25	5	2.70E-05	2.76E-06	2.34E-06	0.00E+00
MANVALVE	25	MANVALVE25	10	2.24E-04	3.24E-05	4.54E-05	0.00E+00
MANVALVE	80	MANVALVE80	10	2.37E-04	3.02E-05	1.34E-05	2.31E-05
PIPE				1.63E-04	2.18E-05	2.04E-05	7.71E-06
TOTAL				**6.50E-04**	**8.72E-05**	**8.15E-05**	**3.09E-05**

QRA-19 Suction Drum Module (LNG to Suction Drum) [Red + Yellow]

				10mm	25mm	50mm	100mm	400mm
Component	**Diameter**	**Lookup**	**COUNT**	**1-15**	**15-40**	**40-60**	**60-165**	**RUPTURE**
INST	15	INST15	3.5	6.03E-04	9.40E-05	0.00E+00	0.00E+00	0.00E+00
VESSEL	200	VESSEL200	0.5	2.54E-04	3.23E-05	1.43E-05	1.47E-05	9.84E-06
FLANGE	25	FLANGE25	14	7.56E-05	7.72E-06	6.56E-06	0.00E+00	0.00E+00
FLANGE	50	FLANGE50	3	1.90E-05	1.93E-06	7.74E-07	1.13E-06	0.00E+00
FLANGE	80	FLANGE80	2	1.49E-05	1.51E-06	6.03E-07	1.05E-06	0.00E+00
FLANGE	200	FLANGE200	2	2.45E-05	2.35E-06	9.14E-07	8.17E-07	1.45E-06
FLANGE	400	FLANGE400	1	2.26E-05	1.56E-06	5.30E-07	4.74E-07	1.59E-06
ACTVALVE	25	ACTVALVE25	2	4.51E-04	3.50E-05	2.63E-05	0.00E+00	0.00E+00
ACTVALVE	50	ACTVALVE50	3	6.10E-04	5.05E-05	1.85E-05	2.18E-05	0.00E+00
ACTVALVE	100	ACTVALVE100	2	3.19E-04	3.02E-05	1.17E-05	1.56E-05	0.00E+00
ACTVALVE	150	ACTVALVE150	2	2.35E-04	2.53E-05	1.04E-05	8.57E-06	7.20E-06
ACTVALVE	300	ACTVALVE300	2	2.15E-04	2.14E-05	8.47E-06	8.78E-06	3.16E-06
ACTVALVE	400	ACTVALVE400	1	1.14E-04	1.01E-05	3.83E-06	3.96E-06	9.09E-07
MANVALVE	25	MANVALVE25	20	4.48E-04	6.49E-05	9.08E-05	0.00E+00	0.00E+00
MANVALVE	50	MANVALVE50	1	2.30E-05	3.15E-06	1.44E-06	2.68E-06	0.00E+00
MANVALVE	80	MANVALVE80	2	4.73E-05	6.04E-06	2.67E-06	4.63E-06	0.00E+00
MANVALVE	150	MANVALVE150	2	5.01E-05	5.43E-06	2.23E-06	1.85E-06	1.45E-06
MANVALVE	300	MANVALVE300	4	1.74E-04	2.18E-05	9.54E-06	1.13E-05	5.55E-06
MANVALVE	400	MANVALVE400	1	5.53E-05	7.85E-06	3.65E-06	5.04E-06	2.33E-06
PIPE				1.25E-03	1.41E-04	7.10E-05	3.41E-05	1.12E-05
TOTAL				**5.01E-03**	**5.64E-04**	**2.84E-04**	**1.37E-04**	**4.47E-05**

QRA-20 Suction Drum Module (Vapour Outlet + Relief) [Light Purple]

Component	Diameter	Lookup	COUNT	10mm 1-15	25mm 15-40	50mm 40-60	100mm 60-165	200mm RUPTURE
FLANGE	25	FLANGE25	12	6.48E-05	6.62E-06	5.62E-06	0.00E+00	0.00E+00
FLANGE	50	FLANGE50	1	6.33E-06	6.44E-07	2.58E-07	3.75E-07	0.00E+00
FLANGE	80	FLANGE80	2	1.49E-05	1.51E-06	6.03E-07	1.05E-06	0.00E+00
FLANGE	100	FLANGE100	6	4.92E-05	4.96E-06	1.98E-06	3.77E-06	0.00E+00
FLANGE	150	FLANGE150	3	3.02E-05	3.03E-06	1.20E-06	9.59E-07	1.67E-06
FLANGE	200	FLANGE200	2	2.45E-05	2.35E-06	9.14E-07	8.17E-07	1.45E-06
ACTVALVE	80	ACTVALVE80	2	3.54E-04	3.18E-05	1.20E-05	1.53E-05	0.00E+00
ACTVALVE	100	ACTVALVE100	5	7.98E-04	7.55E-05	2.93E-05	3.90E-05	0.00E+00
MANVALVE	25	MANVALVE25	10	2.24E-04	3.24E-05	4.54E-05	0.00E+00	0.00E+00
MANVALVE	50	MANVALVE50	1	2.30E-05	3.15E-06	1.44E-06	2.68E-06	0.00E+00
MANVALVE	100	MANVALVE100	2	4.82E-05	5.87E-06	2.54E-06	4.20E-06	0.00E+00
MANVALVE	150	MANVALVE150	4	1.00E-04	1.09E-05	4.47E-06	3.69E-06	2.91E-06
MANVALVE	200	MANVALVE200	2	6.06E-05	6.64E-06	2.74E-06	2.63E-06	1.56E-06
PIPE				5.99E-04	6.18E-05	3.62E-05	2.48E-05	2.53E-06
TOTAL				**2.40E-03**	**2.47E-04**	**1.45E-04**	**9.92E-05**	**1.01E-05**

QRA-21 Suction Drum Module (LNG from Suction Drum to Regas Trains + Return from Pumps) [Red + Yellow + Dark Purple]

Component	Diameter	Lookup	COUNT	10mm 1-15	25mm 15-40	50mm 40-60	100mm 60-165	450mm RUPTURE
INST	15	INST15	2	3.44E-04	5.37E-05	0.00E+00	0.00E+00	0.00E+00
VESSEL	300	VESSEL300	0.5	2.54E-04	3.23E-05	1.43E-05	1.70E-05	7.53E-06
FLANGE	25	FLANGE25	30	1.62E-04	1.65E-05	1.41E-05	0.00E+00	0.00E+00
FLANGE	50	FLANGE50	2	1.27E-05	1.29E-06	5.16E-07	7.50E-07	0.00E+00
FLANGE	150	FLANGE150	5	5.04E-05	5.04E-06	2.00E-06	1.60E-06	2.79E-06
FLANGE	300	FLANGE300	3	5.20E-05	4.24E-06	1.54E-06	1.43E-06	3.43E-06
FLANGE	400	FLANGE400	3	6.77E-05	4.69E-06	1.59E-06	1.42E-06	4.76E-06
FLANGE	450	FLANGE450	1	2.52E-05	1.61E-06	5.27E-07	4.57E-07	1.82E-06
MANVALVE	25	MANVALVE25	6	1.34E-04	1.95E-05	2.72E-05	0.00E+00	0.00E+00
MANVALVE	300	MANVALVE300	2	8.72E-05	1.09E-05	4.77E-06	5.64E-06	2.77E-06
PIPE				3.97E-04	4.99E-05	2.22E-05	9.45E-06	7.70E-06
TOTAL				**1.59E-03**	**2.00E-04**	**8.87E-05**	**3.78E-05**	**3.08E-05**

QRA-22 Regas Module (LNG to Regas T1 Pumps + Pump Drain + Pump Vent) [Red + Yellow + Dark Purple]

Component	Diameter	Lookup	COUNT	10mm 1-15	25mm 15-40	50mm 40-60	100mm 60-165	350mm RUPTURE
INST	15	INST15	9	1.55E-03	2.42E-04	0.00E+00	0.00E+00	0.00E+00
VESSEL	200	VESSEL200	1	5.08E-04	6.45E-05	2.85E-05	2.95E-05	1.97E-05
FILTER	350	FILTER350	1	1.67E-03	1.14E-04	3.83E-05	3.33E-05	5.70E-06
FLANGE	25	FLANGE25	26	1.40E-04	1.43E-05	1.22E-05	0.00E+00	0.00E+00
FLANGE	50	FLANGE50	1	6.33E-06	6.44E-07	2.58E-07	3.75E-07	0.00E+00
FLANGE	80	FLANGE80	2	1.49E-05	1.51E-06	6.03E-07	1.05E-06	0.00E+00
FLANGE	100	FLANGE100	10	8.20E-05	8.27E-06	3.30E-06	6.28E-06	0.00E+00
FLANGE	300	FLANGE300	2	3.47E-05	2.83E-06	1.03E-06	9.53E-07	2.28E-06
FLANGE	350	FLANGE350	2	3.99E-05	3.00E-06	1.05E-06	9.63E-07	2.72E-06
ACTVALVE	80	ACTVALVE80	4	7.08E-04	6.35E-05	2.41E-05	3.05E-05	0.00E+00
ACTVALVE	25	ACTVALVE25	4	9.03E-04	7.00E-05	5.25E-05	0.00E+00	0.00E+00
ACTVALVE	350	ACTVALVE350	1	1.11E-04	1.04E-05	4.03E-06	4.19E-06	1.20E-06
MANVALVE	25	MANVALVE25	18	4.03E-04	5.84E-05	8.17E-05	0.00E+00	0.00E+00
MANVALVE	100	MANVALVE100	4	9.64E-05	1.17E-05	5.09E-06	8.40E-06	0.00E+00
MANVALVE	350	MANVALVE350	1	4.97E-05	6.61E-06	2.98E-06	3.83E-06	1.81E-06
PIPE				2.10E-03	2.24E-04	8.52E-05	3.98E-05	1.11E-05
TOTAL				**8.42E-03**	**8.95E-04**	**3.41E-04**	**1.59E-04**	**4.45E-05**

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QRA-23 Regas Module (LNG from Regas T1 Pumps to LNG Vaporizer + Min Flow Return) [Red + Red-Dash]

				10mm	25mm	50mm	100mm	200mm
Component	**Diameter**	**Lookup**	**COUNT**	**1-15**	**15-40**	**40-60**	**60-165**	**RUPTURE**
INST	15	INST15	9	1.55E-03	2.42E-04	0.00E+00	0.00E+00	0.00E+00
HX TUBE	200	HX TUBE200	1	6.22E-04	1.00E-04	4.93E-05	5.78E-05	5.33E-05
HX PLATE	200	HX PLATE200	0.5	3.78E-03	2.57E-04	8.63E-05	6.54E-05	2.22E-05
VESSEL	150	VESSEL150	1	5.08E-04	6.45E-05	2.85E-05	2.54E-05	2.38E-05
FLANGE	25	FLANGE25	5	2.70E-05	2.76E-06	2.34E-06	0.00E+00	0.00E+00
FLANGE	50	FLANGE50	1	6.33E-06	6.44E-07	2.58E-07	3.75E-07	0.00E+00
FLANGE	100	FLANGE100	6	4.92E-05	4.96E-06	1.98E-06	3.77E-06	0.00E+00
FLANGE	150	FLANGE150	9	9.07E-05	9.08E-06	3.61E-06	2.88E-06	5.02E-06
FLANGE	200	FLANGE200	5	6.13E-05	5.86E-06	2.29E-06	2.04E-06	3.62E-06
ACTVALVE	50	ACTVALVE50	1	2.03E-04	1.68E-05	6.17E-06	7.27E-06	0.00E+00
ACTVALVE	80	ACTVALVE80	2	3.54E-04	3.18E-05	1.20E-05	1.53E-05	0.00E+00
ACTVALVE	150	ACTVALVE150	2	2.35E-04	2.53E-05	1.04E-05	8.57E-06	7.20E-06
ACTVALVE	200	ACTVALVE200	1	1.01E-04	1.12E-05	4.66E-06	4.49E-06	2.80E-06
MANVALVE	25	MANVALVE25	4	8.96E-05	1.30E-05	1.82E-05	0.00E+00	0.00E+00
MANVALVE	100	MANVALVE100	2	4.82E-05	5.87E-06	2.54E-06	4.20E-06	0.00E+00
MANVALVE	150	MANVALVE150	2	5.01E-05	5.43E-06	2.23E-06	1.85E-06	1.45E-06
PIPE				2.59E-03	2.65E-04	7.69E-05	6.64E-05	3.98E-05
TOTAL				**1.04E-02**	**1.06E-03**	**3.08E-04**	**2.66E-04**	**1.59E-04**

QRA-24 Regas Module (BOG to BOG Cooler) [Light Pink]

				10mm	25mm	50mm	100mm	250mm
Component	**Diameter**	**Lookup**	**COUNT**	**1-15**	**15-40**	**40-60**	**60-165**	**RUPTURE**
INST	15	INST15	4	6.89E-04	1.07E-04	0.00E+00	0.00E+00	0.00E+00
HX PLATE	150	HX PLATE150	0.25	1.89E-03	1.28E-04	4.32E-05	2.90E-05	1.48E-05
FLANGE	25	FLANGE25	2	1.08E-05	1.10E-06	9.37E-07	0.00E+00	0.00E+00
FLANGE	150	FLANGE150	7	7.05E-05	7.06E-06	2.81E-06	2.24E-06	3.90E-06
FLANGE	200	FLANGE200	2	2.45E-05	2.35E-06	9.14E-07	8.17E-07	1.45E-06
ACTVALVE	150	ACTVALVE150	2	2.35E-04	2.53E-05	1.04E-05	8.57E-06	7.20E-06
MANVALVE	25	MANVALVE25	1	2.24E-05	3.24E-06	4.54E-06	0.00E+00	0.00E+00
MANVALVE	150	MANVALVE150	1	2.51E-05	2.72E-06	1.12E-06	9.23E-07	7.27E-07
PIPE				9.89E-04	9.25E-05	2.13E-05	1.39E-05	9.34E-06
TOTAL				**3.96E-03**	**3.70E-04**	**8.52E-05**	**5.54E-05**	**3.74E-05**

QRA-25 Regas Module (BOG from BOG Cooler) [Light Pink - Dash]

				10mm	25mm	50mm	100mm	150mm
Component	**Diameter**	**Lookup**	**COUNT**	**1-15**	**15-40**	**40-60**	**60-165**	**RUPTURE**
INST	15	INST15	2	3.44E-04	5.37E-05	0.00E+00	0.00E+00	0.00E+00
HX PLATE	150	HX PLATE150	0.25	1.89E-03	1.28E-04	4.32E-05	2.90E-05	1.48E-05
FLANGE	25	FLANGE25	1	5.40E-06	5.51E-07	4.69E-07	0.00E+00	0.00E+00
FLANGE	150	FLANGE150	8	8.06E-05	8.07E-06	3.21E-06	2.56E-06	4.46E-06
MANVALVE	25	MANVALVE25	2	4.48E-05	6.49E-06	9.08E-06	0.00E+00	0.00E+00
MANVALVE	150	MANVALVE150	1	2.51E-05	2.72E-06	1.12E-06	9.23E-07	7.27E-07
PIPE				7.97E-04	6.67E-05	1.90E-05	1.08E-05	6.65E-06
TOTAL				**3.19E-03**	**2.67E-04**	**7.61E-05**	**4.33E-05**	**2.66E-05**

QRA-26 Regas Module (LNG from LNG Vaporizers to Trim Heater) [Aqua]

				10mm	25mm	50mm	100mm	300mm
Component	**Diameter**	**Lookup**	**COUNT**	**1-15**	**15-40**	**40-60**	**60-165**	**RUPTURE**
INST	15	INST15	5	8.61E-04	1.34E-04	0.00E+00	0.00E+00	0.00E+00
HX PLATE	300	HX PLATE300	1	7.56E-03	5.14E-04	1.73E-04	1.45E-04	2.97E-05
FLANGE	50	FLANGE50	1	6.33E-06	6.44E-07	2.58E-07	3.75E-07	0.00E+00
FLANGE	250	FLANGE250	1	1.48E-05	1.30E-06	4.91E-07	4.54E-07	9.29E-07
FLANGE	300	FLANGE300	2	3.47E-05	2.83E-06	1.03E-06	9.53E-07	2.28E-06
ACTVALVE	50	ACTVALVE50	1	2.03E-04	1.68E-05	6.17E-06	7.27E-06	0.00E+00
PIPE				2.89E-03	2.23E-04	6.02E-05	5.15E-05	1.10E-05
TOTAL				**1.16E-02**	**8.93E-04**	**2.41E-04**	**2.06E-04**	**4.39E-05**

Port Kembla Gas Terminal Project FHA Parts Count Sheets

QRA-27 Regas Module (LNG from Trim Heater to Train 1 discharge) [Aqua]

				10mm	25mm	50mm	100mm	300mm
Component	**Diameter**	**Lookup**	**COUNT**	**1-15**	**15-40**	**40-60**	**60-165**	**RUPTURE**
INST	15	INST15	3	5.16E-04	8.05E-05	0.00E+00	0.00E+00	0.00E+00
HX PLATE	300	HX PLATE300	0.5	3.78E-03	2.57E-04	8.63E-05	7.27E-05	1.49E-05
FLANGE	25	FLANGE25	2	1.08E-05	1.10E-06	9.37E-07	0.00E+00	0.00E+00
FLANGE	80	FLANGE80	1	7.45E-06	7.54E-07	3.01E-07	5.27E-07	0.00E+00
FLANGE	250	FLANGE250	1	1.48E-05	1.30E-06	4.91E-07	4.54E-07	9.29E-07
FLANGE	300	FLANGE300	5	8.67E-05	7.06E-06	2.57E-06	2.38E-06	5.71E-06
ACTVALVE	80	ACTVALVE80	1	1.77E-04	1.59E-05	6.02E-06	7.63E-06	0.00E+00
ACTVALVE	300	ACTVALVE300	1	1.08E-04	1.07E-05	4.24E-06	4.39E-06	1.58E-06
MANVALVE	25	MANVALVE25	2	4.48E-05	6.49E-06	9.08E-06	0.00E+00	0.00E+00
MANVALVE	300	MANVALVE300	1	4.36E-05	5.44E-06	2.38E-06	2.82E-06	1.39E-06
PIPE				1.60E-03	1.29E-04	3.75E-05	3.03E-05	8.16E-06
TOTAL				**6.38E-03**	**5.15E-04**	**1.50E-04**	**1.21E-04**	**3.26E-05**

QRA-28 LNG from Regas Module to Gas Metering [Aqua]

				10mm	25mm	50mm	100mm	600mm
Component	**Diameter**	**Lookup**	**COUNT**	**1-15**	**15-40**	**40-60**	**60-165**	**RUPTURE**
INST	15	INST15	4	6.89E-04	1.07E-04	0.00E+00	0.00E+00	0.00E+00
FLANGE	450	FLANGE450	1	2.52E-05	1.61E-06	5.27E-07	4.57E-07	1.82E-06
FLANGE	600	FLANGE600	1	2.84E-05	1.65E-06	5.17E-07	4.37E-07	2.08E-06
PIPE				2.47E-04	3.69E-05	3.48E-07	2.98E-07	1.30E-06
TOTAL				**9.90E-04**	**1.48E-04**	**1.39E-06**	**1.19E-06**	**5.20E-06**

QRA-29 Gas Metering Unit [Aqua]

				10mm	25mm	50mm	100mm	600mm
Component	**Diameter**	**Lookup**	**COUNT**	**1-15**	**15-40**	**40-60**	**60-165**	**RUPTURE**
INST	15	INST15	7	1.21E-03	1.88E-04	0.00E+00	0.00E+00	0.00E+00
FLANGE	50	FLANGE50	2	1.27E-05	1.29E-06	5.16E-07	7.50E-07	0.00E+00
FLANGE	600	FLANGE600	6	1.70E-04	9.87E-06	3.10E-06	2.62E-06	1.25E-05
ACTVALVE	100	ACTVALVE100	1	1.60E-04	1.51E-05	5.86E-06	7.80E-06	0.00E+00
MANVALVE	50	MANVALVE50	2	4.60E-05	6.29E-06	2.87E-06	5.35E-06	0.00E+00
PIPE				5.31E-04	7.35E-05	4.12E-06	5.51E-06	4.17E-06
TOTAL				**2.12E-03**	**2.94E-04**	**1.65E-05**	**2.20E-05**	**1.67E-05**

QRA-30 Gas Metering to Unloading Manifold [Aqua]

				10mm	25mm	50mm	100mm	600mm
Component	**Diameter**	**Lookup**	**COUNT**	**1-15**	**15-40**	**40-60**	**60-165**	**RUPTURE**
INST	15	INST15	4	6.89E-04	1.07E-04	0.00E+00	0.00E+00	0.00E+00
FLANGE	25	FLANGE25	6	3.24E-05	3.31E-06	2.81E-06	0.00E+00	0.00E+00
FLANGE	50	FLANGE50	4	2.53E-05	2.58E-06	1.03E-06	1.50E-06	0.00E+00
FLANGE	400	FLANGE400	6	1.35E-04	9.38E-06	3.18E-06	2.84E-06	9.52E-06
ACTVALVE	400	ACTVALVE400	2	2.28E-04	2.03E-05	7.65E-06	7.91E-06	1.82E-06
MANVALVE	25	MANVALVE25	4	8.96E-05	1.30E-05	1.82E-05	0.00E+00	0.00E+00
PIPE				4.00E-04	5.20E-05	1.09E-05	4.09E-06	3.78E-06
TOTAL				**1.60E-03**	**2.08E-04**	**4.38E-05**	**1.63E-05**	**1.51E-05**

QRA-31 Headers (LNG feed to regasification) [Red]

				10mm	25mm	50mm	100mm	300mm
Component	**Diameter**	**Lookup**	**COUNT**	**1-15**	**15-40**	**40-60**	**60-165**	**RUPTURE**
FLANGE	25	FLANGE25	3	1.62E-05	1.65E-06	1.41E-06	0.00E+00	0.00E+00
FLANGE	80	FLANGE80	8	5.96E-05	6.03E-06	2.41E-06	4.22E-06	0.00E+00
FLANGE	400	FLANGE400	1	2.26E-05	1.56E-06	5.30E-07	4.74E-07	1.59E-06
ACTVALVE	80	ACTVALVE80	3	5.31E-04	4.76E-05	1.81E-05	2.29E-05	0.00E+00
MANVALVE	25	MANVALVE25	6	1.34E-04	1.95E-05	2.72E-05	0.00E+00	0.00E+00
MANVALVE	80	MANVALVE80	4	9.47E-05	1.21E-05	5.35E-06	9.26E-06	0.00E+00
PIPE				2.86E-04	2.95E-05	1.83E-05	1.23E-05	5.29E-07
TOTAL				**1.14E-03**	**1.18E-04**	**7.33E-05**	**4.91E-05**	**2.12E-06**

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QRA-32 Headers (LNG Spray) [Green]

Component	Diameter	Lookup	COUNT	10mm 1-15	25mm 15-40	50mm 40-60	80mm RUPTURE
FLANGE	80	FLANGE80	4	2.98E-05	3.02E-06	1.21E-06	2.11E-06
ACTVALVE	80	ACTVALVE80	6	1.06E-03	9.53E-05	3.61E-05	4.58E-05
MANVALVE	80	MANVALVE80	2	4.73E-05	6.04E-06	2.67E-06	4.63E-06
PIPE				3.80E-04	3.48E-05	1.33E-05	1.75E-05
TOTAL				**1.52E-03**	**1.39E-04**	**5.33E-05**	**7.00E-05**

QRA-33 Headers (LNG to Cargo Tanks) [Yellow]

Component	Diameter	Lookup	COUNT	10mm 1-15	25mm 15-40	50mm 40-60	100mm 60-165	600mm RUPTURE
INST	15	INST15	4	6.89E-04	1.07E-04	0.00E+00	0.00E+00	0.00E+00
FLANGE	25	FLANGE25	4	2.16E-05	2.21E-06	1.87E-06	0.00E+00	0.00E+00
FLANGE	50	FLANGE50	2	1.27E-05	1.29E-06	5.16E-07	7.50E-07	0.00E+00
FLANGE	100	FLANGE100	2	1.64E-05	1.65E-06	6.60E-07	1.26E-06	0.00E+00
FLANGE	400	FLANGE400	1	2.26E-05	1.56E-06	5.30E-07	4.74E-07	1.59E-06
ACTVALVE	80	ACTVALVE80	1	1.77E-04	1.59E-05	6.02E-06	7.63E-06	0.00E+00
ACTVALVE	100	ACTVALVE100	2	3.19E-04	3.02E-05	1.17E-05	1.56E-05	0.00E+00
MANVALVE	25	MANVALVE25	4	8.96E-05	1.30E-05	1.82E-05	0.00E+00	0.00E+00
MANVALVE	80	MANVALVE80	2	4.73E-05	6.04E-06	2.67E-06	4.63E-06	0.00E+00
MANVALVE	400	MANVALVE400	1	5.53E-05	7.85E-06	3.65E-06	5.04E-06	2.33E-06
MANVALVE	600	MANVALVE600	1	6.57E-05	1.07E-05	5.29E-06	8.79E-06	3.73E-06
PIPE				5.05E-04	6.59E-05	1.70E-05	1.47E-05	2.55E-06
TOTAL				**2.02E-03**	**2.64E-04**	**6.81E-05**	**5.89E-05**	**1.02E-05**

QRA-34 Headers (Cold Gas) [Light Purple]

Component	Diameter	Lookup	COUNT	10mm 1-15	25mm 15-40	50mm 40-60	100mm 60-165	700mm RUPTURE
INST	15	INST15	4	6.89E-04	1.07E-04	0.00E+00	0.00E+00	0.00E+00
FLANGE	25	FLANGE25	22	1.19E-04	1.21E-05	1.03E-05	0.00E+00	0.00E+00
FLANGE	80	FLANGE80	1	7.45E-06	7.54E-07	3.01E-07	5.27E-07	0.00E+00
FLANGE	100	FLANGE100	2	1.64E-05	1.65E-06	6.60E-07	1.26E-06	0.00E+00
FLANGE	250	FLANGE250	1	1.48E-05	1.30E-06	4.91E-07	4.54E-07	9.29E-07
FLANGE	300	FLANGE300	2	3.47E-05	2.83E-06	1.03E-06	9.53E-07	2.28E-06
FLANGE	400	FLANGE400	5	1.13E-04	7.82E-06	2.65E-06	2.37E-06	7.94E-06
FLANGE	700	FLANGE700	11	3.12E-04	1.81E-05	5.69E-06	4.86E-06	2.29E-05
ACTVALVE	50	ACTVALVE50	2	4.07E-04	3.37E-05	1.23E-05	1.45E-05	0.00E+00
ACTVALVE	250	ACTVALVE250	3	3.13E-04	3.29E-05	1.33E-05	1.35E-05	6.27E-06
MANVALVE	25	MANVALVE25	10	2.24E-04	3.24E-05	4.54E-05	0.00E+00	0.00E+00
MANVALVE	100	MANVALVE100	1	2.41E-05	2.93E-06	1.27E-06	2.10E-06	0.00E+00
MANVALVE	150	MANVALVE150	1	2.51E-05	2.72E-06	1.12E-06	9.23E-07	7.27E-07
MANVALVE	400	MANVALVE400	1	5.53E-05	7.85E-06	3.65E-06	5.04E-06	2.33E-06
MANVALVE	700	MANVALVE700	4	2.63E-04	4.28E-05	2.12E-05	3.62E-05	1.39E-05
PIPE				8.72E-04	1.02E-04	3.98E-05	2.76E-05	1.91E-05
TOTAL				**3.49E-03**	**4.10E-04**	**1.59E-04**	**1.10E-04**	**7.63E-05**

QRA-35 Headers (Gas from HD Compressors) [Orange]

Component	Diameter	Lookup	COUNT	10mm 1-15	25mm 15-40	50mm 40-60	100mm 60-165	600mm RUPTURE
INST	15	INST15	2	3.44E-04	5.37E-05	0.00E+00	0.00E+00	0.00E+00
FLANGE	25	FLANGE25	5	2.70E-05	2.76E-06	2.34E-06	0.00E+00	0.00E+00
FLANGE	400	FLANGE400	1	2.26E-05	1.56E-06	5.30E-07	4.74E-07	1.59E-06
FLANGE	600	FLANGE600	3	8.51E-05	4.94E-06	1.55E-06	1.31E-06	6.25E-06
ACTVALVE	250	ACTVALVE250	1	1.04E-04	1.10E-05	4.45E-06	4.51E-06	2.09E-06
MANVALVE	25	MANVALVE25	2	4.48E-05	6.49E-06	9.08E-06	0.00E+00	0.00E+00
MANVALVE	600	MANVALVE600	1	6.57E-05	1.07E-05	5.29E-06	8.79E-06	3.73E-06
PIPE				2.31E-04	3.04E-05	7.75E-06	5.03E-06	4.55E-06
TOTAL				**9.25E-04**	**1.21E-04**	**3.10E-05**	**2.01E-05**	**1.82E-05**

Port Kembla Gas Terminal Project FHA Parts Count Sheets

QRA-36 Headers (Warm Gas from LD Compressors) [Light Pink + Light Blue]

				10mm	25mm	50mm	100mm	250mm
Component	**Diameter**	**Lookup**	**COUNT**	**1-15**	**15-40**	**40-60**	**60-165**	**RUPTURE**
FLANGE	80	FLANGE80	1	7.45E-06	7.54E-07	3.01E-07	5.27E-07	0.00E+00
FLANGE	250	FLANGE250	1	1.48E-05	1.30E-06	4.91E-07	4.54E-07	9.29E-07
ACTVALVE	80	ACTVALVE80	1	1.77E-04	1.59E-05	6.02E-06	7.63E-06	0.00E+00
MANVALVE	250	MANVALVE250	1	3.71E-05	4.34E-06	1.85E-06	1.99E-06	1.05E-06
PIPE				7.88E-05	7.43E-06	2.89E-06	3.53E-06	6.60E-07
TOTAL				**3.15E-04**	**2.97E-05**	**1.15E-05**	**1.41E-05**	**2.64E-06**

QRA-37 Wharf Topside (HP Gas Transfer System)

				10mm	25mm	50mm	100mm	350mm
Component	**Diameter**	**Lookup**	**COUNT**	**1-15**	**15-40**	**40-60**	**60-165**	**RUPTURE**
INST	40	INST40	2	3.44E-04	2.95E-05	2.42E-05	0.00E+00	0.00E+00
INST	50	INST50	8	1.38E-03	1.18E-04	4.38E-05	5.29E-05	0.00E+00
FLANGE	25	FLANGE25	6	3.24E-05	3.31E-06	2.81E-06	0.00E+00	0.00E+00
FLANGE	50	FLANGE50	20	1.27E-04	1.29E-05	5.16E-06	7.50E-06	0.00E+00
FLANGE	300	FLANGE300	11	1.91E-04	1.55E-05	5.65E-06	5.24E-06	1.26E-05
FLANGE	400	FLANGE400	18	4.06E-04	2.82E-05	9.54E-06	8.53E-06	2.86E-05
ACTVALVE	300	ACTVALVE300	8	8.61E-04	8.55E-05	3.39E-05	3.51E-05	1.27E-05
ACTVALVE	400	ACTVALVE400	2	2.28E-04	2.03E-05	7.65E-06	7.91E-06	1.82E-06
MANVALVE	50	MANVALVE50	8	1.84E-04	2.52E-05	1.15E-05	2.14E-05	0.00E+00
MANVALVE	25	MANVALVE25	4	8.96E-05	1.30E-05	1.82E-05	0.00E+00	0.00E+00
MANVALVE	400	MANVALVE400	4	2.21E-04	3.14E-05	1.46E-05	2.02E-05	9.33E-06
PIPE				1.35E-03	1.28E-04	5.90E-05	5.29E-05	2.16E-05
TOTAL				**5.41E-03**	**5.10E-04**	**2.36E-04**	**2.12E-04**	**8.66E-05**

QRA-38 Onshore Receivng Facility

				10mm	25mm	50mm	100mm	400mm
Component	**Diameter**	**Lookup**	**COUNT**	**1-15**	**15-40**	**40-60**	**60-165**	**RUPTURE**
INST	40	INST40	4	6.89E-04	5.90E-05	4.84E-05	0.00E+00	0.00E+00
FLANGE	50	FLANGE50	4	2.53E-05	2.58E-06	1.03E-06	1.50E-06	0.00E+00
FLANGE	200	FLANGE200	1	1.23E-05	1.17E-06	4.57E-07	4.09E-07	7.25E-07
FLANGE	80	FLANGE80	1	7.45E-06	7.54E-07	3.01E-07	5.27E-07	0.00E+00
FLANGE	400	FLANGE400	6	1.35E-04	9.38E-06	3.18E-06	2.84E-06	9.52E-06
ACTVALVE	400	ACTVALVE400	1.5	1.71E-04	1.52E-05	5.74E-06	5.93E-06	1.36E-06
MANVALVE	50	MANVALVE50	4	9.20E-05	1.26E-05	5.75E-06	1.07E-05	0.00E+00
MANVALVE	80	MANVALVE80	1	2.37E-05	3.02E-06	1.34E-06	2.31E-06	0.00E+00
MANVALVE	200	MANVALVE200	1	3.03E-05	3.32E-06	1.37E-06	1.31E-06	7.78E-07
PIPE				3.95E-04	3.57E-05	2.25E-05	8.51E-06	4.13E-06
TOTAL				**1.58E-03**	**1.43E-04**	**9.01E-05**	**3.41E-05**	**1.65E-05**

QRA-39 Port Kembla Pipeline (Above ground section)

				10mm	25mm	50mm	100mm	450mm
Component	**Diameter**	**Lookup**	**COUNT**	**1-15**	**15-40**	**40-60**	**60-165**	**RUPTURE**
INST	40	INST40	1	1.72E-04	1.47E-05	1.21E-05	0.00E+00	0.00E+00
FLANGE	50	FLANGE50	2	1.27E-05	1.29E-06	5.16E-07	7.50E-07	0.00E+00
MANVALVE	25	MANVALVE25	1	2.24E-05	3.24E-06	4.54E-06	0.00E+00	0.00E+00
MANVALVE	50	MANVALVE50	2	4.60E-05	6.29E-06	2.87E-06	5.35E-06	0.00E+00
MANVALVE	450	MANVALVE450	1	6.05E-05	9.15E-06	4.37E-06	6.49E-06	3.00E-06
ACTVALVE	400	ACTVALVE400	0.5	5.69E-05	5.07E-06	1.91E-06	1.98E-06	4.54E-07
PIPE				1.24E-04	1.33E-05	8.77E-06	4.85E-06	1.15E-06
TOTAL				**4.94E-04**	**5.30E-05**	**3.51E-05**	**1.94E-05**	**4.61E-06**

QRA-40 Odourant Package

				10mm	25mm
Component	**Diameter**	**Lookup**	**COUNT**	**1-15**	**RUPTURE**
FLANGE	15	FLANGE15	6	3.02E-05	5.50E-06
VESSEL	15	VESSEL15	2	1.02E-03	2.84E-04
FILTER	15	FILTER15	2	3.34E-03	3.82E-04
INST	15	INST15	6	1.03E-03	1.61E-04
PUMP (Recip)	15	PUMP (Recip)15	2	2.69E-03	1.71E-03
ACTVALVE	15	ACTVALVE15	2	4.69E-04	6.14E-05
MANVALVE	15	MANVALVE15	26	5.76E-04	2.08E-04
PIPE				3.05E-03	9.38E-04
TOTAL				**1.22E-02**	**3.75E-03**

Appendix I. FHA Frequency Analysis

The following table presents the detailed frequency analysis based on the leak frequencies calculated for each QRA parts count section (refer Section 7.1) with ignition probabilities calculated based on release rates determined using DNV SAFETI software at the 'base case' operating conditions (refer Section 7.4). Corresponding scenarios and QRA parts count sections are presented in Table 6-2 of Section 6. The overall fire frequency is equal to the leak frequency multiplied by the ignition probability. Noting the frequencies presented do not consider the risk reduction measures detailed in Section 7.3 and therefore present the worst case event frequencies.

No	Parts Count Section	Hole Size	Pressure (barg)	Temp (°C)	Leak Frequency (pa)	Peak Release Rate (kg/s)	Ign. Prob (fraction)	Fire Frequency (pa)
1	No. 4 Tank (Incl tank instr & tank PSVs; Excl tank)	10mm	0.1	-158.5	2.09E-03	0.01	1.00E-03	2.09E-06
		25mm			2.89E-04	0.1	1.06E-03	3.08E-07
		50mm			9.28E-05	0.3	1.18E-03	1.09E-07
		100mm			2.34E-05	1.0	1.32E-03	3.08E-08
		FB			1.84E-05	9.1	1.90E-02	3.49E-07
2	No. 4 Tank (To LNG Feed Header) [Red]	10mm	5.5	-160	1.79E-03	1.1	1.43E-03	2.56E-06
		25mm			2.14E-04	6.8	1.32E-02	2.82E-06
		50mm			9.81E-05	27.0	7.10E-02	6.97E-06
		100mm			3.17E-05	108.0	1.50E-01	4.76E-06
		FB			2.61E-05	72.0	1.50E-01	3.92E-06
3	No. 4 Tank (From Cargo Liquid header) [Yellow]	10mm	5.5	-160	1.80E-03	1.1	1.43E-03	2.57E-06
		25mm			2.09E-04	6.8	1.32E-02	2.76E-06
		50mm			9.01E-05	27.0	7.10E-02	6.40E-06
		100mm			4.00E-05	108.0	1.50E-01	5.99E-06
		FB			2.66E-05	72.0	1.50E-01	4.00E-06
4	No. 4 Tank (To Spray Main) [Green]	10mm	5.5	-160	4.62E-03	1.1	1.43E-03	6.59E-06
		25mm			4.02E-04	6.8	1.32E-02	5.31E-06
		FB			2.68E-04	45.7	1.34E-01	3.59E-05
5	No. 4 Tank (To Cargo Vapour Header) [Light Purple]	10mm	0.1	-158.5	7.09E-04	0.01	1.00E-03	7.09E-07
		25mm			8.39E-05	0.1	1.06E-03	8.93E-08
		50mm			6.42E-05	0.3	1.18E-03	7.55E-08
		100mm			2.91E-05	1.0	1.32E-03	3.84E-08
		FB			2.02E-05	16.2	3.81E-02	7.70E-07
6	Cargo Machinery (HD Comp Inlet) [Light Purple]	10mm	0.1	-158.5	1.32E-02	0.01	1.00E-03	1.32E-05
		25mm			1.23E-03	0.1	1.06E-03	1.31E-06

No	Parts Count Section	Hole Size	Pressure (barg)	Temp (°C)	Leak Frequency (pa)	Peak Release Rate (kg/s)	Ign. Prob (fraction)	Fire Frequency (pa)
		50mm			4.02E-04	0.3	1.18E-03	4.72E-07
		100mm			3.52E-04	1.0	1.32E-03	4.64E-07
		FB			1.32E-04	49.6	1.48E-01	1.96E-05
7	Cargo Machinery (LNG Vaporizer Outlet) [Light Purple]	10mm	0.1	-158.5	2.09E-03	0.01	1.00E-03	2.09E-06
		25mm			2.47E-04	0.1	1.06E-03	2.63E-07
		50mm			8.30E-05	0.3	1.18E-03	9.76E-08
		100mm			8.39E-05	1.0	1.32E-03	1.11E-07
		FB			3.73E-05	36.4	1.02E-01	3.81E-06
8	Cargo Machinery (Forcing Vaporizer Outlet) [Light Purple]	10mm	0.1	-158.5	1.97E-03	0.01	1.00E-03	1.97E-06
		25mm			2.31E-04	0.1	1.06E-03	2.45E-07
		50mm			8.45E-05	0.3	1.18E-03	9.95E-08
		100mm			5.38E-05	1.0	1.32E-03	7.09E-08
		FB			3.08E-05	6.3	1.22E-02	3.75E-07
9	Cargo Machinery (Heaters Outlet) [Light Purple]	10mm			3.20E-03	0.03	1.01E-03	3.24E-06
		25mm			3.65E-04	0.2	1.16E-03	4.22E-07
		50mm	1	-120	1.40E-04	0.8	1.28E-03	1.80E-07
		100mm			1.28E-04	3.2	5.33E-03	6.83E-07
		FB			6.25E-05	72.0	1.50E-01	9.38E-06
10	Cargo Machinery (Mist Sep & LD Comp Inlet) [Light Purple]	10mm	0.1	-158.5	1.63E-02	0.01	1.00E-03	1.63E-05
		25mm			1.48E-03	0.1	1.06E-03	1.58E-06
		50mm			5.19E-04	0.3	1.18E-03	6.10E-07
		100mm			4.13E-04	1.0	1.32E-03	5.44E-07
		FB			1.55E-04	9.1	1.90E-02	2.94E-06
11	Cargo Machinery (HD Comp Outlet) [Orange]	10mm			8.50E-03	0.03	1.01E-03	8.61E-06
		25mm			8.71E-04	0.2	1.16E-03	1.01E-06
		50mm	1	-120	3.39E-04	0.8	1.28E-03	4.33E-07
		100mm			3.16E-04	3.2	5.33E-03	1.68E-06
		FB			1.57E-04	115.2	1.50E-01	2.35E-05
12	Cargo Machinery (Heaters Inlet) [Orange]	10mm			3.53E-03	0.03	1.01E-03	3.57E-06
		25mm	1	-120	4.05E-04	0.2	1.16E-03	4.68E-07
		50mm			1.56E-04	0.8	1.28E-03	2.00E-07

No	Parts Count Section	Hole Size	Pressure (barg)	Temp (°C)	Leak Frequency (pa)	Peak Release Rate (kg/s)	Ign. Prob (fraction)	Fire Frequency (pa)
		100mm			1.33E-04	3.2	5.33E-03	7.08E-07
		FB			7.28E-05	80.0	1.50E-01	1.09E-05
13	Cargo Machinery (LD Comp Outlet to Aftercoolers) [Light Blue]	10mm	5.5	60	1.13E-02	0.1	1.08E-03	1.22E-05
		25mm			1.23E-03	0.5	1.23E-03	1.52E-06
		50mm			4.66E-04	1.9	2.89E-03	1.34E-06
		100mm			3.64E-04	7.7	1.55E-02	5.64E-06
		FB			1.78E-04	30.9	8.35E-02	1.48E-05
14	Cargo Machinery (Aftercoolers to Engines) [Light Blue]	10mm	5.5	60	5.66E-03	0.1	1.08E-03	6.11E-06
		25mm			6.57E-04	0.5	1.23E-03	8.10E-07
		50mm			2.50E-04	1.9	2.89E-03	7.22E-07
		100mm			2.01E-04	7.7	1.55E-02	3.12E-06
		FB			1.07E-04	69.4	1.50E-01	1.61E-05
15	Cargo Machinery (Spray to Vaporizers & Mist Sep) [Green]	10mm	5.5	-160	1.12E-02	1.1	1.43E-03	1.60E-05
		25mm			1.05E-03	6.8	1.32E-02	1.39E-05
		FB			8.31E-04	69.2	1.50E-01	1.25E-04
16	Ship-to-ship Loading Connections (Gas Return) [Orange]	10mm	1	-120	2.01E-04	0.03	1.01E-03	2.03E-07
		25mm			1.63E-05	0.2	1.16E-03	1.89E-08
		50mm			6.53E-06	0.8	1.28E-03	8.36E-09
		100mm			3.61E-06	3.2	5.33E-03	1.93E-08
		FB			5.62E-07	51.2	1.50E-01	8.44E-08
17	Ship-to-ship Loading Connections (Cargo Liquid) [Yellow]	10mm	5.5	-160	9.45E-04	1.1	1.43E-03	1.35E-06
		25mm			7.64E-05	6.8	1.32E-02	1.01E-06
		50mm			2.36E-05	27.0	7.10E-02	1.68E-06
		100mm			2.42E-05	108.0	1.50E-01	3.64E-06
		FB			3.14E-06	72.0	1.50E-01	4.71E-07
18	Ship-to-ship Loading Connections (Cargo Spray) [Green]	10mm	5.5	-160	4.64E-05	1.1	1.43E-03	6.63E-08
		25mm			6.23E-06	6.8	1.32E-02	8.22E-08
		FB			8.02E-06	69.2	1.50E-01	1.20E-06
19	Suction Drum Module (LNG to Suction Drum) [Red + Yellow]	10mm	5.5	-160	5.01E-03	1.1	1.43E-03	7.15E-06
		25mm			5.64E-04	6.8	1.32E-02	7.45E-06
		50mm			2.84E-04	27.0	7.10E-02	2.02E-05

No	Parts Count Section	Hole Size	Pressure (barg)	Temp (°C)	Leak Frequency (pa)	Peak Release Rate (kg/s)	Ign. Prob (fraction)	Fire Frequency (pa)
		100mm			1.37E-04	108.0	1.50E-01	2.05E-05
		FB			4.47E-05	72.0	1.50E-01	6.70E-06
20	Suction Drum Module (Vapour Outlet + Relief) [Light Purple]	10mm	5.5	-160	2.40E-03	1.1	1.43E-03	3.42E-06
		25mm			2.47E-04	6.8	1.32E-02	3.26E-06
		50mm			1.45E-04	27.0	7.10E-02	1.03E-05
		100mm			9.92E-05	108.0	1.50E-01	1.49E-05
		FB			1.01E-05	72.0	1.50E-01	1.52E-06
21	Suction Drum Module (LNG From Suction Drum to Regas Trains + Return From Pumps) [Red + Yellow + Dark Purple]	10mm	5.5	-160	1.59E-03	1.1	1.43E-03	2.26E-06
		25mm			2.00E-04	6.8	1.32E-02	2.64E-06
		50mm			8.87E-05	27.0	7.10E-02	6.30E-06
		100mm			3.78E-05	108.0	1.50E-01	5.67E-06
		FB			3.08E-05	72.0	1.50E-01	4.62E-06
22	Regas Module (LNG to Regas T1 Pumps + Pump Drain + Pump Vent) [Red + Yellow + Dark Purple]	10mm	5.5	-160	8.42E-03	1.1	1.43E-03	1.20E-05
		25mm			8.95E-04	6.8	1.32E-02	1.18E-05
		50mm			3.41E-04	27.0	7.10E-02	2.42E-05
		100mm			1.59E-04	108.0	1.50E-01	2.39E-05
		FB			4.45E-05	72.0	1.50E-01	6.68E-06
23	Regas Module (LNG From Regas T1 Pumps to LNG Vaporizer + Min Flow Return) [Red + Red-Dash]	10mm	120	-160	1.04E-02	5.1	9.28E-03	9.62E-05
		25mm			1.06E-03	31.6	8.58E-02	9.11E-05
		50mm			3.08E-04	126.2	1.50E-01	4.62E-05
		100mm			2.66E-04	505.0	1.50E-01	3.98E-05
		FB			1.59E-04	72.0	1.50E-01	2.39E-05
24	Regas Module (BOG to BOG Cooler) [Light Pink]	10mm	5.5	-160	3.96E-03	1.1	1.43E-03	5.65E-06
		25mm			3.70E-04	6.8	1.32E-02	4.89E-06
		50mm			8.52E-05	27.0	7.10E-02	6.05E-06
		100mm			5.54E-05	108.0	1.50E-01	8.32E-06
		FB			3.74E-05	72.0	1.50E-01	5.61E-06
25	Regas Module (BOGFrom BOG Cooler) [Light Pink - Dash]	10mm	5.5	60	3.19E-03	0.1	1.08E-03	3.44E-06
		25mm			2.67E-04	0.5	1.23E-03	3.29E-07
		50mm			7.61E-05	1.9	2.89E-03	2.19E-07
		100mm			4.33E-05	7.7	1.55E-02	6.73E-07

No	Parts Count Section	Hole Size	Pressure (barg)	Temp (°C)	Leak Frequency (pa)	Peak Release Rate (kg/s)	Ign. Prob (fraction)	Fire Frequency (pa)
		FB			2.66E-05	17.4	4.15E-02	1.10E-06
26	Regas Module (LNG From LNG Vaporizers to Trim Heater) [Aqua]	10mm	120	10	1.16E-02	2.1	3.22E-03	3.73E-05
		25mm			8.93E-04	13.2	2.98E-02	2.66E-05
		50mm			2.41E-04	52.8	1.50E-01	3.61E-05
		100mm			2.06E-04	211.3	1.50E-01	3.09E-05
		FB			4.39E-05	72.0	1.50E-01	6.59E-06
27	Regas Module (LNG From Trim Heater to Train 1 discharge) [Aqua]	10mm	120	10	6.38E-03	2.1	3.22E-03	2.06E-05
		25mm			5.15E-04	13.2	2.98E-02	1.53E-05
		50mm			1.50E-04	52.8	1.50E-01	2.25E-05
		100mm			1.21E-04	211.3	1.50E-01	1.82E-05
		FB			3.26E-05	72.0	1.50E-01	4.89E-06
28	LNG From Regas Module to Gas Metering [Aqua]	10mm	120	10	9.90E-04	2.1	3.22E-03	3.19E-06
		25mm			1.48E-04	13.2	2.98E-02	4.39E-06
		50mm			1.39E-06	52.8	1.50E-01	2.09E-07
		100mm			1.19E-06	211.3	1.50E-01	1.79E-07
		FB			5.20E-06	72.0	1.50E-01	7.80E-07
29	Gas Metering Unit [Aqua]	10mm	120	10	2.12E-03	2.1	3.22E-03	6.85E-06
		25mm			2.94E-04	13.2	2.98E-02	8.76E-06
		50mm			1.65E-05	52.8	1.50E-01	2.47E-06
		100mm			2.20E-05	211.3	1.50E-01	3.30E-06
		FB			1.67E-05	72.0	1.50E-01	2.50E-06
30	Gas Metering to Unloading Manifold [Aqua]	10mm	120	10	1.60E-03	2.1	3.22E-03	5.15E-06
		25mm			2.08E-04	13.2	2.98E-02	6.19E-06
		50mm			4.38E-05	52.8	1.50E-01	6.57E-06
		100mm			1.63E-05	211.3	1.50E-01	2.45E-06
		FB			1.51E-05	72.0	1.50E-01	2.27E-06
31	Headers (LNG Feed to regasification) [Red]	10mm	5.5	-160	1.14E-03	1.1	1.43E-03	1.63E-06
		25mm			1.18E-04	6.8	1.32E-02	1.56E-06
		50mm			7.33E-05	27.0	7.10E-02	5.21E-06
		100mm			4.91E-05	108.0	1.50E-01	7.37E-06
		FB			2.12E-06	72.0	1.50E-01	3.17E-07

No	Parts Count Section	Hole Size	Pressure (barg)	Temp (°C)	Leak Frequency (pa)	Peak Release Rate (kg/s)	Ign. Prob (fraction)	Fire Frequency (pa)
32	Headers (LNG Spray) [Green]	10mm	5.5	-160	1.52E-03	1.1	1.43E-03	2.17E-06
		25mm			1.39E-04	6.8	1.32E-02	1.84E-06
		FB			5.33E-05	69.2	1.50E-01	8.00E-06
33	Headers (LNG to Cargo Tanks) [Yellow]	10mm	5.5	-160	2.02E-03	1.1	1.43E-03	2.89E-06
		25mm			2.64E-04	6.8	1.32E-02	3.48E-06
		50mm			6.81E-05	27.0	7.10E-02	4.84E-06
		100mm			5.89E-05	108.0	1.50E-01	8.83E-06
		FB			1.02E-05	72.0	1.50E-01	1.53E-06
34	Headers (Cold Gas) [Light Purple]	10mm	0.1	-158.5	3.49E-03	0.003	1.00E-03	3.49E-06
		25mm			4.10E-04	0.02	1.00E-03	4.10E-07
		50mm			1.59E-04	0.1	1.08E-03	1.72E-07
		100mm			1.10E-04	0.3	1.19E-03	1.32E-07
		FB			7.63E-05	15.3	3.56E-02	2.72E-06
35	Headers (Gas From HD Compressors) [Orange]	10mm	5.5	-160	9.25E-04	1.1	1.43E-03	1.32E-06
		25mm			1.21E-04	6.8	1.32E-02	1.60E-06
		50mm			3.10E-05	27.0	7.10E-02	2.20E-06
		100mm			2.01E-05	108.0	1.50E-01	3.02E-06
		FB			1.82E-05	72.0	1.50E-01	2.73E-06
36	Headers (Warm Gas From LD Compressors) [Light Pink + Light Blue]	10mm	5.5	-160	3.15E-04	1.1	1.43E-03	4.50E-07
		25mm			2.97E-05	6.8	1.32E-02	3.92E-07
		50mm			1.15E-05	27.0	7.10E-02	8.20E-07
		100mm			1.41E-05	108.0	1.50E-01	2.12E-06
		FB			2.64E-06	72.0	1.50E-01	3.96E-07
-	Ship-to-ship Hose Transfer Between LNGC and FSRU	10mm	2.4	-160	7.41E-04	0.7	1.00E-03	7.41E-07
		25mm			8.55E-05	4.5	1.10E-03	9.42E-08
		50mm			1.42E-04	17.8	1.22E-03	1.73E-07
		100mm			0.00E+00	71.4	2.37E-03	0.00E+00
		1FB			1.78E-06	298.1	2.19E-02	3.90E-08
		5FB			7.12E-09	1195.2	1.19E-01	8.48E-10

No	Parts Count Section	Hole Size	Pressure (barg)	Temp (°C)	Leak Frequency (pa)	Peak Release Rate (kg/s)	Ign. Prob (fraction)	Fire Frequency (pa)
37	FSRU ESD Valve to ORF (up to SDV-064001 / SDV-064002) including MLA	10mm	120	10	5.41E-03	2.1	8.08E-03	4.37E-05
		25mm			5.10E-04	13.2	4.16E-02	2.12E-05
		50mm			2.36E-04	52.8	1.15E-01	2.72E-05
		100mm			2.12E-04	211.3	3.19E-01	6.76E-05
		FB			8.66E-05	1901.0	6.00E-01	5.20E-05
38	ORF Pipework (from SDV-064001 / SDV-064002 to SDV-064007)	10mm	120	10	1.58E-03	2.1	8.08E-03	1.28E-05
		25mm			1.43E-04	13.2	4.16E-02	5.93E-06
		50mm			9.01E-05	52.8	1.15E-01	1.04E-05
		100mm			3.41E-05	211.3	3.19E-01	1.09E-05
		FB			1.65E-05	3380.0	6.00E-01	9.91E-06
39	Above ground section of PKP (from SDV-064007 to above ground / below ground interface)	10mm	120	10	4.94E-04	2.1	8.08E-03	3.99E-06
		25mm			5.30E-05	13.2	4.16E-02	2.21E-06
		50mm			3.51E-05	52.8	1.15E-01	4.04E-06
		100mm			1.94E-05	211.3	3.19E-01	6.20E-06
		FB			4.61E-06	3380.0	6.00E-01	2.77E-06
40	Odourant Storage & Pipework	10mm	2.5	10	1.22E-02	1.1	2.77E-03	3.38E-05
		FB			3.75E-03	6.7	2.52E-02	9.46E-05