Department of Planning and Environment

Our ref: SSI-9471-PA-100

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

6 October 2023

Subject: Fire Safety Study for Port Kembla Gas Terminal (SSI-9471)

Dear Ms. Lovell

I refer to your submission requesting review and approval of the Fire Safety Study for the Port Kembla Gas Terminal.

I note the Fire Safety Study has been prepared in accordance with DPE's HIPAP 2.

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

Accordingly, as nominee of the Planning Secretary, I approve the Safety Management Study (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

Fire Safety Study Report

Document No Rev 3: PKGT-WOR-ORF-SAF-STY-0001
Worley Document No Rev 3: 411010-00417-SR-REP-0001
15 September 2023

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WORLEY PROJECT: 411010-00417 - Port Kembla Gas Terminal Project - Fire Safety Study Report

Rev	Description	Originator	Reviewer	Worley Approver	Revision Date	Customer Approver	Approval Date
0	Issued for Use	AS A. Stembridge	AF A. Fergusson	AF A. Fergusson	25 Nov 2021	NA	
1A	Re-Issued for Review	AS A. Stembridge	AF A. Fergusson	FL F. Losty	30 Sept 2022	NA	
1	Re-Issued for Use	AS A. Stembridge	AF A. Fergusson	FL F. Losty	18 Nov 2022	NA	
2	Re-Issued for Use	AS A. Stembridge	AF A. Fergusson	FL F. Losty	27 Apr 2023	NA	
3	Re-Issued for Use	A. Stembridge	A. Fergusson	F. Losty	15 Sept 2023	NA	

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Appendices

Revision History	
Revision 0	
Location	**Description**
-	Issued for Use
Revision 1	
Location	**Description**
General	Report updated to include hazardous scenarios on board the FSRU (and LNGC) and toxic release scenarios. ORF scenarios updated based on berth issued for construction design deliverables.
Revision 2	
Location	**Description**
General	Report updated to provide further clarity based on comments provided by Fire and Rescue New South Wales including key elements to be included in the emergency response arrangements. Report also updated to remove HOLDs.
Section 1	Table 1-1 added to document where items in the Infrastructure Approval SS 9471, Schedule 3, Condition 21(a) are addressed in the report. Reference to Schedule 3, Condition 23(a) added to detail how this study will highlight specific items to be included in the emergency response arrangements.
Section 2	Section 2.1 added to highlight operating condition variations depending on seasonal demand. Figure 2-2 updated to present pipeline route based on approval of MOD4.
Section 4	Section 4.2.6 revised to specific different oil types on board FSRU. Section 4.4 updated to include further information regarding selection of impact criteria for thermal radiation and explosion overpressure. Section 4.5.2.5 added to provide further information of ESD response times and selection of 5 minutes to assess change in fire impacts over time.
Section 5.2	Figure 5-1 added to highlight locations of key infrastructure at which impacts have been assessed in this report and to show how critical firefighting equipment has been separated from the process.
Section 5.4	Section updated to include further information regarding vulnerability of fire and gas detection systems.

Revision History	
Revision 2 Cont.	
Section 5.5	Section updated to include further information regarding redundancy of control systems. Figure 5-4 added to highlight fire and gas / ESD interactions between FSRU, berth and Jemena EGP control room.
Section 6.2	Section updated to include further information regarding primary control point during emergency event on berth and control of tower mounted fire water monitors. HOLD 4 and HOLD 6 removed as details regarding fire water pump arrangements confirmed.
Section 6.5	Section updated to remove HOLD 1 and detail consultation with FRNSW. This consultation will be ongoing for the development of the emergency response arrangements for the berth.
Section 7	Section updated to provide further clarity regarding the FSRU (and LNGC) fire detection and prevention measures on scenario basis. Figure 7-17 and Figure 7-18 updated based on findings from the PKGT Final Hazard Analysis.
Section 8	Section updated to provide further clarity regarding the ORF fire detection and prevention measures on scenario basis. Figure 8-11 and Figure 8-12 added based on findings from the PKGT Final Hazard Analysis.
Section 11	Section updated to add summary of key elements to be included in the emergency response arrangements to be developed in consultation with FRNSW and PANSW.
Appendices	Appendix C updated to include berth escape route layouts. Appendix E updated to include berth fire water pump curves.
Revision 3	
Location	**Description**
General	Report updated to remove HOLDs.
Section 4.3	Table 4-2 updated to remove HOLD and present vendor details of fire and gas detection system within the odourant package.
Section 4.5.2	Section updated to clarify basis for design of fire protection systems.
Section 5.4	Section updated to present vendor details of fire and gas detection system within the odourant package.
Section 6.1.2	Section updated to remove HOLD and action raised to ensure PFAS type foam will not be used on board the FSRU.
Section 8.4	Section updated to present vendor details of fire and gas detection system within the odourant package.
Section 8.5	Section updated to present vendor details of fire and gas detection system within the odourant package.
Appendix A	Appendix updated to provide further clarity regarding the definition of worst case consequences.

1. 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)) which 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 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 [19] is subject to a number of conditions including Condition 21(a) which requires the development of a Fire Safety Study which covers *"All relevant aspects of the Department of Planning's Hazardous Industry Planning Advisory Paper No. 2, 'Fire Safety Study Guidelines' and the New South Wales Government's Best Practice Guidelines for Contaminated Water Retention and Treatment Systems. The Fire Safety Study must be developed in consultation with Fire and Rescue NSW and the Port Authority of NSW"*

As part of the Detailed Design scope and in compliance with Condition 21(a) of the Infrastructure Approval SS 9471 [19] AIE has engaged Worley to complete a Fire Safety Study (FSS). Table 1-1 presents the items specified in Condition 21(a) required to be included in the FSS and where they have been addressed in this report.

Table 1-1: Infrastructure Approval SS 9471, Condition 21(a) Fire Safety Study Requirements

Condition 21(a) Requirement	Section of this FSS
• Consequence analysis (including appropriate consequence diagrams) for all potential fire and explosion scenarios on the FSRU throughout its operation, including but not limited to, fire or explosion from escalation events	Section 7

Condition 21(a) Requirement	Section of this FSS
• Consequence analysis (including appropriate consequence diagrams) for all potential fire and explosion scenarios when an LNG Carrier is entering or exiting the Inner Harbour or Outer Harbour of Port Kembla and during transfer operations when alongside the FSRU;	Section 7
• Consequence analysis (including appropriate consequence diagrams) for all potential fire and explosion scenarios at Berth 101 and the gas pipeline including, but not limited to, incidents arising from equipment and operations when odorant is added to natural gas;	Section 8
• Details of all fire engineering controls and measures including but not limited to: • All relevant fire and gas detection and protection systems required under class society rules for the FSRU; • All relevant fire and gas detection and protection systems for the onshore operation;	Section 5, Section 6
• Details of the roles and duties of various parties if a fire, explosion or spillage occur, particularly occur within the harbour area; and	Section 10
• Details and outcomes of the review of the Port Kembla firefighting service in relation to berth firefighting capacity and Fire Fighting tugs.	Section 6

In addition to the above, Infrastructure Approval SS 9471 [19] is also subject to a Condition 23(a) which requires *"Prior to the commencement of operations, the Proponent must prepare and submit to the satisfaction of the Planning Secretary an Emergency Plan and detailed emergency procedures for the development prepared in consultation with Safework NSW, Fire and Rescue NSW and the Port Authority of NSW"*. At the time of issue of this revision of the FSS, the Emergency Response arrangements developed in consultation with Safework NSW, Fire and Rescue NSW and the Port Authority of NSW for the ORF are yet to be determined. Specific elements to be addressed as part of the Emergency Response arrangements are specified throughout this document and summarised as part of the key findings of the study. Noting the FSRU already has Fire Contingency Plans [51] in compliance with DNV-RU-SHIP-Pt6Ch4 Section 1.5 (Documentation, Z1601 - Operation manual includes emergency procedures). Any firefighting response onboard the FSRU is expected to be performed by the FSRU crew who are trained in compliance with the IMO International Convention of Standards of Training, Certification and Watchkeepers (STCW) for Seafarers [6] which includes advanced firefighting. Crews onboard the LNGC vessels are also expected to have the same certifications.

1.1 Objective

In addition to the requirements of Condition 21(a) of the Infrastructure Approval SS 9471 [19] and in line with NSW Planning Hazardous Industry Planning Advisory Paper No 2 (HIPAP2), the objective of this FSS is to assess that:

- All Loss of Containment (LOC) of hazardous substances and associated escalation events are understood and can be linked to the potential hazards associated with the project;
- The potential impacts of these LOC of hazardous substances and associated escalation events have been quantified; and

- Protection systems are adequate and suitable. Where additional controls are required, recommendations are made.

1.2 Scope

This FSS will include consideration of all 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.

The scope excludes hazards associated with construction, commissioning and decommissioning activities, as well as provision for future facilities.

1.3 Acronyms and Abbreviations

In this document, the following acronyms and abbreviations apply.

Table 1-2: Acronyms and Abbreviations

Acronym/Abbreviation	Definition
30B(E)	Fire extinguisher classification for use on flammable liquids (B) or electrical equipment (E)
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
CAAP	Critical Alarm and Action Panel
CCS	Cargo Containment System
CCTV	Closed Circuit Television
CFD	Computational Fluid Dynamics
DN	Nominal Diameter
DNV	Det Norske Veritas
EIS	Environmental Impact Statement
EGP	Eastern Gas Pipeline
EMERA	Evacuation, Muster, Escape and Rescue Assessment
EP&A	Environmental Planning and Assessment Act 1979

Acronym/Abbreviation	Definition
ERPG	Emergency Response Planning Guideline
ESD	Emergency Shutdown
DTL	Dangerous Toxic Load
F&G	Fire and Gas
FB	Full Bore
FEED	Front End Engineering Design
FFS	Firefighting Support
FiFi	Firefighting
FRNSW	Fire and Rescue NSW
FRP	Fibre-reinforced Plastic
FSRU	Floating Storage Regasification Unit
FSS	Fire Safety Study
FW	Fire Water
GCU	Gas Combustion Unit
GRP	Glass Reinforced Plastic
GVU	Gas Valve Unit
HAZID	Hazard Identification Study
HAZOP	Hazard and Operability Study
HIPPS	High Integrity Pressure Protection System
HMI	Human-Machine Interface
HP	High Pressure
IAS	Integrated Automation System
IDTL	Immediately Dangerous to Life
IR	Infrared
ISGOTT	International Safety Guide for Oil Tankers and Terminals
KGMS	Kembla Grange Metering Station
LFL	Lower Flammable Limit
LNG	Liquefied Natural Gas
LNGC	Liquefied Natural Gas Carrier
LOC	Loss of Containment
LOS	Line of Site

Acronym/Abbreviation	Definition
LPM	Litres per minute
MGE	Main generator engine
MHF	Major Hazard Facility
ML	Million Litres
MLA	Marine Loading Arm
NSW	New South Wales
NA	Not Applicable
NR	Not Reached
ORF	Onshore Receiving Facility
OS	Operator Station
PAGA	Public Address General Alarm
PANSW	Port Authority NSW
PFAS	Per- and Polyfluoroalkyl Substances
PFP	Passive Fire Protection
PHA	Preliminary Hazard Analysis
PJ	Petajoule
PKCT	Port Kembla Coal Terminal
PKGT	Port Kembla Gas Terminal
PKP	Port Kembla Pipeline
PSD	Process Shutdown
PSV	Pressure Safety Valve
SBC	Semi Bulk Container
SFAIRP	So Far As Is Reasonably Practicable
SIS	Safety Instrumented System
SLOD	Significant Likelihood of Death
SLOT	Specific Level of Toxicity
SOLAS	Safety of Life at Sea
STCW	Standards of Training Certification and Watchkeeping
STEL	Short-Term Exposure Limit
TBM	Tert-Butyl Mercaptan
THT	Tetra Hydro-Thiophene

Acronym/Abbreviation	Definition
TPSD	Total Process Shutdown
IR3	Triple infrared
UFL	Upper Flammable Limit
VCE	Vapour Cloud Explosion

1.4 Applicable Laws, Regulations, Codes and Specifications

The PKGT berth infrastructure has been designed to comply with national and international regulations listed in this section. Relevant project documentation is also listed. The list of codes, standards and guidelines in this document are not exhaustive and are to be considered the minimum requirements. The applicable sections of the latest edition of the codes, standards and regulations, including revision, addenda and other documents incorporated by reference, issued by the following organisation and regulatory bodies, shall be considered:

1. Regulatory Requirements;
2. Australian Standards; and
3. International Standards.

In the event of an inconsistency, conflict or discrepancy between any of the Standards, Guidelines and Regulatory requirements, the most stringent and safest requirement applicable to the project will prevail to the extent of the inconsistency, conflict or discrepancy.

The FSRU vessel is a DNV Class vessel subject to the relevant Rules for Classification including the additional Regas Notation [1, 2]. Marine Order 15 (Construction — fire protection, fire detection and fire extinction) [7] 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 [7].

1.4.1 International Codes, Standards and Guidelines

The latest edition of international codes and standards at the time of the proposal shall apply for the following.

Ref. No.	International Standard	Description
1.	DNV-RU-SHIP-Pt5Ch7	DNV Rules of Classification – Part 5, Chapter 7 Liquified Gas Tankers
2.	DNV-RU-SHIP-Pt6Ch4	DNV Rules of Classification – Part 6, Chapter 4 Cargo Operations
3.	SOLAS	International Convention for the Safety of Life at Sea (SOLAS)
4.	ISGOTT	International Safety Guide for Oil Tankers and Terminals
5.	IGC Code	International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk
6.	-	IMO International Convention of Standards of Training, Certification and Watchkeepers (STCW) for Seafarers

1.4.2 Australian Standards and Guidelines

Ref. No.	Australian Standard	Description
7.	-	Marine Order 15 (Construction — fire protection, fire detection and fire extinction) 2014v
8.	AS 1841.5	Portable Fire Extinguishers Part 5: Specific Requirements for Powder Type Extinguishers

Ref. No.	Australian Standard	Description
9.	AS 1940	Flammable Liquids Storage and Handling
10.	AS 2304	Water Storage Tanks for Fire Protection Systems
11.	AS 2419.1	Fire Hydrant Installations
12.	AS 2444	Portable fire extinguisher and fire blankets
13.	AS 2941	Fixed Fire Protection Installations – Pump Set Systems
14.	AS 3846	The handling and transportation of dangerous cargoes in port areas
15.	AS 60079.10.1	Explosive Atmospheres – Classification of Areas – Explosive Gas Atmospheres
16.	-	NSW Planning, Hazardous Industry Planning Advisory Paper No 2 – Fire Safety Study Guidelines
17.	-	NSW Planning, Hazardous Industry Planning Advisory Paper No 4 – Risk Criteria for Land Use Safety Planning
18.	-	Regulation of PFAS firefighting foams

1.4.3 Project Documents

Ref. No.	Document Number	Description
19.	-	Infrastructure Approval, Application SSI 9471
20.	PKGT-AIE-STE-TEC-SPC-0001	PKGT Project Technical Basis, May 2022
21.	PKGT-AIE-ORF-TEC-TNO-0002	PKGT Technical Note - Parameters of the Odorant Injection System for Hazard Studies, Aug 2022
22.	PKGT-AIE-BTH-FIR-MEM-0001	PKGT Fire Water Supply, May 2022
23.	GAS-599-RP-HZ-009	Project Marlin, EGP Reversal Facilities, Detailed Design, HAZOP Study Report, Jul 2021
24.	GAS-556-RP-RM-002	Port Kembla Pipeline - Detailed Design SMS Report, July 2022
25.	PKGT-LOG-ORF-PRO-PHL-0001	PKGT Wharf Topside Process Design Philosophy, Sept 2022
26.	PKGT-LOG-ORF-PRO-LIS-0003	PKGT ORF Cause and Effect Matrix, Sept 2022
27.	PKGT-LOG-ORF-PEQ-DGA-0001	PKGT General Arrangement Plan, January 2022
28.	PKGT-LOG-ORF-SAF-RPT-0001	Fire and Gas Detection Coverage Assessment, Sept 2022
29.	PKGT-LOG-ORF-ELE-LAD-0002	PKGT Wharf Topside E&I Building Layout, May 2022
30.	401010-01496-SR-PHL-0001	PKGT FEED Safety Philosophy, Nov 2018
31.	401010-01496-SR-RPT-0002	PKGT FEED Preliminary Hazard Analysis Report, Oct 2018
32.	401010-01496-SR-TEN-0002	PKGT FEED, Preliminary Hazard Analysis Report – Addendum, Feb 2019
33.	401010-01496-SR-TEN-0003	PKGT FEED Preliminary Hazard Analysis Report – Addendum 2 – Seasonal Variations, Jan 2020
34.	401001-01093-SR-HZD-0001	PKGT Feasibility Phase HAZID Study Report, Apr 2018

Ref. No.	Document Number	Description
35.	401010-01496-SR-RPT-0003	PKGT FEED HAZID and HAZOP Studies Report, Dec 2018
36.	PKGT-WOR-ORF-SAF-RPT-0001	PKGT Project HAZOP Study Report, Mar 2022
37.	PKGT-WOR-ORF-SAF-RPT-0003	PKGT Project HAZID Study Report, Mar 2022
38.	PKGT-WOR-ORF-SAF-RPT-0010	PKGT Project Escape, Muster, Evacuation and Rescue Analysis, Dec 2022
39.	PKGT-WOR-ORF-SAF-RPT-0015	PKGT Project PFP Requirement Assessment, Sept 2022
40.	PKGT-WOR-ORF-SAF-RPT-0017	PKGT Project "Class A" Fire Fighting Tug Support Risk Assessment Report, Sept 2022
41.	PKGT-WOR-ORF-SAF-RPT-0018	PKGT Project Final Hazard Analysis, Sept 2023
42.	PKGT-WOR-ORF-SAF-TNO-0002	PKGT MOD4 Technical Note, Nov 2022
43.	PKGT-ADV-PMT-SAF-PHL-0002	PKGT Fire and Gas Detection Philosophy, May 2022
44.	PF10110	SN2220 Höegh 170,000 CBM LNG FSRU, General Arrangement, July 2019
45.	MB60100	Höegh Galleon Piping Diagram of Hull Part (Booklet), July 2019
46.	2012-0183 / 13YDBV2-1	DNV HAZID for LNG FSRU, Feb 2012
47.	EF00109	Höegh Galleon Blowdown, ESD and PSD Philosophy, July 2019
48.	-	SN2220 Höegh 170,000 m^3 LNG FSRU, Relief and Blowdown Calculation Report, Sept 2017
49.	GS16092.FS03	Outline Specification for Höegh Galleon, 170,000m3 LNG FSRU, Chapter 4.4 Fire Extinguishing System, Sept 2017
50.	-	AIE – Port Kembla FSRU Safety Philosophy v2, Aug 2022
51.	-	Höegh LNG FSRU Contingency Plans, Feb 2022
52.	13.07.01	Höegh LNG Storage and Handling Chemicals, Paints and Hazardous Substances
53.	J-000489-CTR 2-Met.Data	Arriscar Memo: Meteorological Data for Port Kembla, Aug 2022

1.4.4 Technical Papers and Other References

Ref. No.	Document Number	Description
54.	ICE000102	Spotleak 1005 MSDS
55.	-	CMPT, A Guide to Quantitative Risk Assessment for Offshore Installations, 1999
56.	-	G.A. Melham, H. Ozog and S. Saraf, Understanding LNG Rapid Phase Transitions, Hydrocarbon Processing (2006)
57.	-	UK HSE Toxicity levels of chemicals https://www.hse.gov.uk/chemicals/haztox.htm
58.	CPR 14E	TNO Yellow Book, Methods for the Calculation of Physical Effects
59.	-	A. Ronza, S. Carol, V. Espejo, J.A. Vilchez and J. Arnaldos, A Quantitative Risk Analysis Approach to Port Hydrocarbon Logistics, Journal of Hazardous Materials, Jan 2006.

Ref. No.	Document Number	Description
60.	CPR 18E	TNO Purple Book, Guidelines for Quantitative Risk Assessment
61.	-	AIChe Wiley, LNG Risk Based Safety – Modelling and Consequence Analysis (2010)
62.	-	Letter from NSW Department of Planning and Environment to Alexandra Lovell (AIE), Subject: Safety Management Study for Port Kembla Gas Terminal (SSI-9471), Sept 2022

2. Facility Description

2.1 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 [41]. It is a DNV Class vessel subject to the relevant Rules for Classification including the additional Regas Notation [1, 2] 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 2-1).

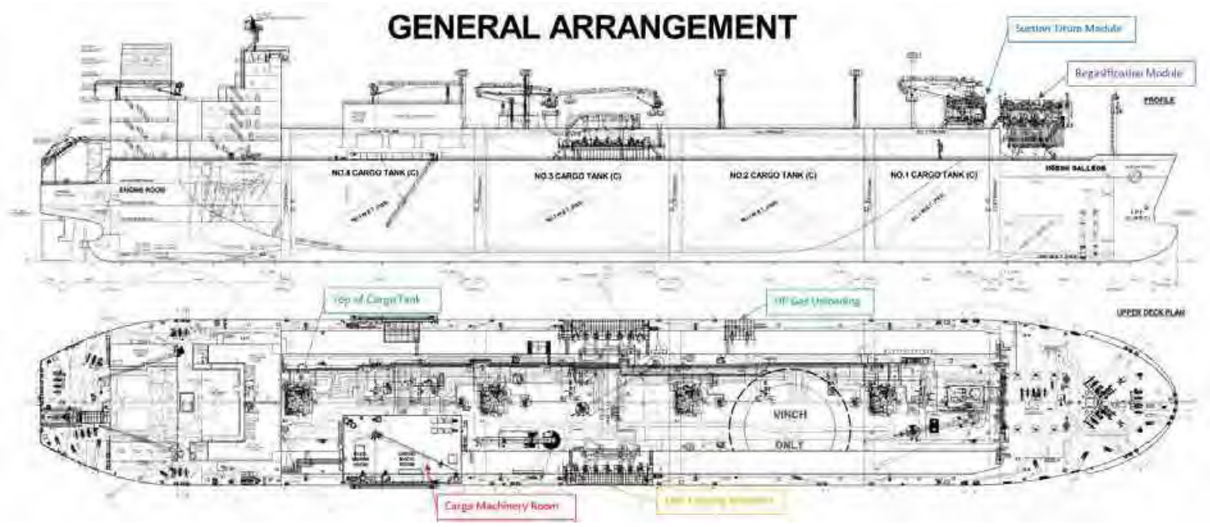

Figure 2-1: FSRU General Arrangement

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 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.

2.1.1 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 Preliminary Hazard Analysis [33] and the PKGT Final Hazard Analysis [41].

Table 2-1 summarises the expected FSRU operating conditions, LNGC deliveries and quantity of 500L odourant containers required based on the seasonal demand.

Table 2-1: Seasonal Variation in Production

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

2.2 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, 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.

The intent of the ORF is for odourant to be injected into the natural gas 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 2-2.

Nitrogen from BOC will be injected into the PKP at Cringila for Wobbe Index correction as required.

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

2.3 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 land adjoining Berth 101 to the east is currently managed by NSW Ports.

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

The surrounding land use is primarily categorised as industrial. There are no significant commercial spaces that routinely have large number of people present. Seawall road to the east of Berth 101 is a public road managed by NSW Ports. 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, which is used 2 to 5 times a year.

Port Kembla Inner Harbour has numerous other berths and associated industrial facilities.

A Preliminary Hazard Analysis (PHA) was carried out during Front End Engineering Design (FEED) [31, 32, 33]. Risk modelling conducted was assessed against the Risk Criteria for Land Use Safety Planning outlined in the NSW Planning, Hazardous Industry Planning Advisory Paper No 4 (HIPAP4) [17] including injury and escalation propagation risk. These studies supported the EIS, and project approval was granted from the Minister for Planning and Public Spaces on the 24th of April 2019.

2.4 Personnel

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 onsite. 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. Methodology

The steps taken for this FSS are in compliance with those outlined in the NSW Planning, Hazardous Industry Planning Advisory Paper No 2 (HIPAP2) [16]. Table 3-1 presents each step and details the corresponding section of this report.

Table 3-1: HIPAP2 Fire Safety Study Process [16]

Step	Description	Section of this FSS
1	Hazard identification and analysis of consequences of incidents	Section 4
3	Identification of fire prevention and mitigation strategies / measures	Section 5
4	Identification of fire protection and suppression strategies / measures	Section 6
6	Selection of measures to be implemented	Section 7 (FSRU / LNGC) & Section 8 (ORF)
7	Calculation of the fire water demand and assessment of adequacy of the supply (mains and static)	Section 6
8	Details of contaminated fire water containment system	Section 9
9	Details of first aid fire protection arrangements and equipment	Section 10

4. Hazard Identification

4.1 Hazard Identification

A number of Hazard Identification (HAZID) and Hazard and Operability (HAZOP) workshops [34, 35, 36, 37, 46] have been held over the various phases of the project.

These workshops identified the hazardous inventories, hazardous events, and credible hazard consequences from potential LOC scenarios as detailed in the following sections. Preventative and mitigative controls documented in the HAZID and HAZOP studies are detailed further in Sections 5 and 6.

4.2 Hazardous Inventories

4.2.1 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 4.4.

4.2.2 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.

When LNG is warmed it returns to its gaseous state as natural gas, described in Section 4.2.1. The main hazards of handling LNG are the same as natural gas with the additional hazards of pool fire if pooling occurs and an ignition source is present.

4.2.3 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. The project has approval for a total on site storage of 2,400kg as a result of MOD4 [42] to Infrastructure Approval SS 9471 [19]. As such, a total inventory of 2,400kg has been used in this FSS. The shipping container will also contain the injection packages. Odourant shall 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 send out flowrate, supplied from the site control room to the package PLC.

The odourant selected for use is known as Spotleak 1005 [54] 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 4.4.

4.2.4 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 water is expected to be 100°C. The temperature of the glycol water 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 is expected to be contained within the space which is provided with fire detection (refer Section 5.4.1) and protection (refer Section 6.1.7). A fire in the regasification plant will be dominated by the pressurised LNG and natural gas release (refer Section 7.5). As such, glycol is not considered further in this study.

4.2.5 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) [9]. 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.

4.2.6 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) [9]. 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 its flash point and is not considered to be flammable. As such, hydraulic oil and marine fuel oils are not considered further in this study.

4.2.7 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 [52]. 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.

4.2.8 Hazardous Material Storage

The identified hazardous inventories considered for this study will be stored at the facility in various quantities as summarised in Table 4-1.

Table 4-1: 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 FSS.

4.3 Potential Loss of Containment Scenarios

A summary of the potential LOC scenarios, and associated controls identified during the HAZID and HAZOP [34, 35, 36, 37, 46] studies are provided in Table 4-2. As previously detailed, preventative and mitigative controls documented in the HAZID and HAZOP studies have been expanded as a result of this report and are detailed further in Sections 5 and 6.

Table 4-2: PKGT Project Hazards Identification [34, 35, 36, 37, 46]

Facility / Event	Cause	Preventative Controls	Possible Consequence	Mitigation Measures

LOC 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)
				• Executive actions on confirmed gas further detailed in Section 5.4 and 5.5.
				• Höegh Fire Contingency Plans (emergency response) which covers LOC events [51]

			• 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)
				• Executive actions on confirmed fire further detailed in Section 5.4 and 5.5.
				• Active fire protection including water spray and independent hydrant system, dry powder and CO_2 extinguishing systems further detailed in Section 6.1.
				• 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 [51]

			• 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).
				• Executive actions on confirmed gas further detailed in Section 5.4 and 5.5.
				• Cargo machinery has CO_2 extinguishing system further detailed in Section 6.1.

LOC on LNGC	• Refer LOC on FSRU. Only approved vessels in accordance with DNV Rules for Classification [1, 2] 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). The ESD link is further detailed in Section 5.5			

Facility / Event	Cause	Preventative Controls	Possible Consequence	Mitigation Measures

LOC 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). Executive actions on confirmed gas further detailed in Section 5.4 and 5.5.

			• 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). Executive actions on confirmed fire further detailed in Section 5.4 and 5.5. • Active fire protection including tower mounted fire water monitors and hydrant system further detailed in Section 6.2. Noting, FRNSW is the statutory firefighting authority for the PKGT ORF.

LOC 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 (refer Section 6.4)
			• Unignited gas release	• Acoustic, line-of-sight (open path) and point gas detectors installed (PKGT-LOG-ORF-SAF-LAD-0001). Executive actions on confirmed gas further detailed in Section 5.4 and 5.5.

			• 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). Executive actions on confirmed fire further detailed in Section 5.4 and 5.5. • Active fire protection including tower mounted fire water monitors and hydrant system further detailed in Section 6.2. Noting, FRNSW is the statutory firefighting authority for the PKGT ORF.

LOC at Odourant Storage and Injection	• Small (10mm)
	  ◦ Corrosion
	  ◦ Fatigue or defective material
	  ◦ Flange leak
	• Medium (25mm)
	  ◦ Leak from small-bore fitting
		• 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 for container 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
Weather / natural events	• Extreme weather • Lightning • Flooding • Earthquake	• Engineering design to relevant codes and standards • Drainage	• Refer above consequences	• Lightning protection • Emergency response plans

4.4 Potential Hazardous Consequences

Release of LNG, natural gas and odourant can potentially lead to flammable and 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.

4.4.1 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, this is not considered further. The cargo machinery room, and engine room have gas detection provided (refer Section 5.4).

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

4.4.1.1 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 being 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 the flammable limit of the cloud. Flash fire durations are short, in which the flame rapidly passes through the fuel without generating damaging overpressures. While high levels of radiant heat result the events do not result in structural and equipment damage [58].

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

Table 4-3: 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

4.4.1.2 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 4-4 are based on HIPAP4 [17].

Table 4-4: Explosion Overpressure Criteria [17]

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

4.4.2 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.

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 4-5 are based on HIPAP4 [17]. This FSS assesses impacts of the 4.7kW/m^2 (personnel) and 23kW/m^2 (equipment) radiant heat levels, direct jet fire and/or pool fire impingement. Noting the 23kW/m^2 radiant heat level was selected over the 12.6kWm^2 due to equipment materials of construction onsite. The 3kW/m^2 radiant heat level contours are provided for information in compliance with AS 1940.

The time to fail a steel beam, pipe or process vessel by direct jet or pool fire impingement are 5 and 10 minutes respectively [55]. This study considers jet fire release conditions at 5 minutes (post initial release) to review potential for escalation and impacts to steel structures including the MLAs and tower mounted fire water monitors (refer Section 4.5.2.5).

Table 4-5: Radiant Heat Criteria [17]

Radiation (kW/m²)	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 [9]	• Nil
4.7	• Pain in 15-20 seconds • Injury after 30 seconds exposure (second degree burns minimum)	• Nil
12.6	• Significant chance of fatality with extended exposure • High chance of injury	• Temperature of wood rises to point where it can be ignited by a naked flame after long exposure • Thin steel with insulation on non-fire side may reach thermal stress level high enough to cause structural failure
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

4.4.3 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 to reduce risk of pool fires on board the FSRU. Subsequent consequences of this are likely to be flammable dispersion (refer Section 4.4.1) or rapid phase transition (refer Section 4.4.4). 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 2.1.

The ORF odourant is stored within a shipping container, potential pools will 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 shall 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 4-5 apply.

4.4.4 Rapid Phase Transition

Rapid phase transition was assessed in the FEED PHA [31] and the findings have been reproduced for this FSS.

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 [56].

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.

4.4.5 Toxic Gas Dispersion

Spotleak 1005 [54] 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.

UK HSE Specified Level of Toxicity (SLOT) and Significant Likelihood of Death (SLOD) Dangerous Toxic Loads (DTLs) data [57] indicates the DTL for TBM is 6 times higher compared to 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 [57]. The HIPAP4 injury risk criteria specify exposure to a short duration and hence AEGL thresholds with 30 minutes exposure time have been used.

Table 4-6: Toxic Criteria

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

4.4.6 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. In this FSS, the impacts of the secondary fire event are considered to as being represented by the consequence analysis carried out for that inventory (being impacted). As the odourant storage and injection equipment is located within a shipping container, it is not expected that external natural gas jet fires will directly impact the odourant storage and injection equipment and 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. Release durations once detection and shutdown has been initiated are further detailed in Appendix A.1.

Other escalation events considered in this FSS include Boiling Liquid Expanding Vapor Explosion (BLEVE) and vessel rupture.

BLEVE is an escalation scenario that occurs as a result of prolonged flame impingement on above ground pressurised vessels and can result if a flame from a jet fire or pool fire impinges on a pressurised vessel containing a volatile flammable liquid. If the flame remains in contact with the part of the vessel containing liquid then the heat is transferred into the liquid and is dissipated through the effect of increasing the liquid temperature and, ultimately, boiling the liquid, thus preventing the steel from overheating to the point of failure. However, if the flame is in contact with any part of the vessel above the liquid level, then the steel could rapidly (in the case of direct jet fire impingement) overheat and fail, causing a sudden release of the pressure and material in the vessel. This would cause some or all of the liquid to immediately vapourise, forming a large expanding fireball.

BLEVEs of hydrocarbons up to butane and potentially pentane are credible. However, BLEVEs of heavier (C6+) hydrocarbons such as crude oil or petroleum do not occur. Therefore, odourant storage tank BLEVE has not been considered as a credible escalation scenario due to the flash point and boiling point of the odourant (Spotleak1005 [54]) which is comparable with a C6 hydrocarbon. Should there be an odourant tank pool fire within the shipping container, heating of the stored Spotleak1005 [54] “can cause expansion or decomposition”, noting the decomposition temperature 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. The design pressure of the odourant SBCs is 3.3 MPag. The resultant fire events are considered in Section 8.4.

BLEVE of the LNG cargo storage tank requires a fire event to occur (i.e. either jet fire at ORF or pool fire on water from FSRU). However, it also requires failure of numerous engineering design features including the tank / double hull of the FSRU vessel and sufficient heating to be applied to a 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 [61]. As such, BLEVE of the LNG cargo storage tanks has been excluded from this study.

4.5 Hazardous Consequence Analysis

4.5.1 Process Conditions and Isolatable Inventories

The hazardous inventories, hazardous events, and credible hazard consequences from potential LOC identified above are further refined into representative release scenarios to be modelled in DNV PHAST and summarised in Table 4-7. 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 natural gas export pressure presented in Table 4-7 is based on the highest discharge pressure that can be achieved by the regasification plant on the FSRU which will occur during the 'low season' (refer Table 2-1, Section 2.1.1). During 'high season', the throughput of the regasification plant will be higher. However, the resulting discharge pressure from the FSRU will be limited to 100 barg due to limitations and performance characteristics of plant equipment. The worst case discharge pressure is used for the FSS.

The odourant is stored at 2.5barg with an operating temperature ranging from 1 – 43°C. However, 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 isolatable inventories have been used in this FSS. Noting isolatable inventories for the FSRU were considered in Addendum 2 to the FEED PHA [33].

- 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 the regasification plant. The volume is calculated from the piping length estimated in the PHA parts count and estimated volume size of the regasification suction drum [31].
- Downstream of the booster pumps, the available 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 [31].
- 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 [48] is used and has a blowdown orifice area of 670 mm^2.
- 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 4-7: Release Scenarios

No.	Release Location	Release Scenario	Pressure (barg)	Temp. (°C)	Isolatable Inventory (m^3)
1	FSRU	BOG from cargo tanks via vapour header to cargo machinery room (compressor suction conditions)	0.1	-158.5	47
2		LNG from cargo tank via liquid header to regasification plant (including cargo spray main, and LNG loading headers)	5.5	-160	47
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

No.	Release Location	Release Scenario	Pressure (barg)	Temp. (°C)	Isolatable Inventory (m^3)
4		LNG from regasification booster pumps	120	-160	3
5		NG from regasification plant to FSRU ESD Valve	120	10	56.6
6	MLA	NG from FSRU ESD Valve to ORF (up to SDV-064001 / SDV-064002) including MLA	120	10	5.7
7	ORF	ORF Pipework (from SDV-064001 / SDV-064002 to SDV-064007)	120	10	4.7
8		PKP (from SDV-064007 to MLV-064011) (~300m)	120	10	49
9a		Odourant Storage & Pipework	2.5	1	2400 kg
9b		Odourant Dosing	120	10	2400 kg
10	Harbour	Ship Collision	0	-160	42500
11		Ship to Ship Loading Hose Failure	2.4	-160	42500

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.

4.5.2 Modelling Conditions

4.5.2.1 Leak Characteristics

Various leak sizes were considered in the FEED PHA risk assessments [31, 32, 33] and have been maintained for this study. The representative hole size are presented in Table 4-8 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 4-8: Leak Size

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

A hole size of 25mm is considered as the design hole size for layout considerations as statistically this size includes 95% of releases, is consistent with good industry practice and provides a practicable basis. Fire protection systems (refer Section 6) are designed in compliance with the relevant Australian Standards or DNV Rules for classification and are detailed throughout this study where applicable.

4.5.2.2 Elevation and Orientation

Three different release orientations were modelled as follows:

- Horizontal;
- Vertical (up); and
- Vertical (down).

The exceptions to this are a leak due to a ship collision, which is all assumed to be in a horizontal direction.

Three different 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
- 1m above grade for all releases from the ORF.

4.5.2.3 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 [53]. The weather parameters presented in Table 4-9 were used as the basis for the consequence modelling. Note solar radiation is excluded from the modelling.

Table 4-9: Weather Parameters

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

4.5.2.4 Explosion Modelling

Vapour cloud explosion (VCE) was included in the FEED PHA [31] consequence analysis. The results have been reproduced for this FSS. Noting it has been confirmed by Höegh that Computational Fluid Dynamics (CFD) explosion modelling has not been carried out for the FSRU. VCE modelling carried out using DNV PHAST is generally more conservative than CFD. DNV PHAST does not account for attenuation provided by structures such as the odourant shipping container or the machinery room.

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

- Piping directly above each LNG cargo tank;
- Cargo machinery room;
- Suction drum module;

- Regasification module (top and bottom half); and
- Space between FSRU and LNGC.

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.

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 4-10 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 [58].

Table 4-10: 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 4-1 shows the theoretical peak overpressure which can be achieved for each blast strength number. The figure shows that a blast strength of at least 4 is necessary to achieve a peak overpressure greater than 7kPa (threshold level for overpressure likely to result in personnel injuries from flying debris) while a blast strength of approximately 5 is necessary to achieve a peak overpressure of 21kPa (threshold level for overpressure required to distort reinforced structures and fail storage tanks). These impacts are based on HIPAP4 [17] as summarised in Table 4-4, Section 4.4.1.2. With the exception of the space between the FSRU and LNGC, all of the congested / enclosed areas identified with the potential for a VCE have a blast strength greater than 4. Based on this, the localised overpressure generated from an explosion in the space between the FSRU and LNGC is not considered severe enough to damage the cargo tanks of the vessel (i.e. 21kPa or greater) thus leading to further LOC and escalation. Therefore, this scenario has not been considered further.

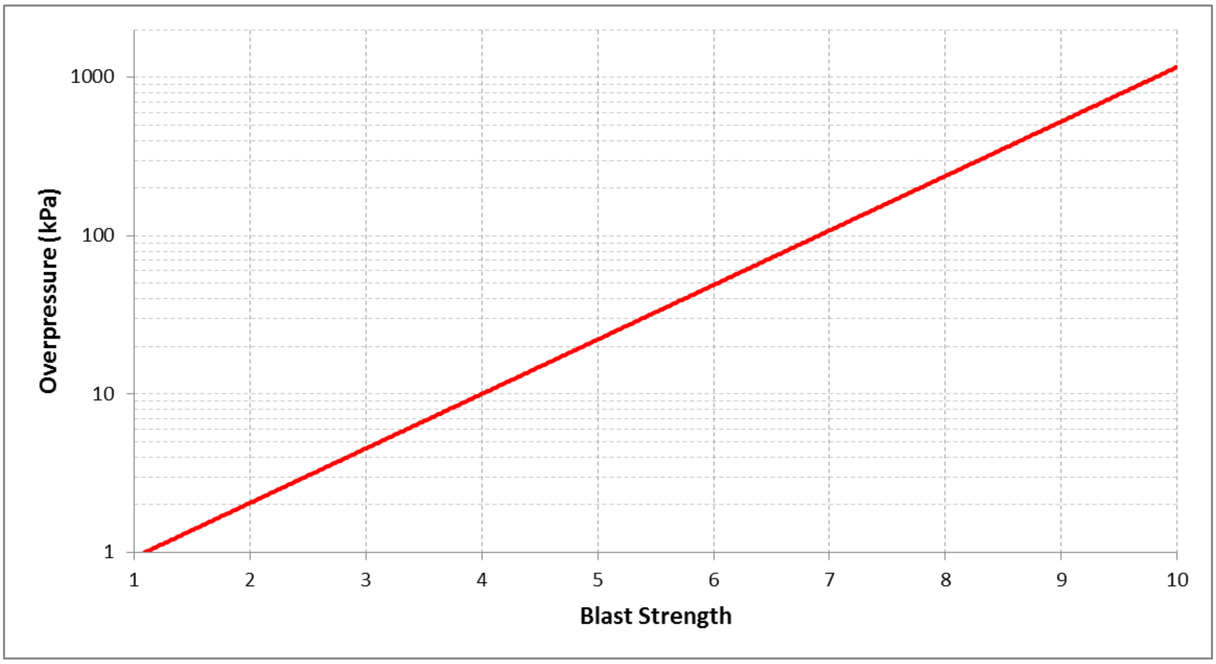

Figure 4-1: Theoretical Peak Overpressure [58]

VCE Stoichiometric Flammable Mass

Table 4-11 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 2-1).

Table 4-11: 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			5.5
Cargo Machinery Room	2484	373	2112			164
Suction Drum Module	331	50	282	0.816	0.095	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 2-1).

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

4.5.2.5 Fire Impacts Following Shutdown and Isolation

Jet / spray fire impacts were modelled at the initial release rate prior to depressurisation. However, when Emergency Shutdown (ESD) systems are activated (refer Section 5.5), hazardous inventories will be isolated, and pressure sources (i.e. pumps) are de-energised. The FSRU vessel and the ORF are equipped with ESD valves in strategic locations to isolate and minimise the available flammable inventory in case of an emergency event (refer Section 5.1). In the case of confirmed fire, FSRU / LNGC Total Plant Shutdown (TPSD) and ORF ESD will automatically close these valves. In addition, blowdown of the regasification plant (trains, suction drum) and HP gas export area (including metering skid, and HP gas export manifold) can be automatically (confirmed fire in the above areas) or manually (operator) initiated. As ESD / depressurisation occurs, the 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). Depressurisation occurs as inventory is lost from the isolatable section via the depressurisation and via the leak.

A detailed summary of the Fire and Gas (F&G) detection system is provided in Section 5. However, based on a confirmed fire response time of 60 seconds until completion of detection, isolation and start of depressurisation (refer Section 5.4) and the assumption that impairment of equipment / vessels is assumed to occur after 5 minutes of direct jet fire impingement. The potential for impairment from jet / spray fire impacts following shutdown, isolation and depressurisation is therefore based on the release rate at 240 seconds post isolation (5 minutes post initial release).

In addition to the above, for the liquid LNG release scenarios where the pressure source of the liquid is from pumps, the pressure is reduced to atmospheric. As liquid is typically incompressible, once the pumps trip, the inventory pressure will drop to approximately atmospheric pressure which would significantly reduce the release rate and subsequent spray fire impact distances.

4.5.3 Modelling Results

Based on the above modelling parameters applied in DNV PHAST, the extent of potential hazardous consequences have been determined. The impacts are reported at both the FSRU level and the ORF level. Detailed results are provided in Appendix A. These results also indicate how the release rates and impacts change within the first 5 minutes post release. Each potential fire scenario and corresponding fire prevention and mitigation strategy is further reviewed in detail in Section 7 and Section 8 for the FSRU (and LNGC) and ORF respectively.

5. Fire Prevention and Mitigation Strategies

Typical of hydrocarbon processing plants, the hazard management for the PKGT facilities are predominantly based on control measures that reduce the potential for a LOC scenario, and subsequent fire to eventuate.

The following section outlines the key fire prevention and mitigation strategies, which primarily comprise safety in design measures, and reducing the potential for events to escalate through:

- Minimisation of leak sources and inventory;
- Facility layout;
- Control of ignition sources;
- Gas and fire detection; and
- Emergency shutdown systems.

5.1 Minimisation of Leak Sources and Inventory

The PKGT Safety Philosophy [30] outlines the considerations that have been adopted to ensure the design shall minimise the number of sources of release of flammable materials So Far As Is Reasonably Practicable (SFAIRP) and include the following:

- Minimise number of known common leakage sources (i.e. flanges, pumps, valves);
- Use of high quality components (i.e. dual-seal pumps or seal-less pumps);
- Systems in hydrocarbon service to be hydrotested and leak tested prior to use;
- Optimise pipe routing and decrease inventory and storage of hydrocarbons;
- Minimise corrosion potential through material selection;
- Minimise facility / LNGC relative movement during unloading; and
- Implement stringent procedures for inspection and maintenance of the FSRU hull for prevention of corrosion and pitting that causes leaks.

The safety philosophy for the FSRU provided by Höegh [50] outlines the following additional considerations adopted, specific to the FSRU process:

- Use of collection trays for possible cryogenic leak sources in the process plant;
- General focus on simplicity of the design and operating activities; and
- Use of well proven technology and techniques.

The FSRU vessel process and the ORF is equipped with ESD valves in strategic locations to isolate and minimise the available flammable inventory in case of an emergency event. The following isolatable inventories include the:

- LNG liquid and vapour headers;
- Regasification plant (from suction drum to FSRU discharge ESD valves);
- MLAs;
- ORF pipework; and
- PKP tie-in facilities.

The regasification plant has the largest inventory onboard the FSRU. However, this system is provided with automatic blowdown in accordance with 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) such that the inventory can be depressured within 15 minutes. A dedicated vent is provided for this onboard the FSRU. The cargo machinery room contains approximately 30% of the leak sources in the

FSRU process as rotating equipment is typically considered a high risk of release due to the number of fittings and connections associated with the compression equipment. The cargo machinery room has gas detection provided (refer Section 5.4.1). Confirmed gas in the cargo machinery room will activate an alarm at the Critical Alarm and Action Panel (CAAP) and isolate the gas inventory. The cargo machinery room is also provided a high pressure CO_2 extinguishing system which is manually activated [49].

Onshore, the PKP tie-in has the largest inventory with approximately 300 m of pipeline available. The above ground section of the PKP is provided with Passive Fire Protection (PFP) to protect against potential FSRU and ORF jet fire impacts and reduce escalation risk [39]. The number of leak sources are minimal as the piping is fully welded downstream of the ESD valve and in clean dry service significant corrosion is not expected.

5.2 Facility Layout

The layout of the FSRU and ORF are arranged to reduce the probability and consequence of undesirable events through the separation and orientation of buildings and equipment. Key locations (sensitive receptors) assessed in this study are overlayed, marked-up and presented in Figure 5-1.

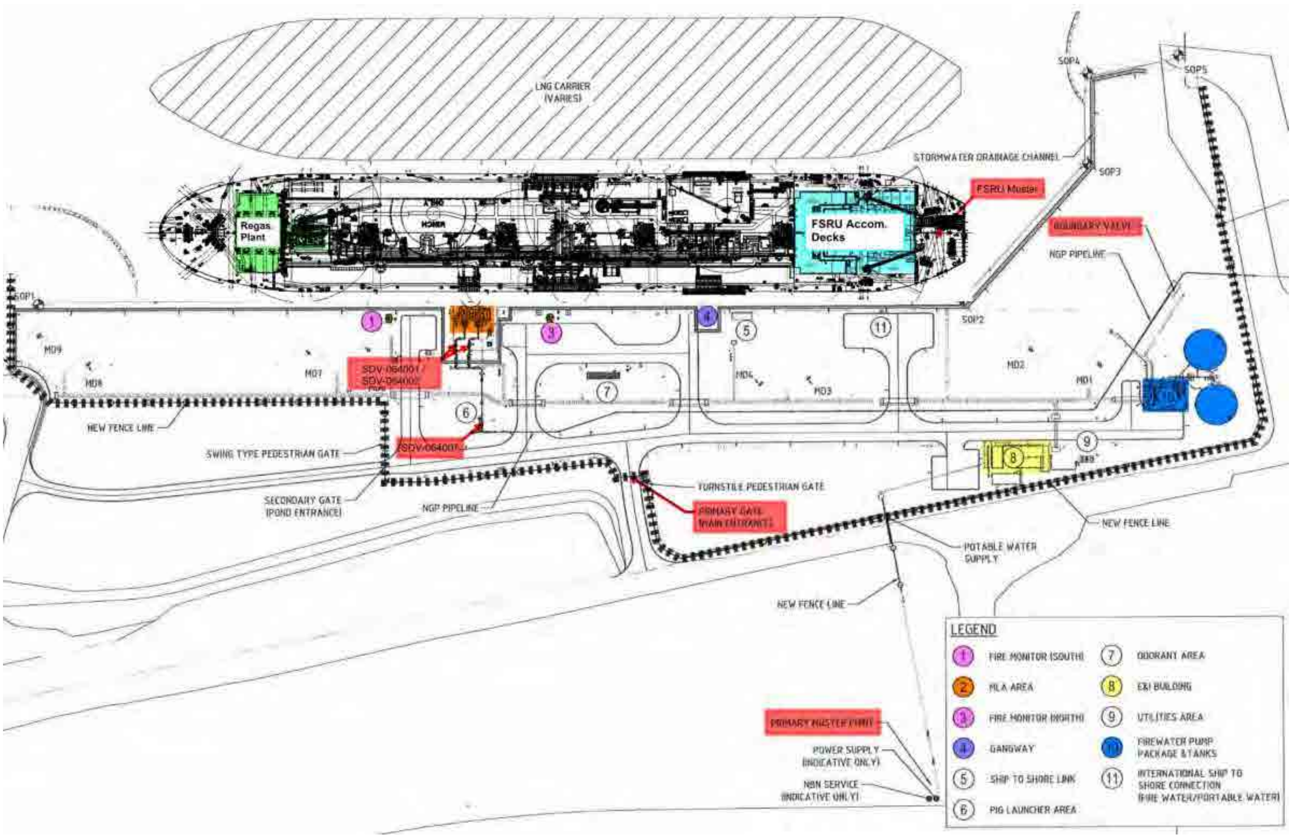

Figure 5-1: PGKT Sensitive Receptor Locations

The safety philosophy for the FSRU provided by Höegh [50] specifies the layout of the FSRU is designed with respect to reducing risk 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 adequate arrangements for escape and evacuation. Noting DNV-RU-SHIP-Pt6Ch4 Section 7 (Regasification Plant), specify at least two escape routes shall be provided from the regasification plant. The escape routes shall be safe, direct and unobstructed, and shall be provided from each level of the regasification units to muster areas and embarkation or evacuation points.
- Facilitate effective emergency response

The FSRU Fire Control and Safety Plan is provided in Appendix B and presents the location of safety equipment on board the FSRU**.** It also shows the emergency escape routes available and how areas containing critical firefighting equipment (i.e. water spray pumps and fire water pumps) are separated from the process areas (i.e. pumps located below the main deck).

Although the ORF is designed to be operated from a remote control room and therefore is not normally manned, the layout considers the location of onsite equipment and buildings in relation to potential fire and explosion events such that mitigation measures are not impaired. They following key points are noted:

- The berth emergency control room (located in the electrical and instrument building which also contains the instrumented safety system) and other ancillary equipment (i.e. fire water pumps and tanks) are located outside of the 25mm thermal radiation contours.
- Likelihood of ignition is minimised through separation of hazardous areas from potential and known ignition sources (i.e. non-rated equipment and electrical areas)
- Potential for explosions to develop is minimised by minimising congestion and maximising natural ventilation.
- Location of muster points and evacuation routes are considered in the project Evacuation, Muster, Escape and Rescue Assessment (EMERA) [38]. Alternate muster points are available.

The general arrangement plan for the berth is provided in Appendix C and presents the location of key infrastructure**.** The ORF fire service layouts and escape route layouts are also provided in Appendix C**.** Emergency response arrangements including FRNSW access to the berth and potential emergency services staging area will be documented in the facility's emergency response procedures which will be developed and approved prior to operation per the requirements of Infrastructure Approval [19] Schedule 3, Condition 23(a).

5.3 Control of Ignition Sources

Control of ignition sources is crucial for preventing fire and explosion from occurring as a result of LOC event. Ignition control includes:

- Eliminating / reducing ignition sources where possible;
- Separating known ignition sources from process areas;
- Allocating appropriate hazardous areas on the facility; and
- Installing appropriately rated equipment within hazardous areas.

Onboard the FSRU, electrical and instrument installations are in accordance with the hazardous area zoning requirements of DNV Rules for Classification Part 5 (Ship types) Chapter 7 (Liquified gas Tankers) (hereinafter referred as DNV-RU-SHIP-Pt5Ch7). The ORF will also be hazardous area zoned and equipment appropriately rated [15]. Utility equipment and other non-hazardous area rated equipment is located outside the hazardous area zoning.

The berth emergency control room (located in the electrical and instrument building) is located outside of most of the 25mm flammable dispersion contours while the fire water pumps are located outside of all of the 25mm flammable dispersion contours. Gas detection is provided on the ORF (refer Section 5.4) and includes Line of Sight (LOS) detection between the ORF and the electrical and instrument building. Executive actions on confirmed gas are further detailed in Section 5.4 and 5.5.

The ORF entry gates are located within some of the 25mm flammable dispersion contours and vehicle access to the ORF is via roads which can also be impacted by flammable gas clouds. Emergency response arrangements including safe approach to the facility and notification of an incident will be documented in the facility's emergency response procedures which will be developed and approved prior to operation per the requirements of Infrastructure Approval [19] Schedule 3, Condition 23(a). Specific elements relating to the above will include the following:

- On detection of a LOC of hydrocarbons or odourant, site Public Address General Alarm (PAGA) and flashing beacons to be activated, including a flashing beacon to be provided and located near the entry of the ORF to alert personnel approaching the site of a potential LOC of hydrocarbons;
- Communication protocols between Jemena EGP Control Room, FSRU personnel, and third-party contractors (i.e. security). The Jemena EGP Control Room is the primary point of control during an emergency event;
- Communication protocols between primary point of control and FRNSW for notification of an incident;
- Ability to mobilise third-party security contractors to the site if required; and
- FRNSW access to the berth including potential emergency services staging area.

In addition to the above, it is recommended that further consultation is required with NSW Ports to determine response actions for potential scenarios which could impact Seawall Road to the east of Berth 101 and the ORF site. Seawall Road is a public road managed by NSW Ports. Should they decide, to maintain public access to Seawall Road once the import terminal is operational, then the emergency response arrangements need to take into consideration this particular location.

Vehicle access to the ORF is subject to AIE / Jemena access control procedures and induction. Public access is not permitted.

5.4 Fire and Gas Detection

The intent of Fire and Gas (F&G) detection systems are for the protection of personnel, the environment and assets. A F&G detection system does not prevent uncontrolled releases resulting in gas dispersion, fire or explosion. However, the system is an industry recognised and accepted method for managing and controlling these hazards. The overall goals of the fire and gas detection system are to:

- Alert personnel at a location to the presence, location and nature of the fire or gas emergency.
- Alert personnel in the area to the hazard, such that they can escape if able to do so.
- Reduce the risk to personnel by implementing executive control actions and/or shutdown events.
- Minimize asset and environmental impact.

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.

In general, gas detectors are not vulnerable to a gas release and will be suitably rated to operate safely during a gas release. While they may be damaged in a fire or explosion event, they have no function post ignition.

Flame detectors are also not vulnerable to a gas release and will be suitably rated to operate safely during a gas release. Flame detectors local to a fire or explosion event may be impaired, however are expected to operate long enough to detect a fire and activate ESD. If a detector is damaged and signal is lost, this would be counted as a vote. Noting the fusible melt links (provided on the FSRU), by design fail to provide detection.

5.4.1 FSRU F&G System

A F&G detection system on board the FSRU is provided in compliance with the DNV Rules for Classification DNV-RU-SHIP-Pt5Ch7 and DNV-RU-SHIP-Pt6Ch4 Section 7 (Regasification Plant). It forms a component of the Integrated Automation System (IAS) ESD / Process Shutdown (PSD) systems (refer Section 5.5.1). The F&G detection system is required to alert personnel and allow control actions to be initiated manually or automatically to minimise the probability of explosion and fire.

The FSRU Blowdown, ESD and PSD Philosophy [47] specifies that two types of gas detection are provided, and comprises the following:

- Centralised gas sampling type system provided to detect methane in spaces surrounding the cargo tanks inter barrier spaces and insulation spaces; and
- Fixed gas detection system provided in the accommodation, cargo machinery room, engine room and process areas.

The gas sampling system automatically takes a gas sample from each sampling point sequentially every 25 minutes. This is less than the maximum period of 30 minutes which is required by DNV-RU-SHIP-Pt5Ch7 and the IGC Code [5]. Samples are brought to the detection cabinet through a sample line system and then individually analysed. This sampling system does not initiate automatic shutdown actions, and provides alarming only.

The IR point gas detectors are located in areas where an accidental release of flammable gas can occur, accumulate or where the presence of gas cannot be tolerated. As such, IR point gas detectors are located in the following areas:

- Engine room
  - Engine room ventilation fans (port and starboard)
  - Generator engines gas valve unit (GVU) rooms (port and starboard)
  - Main generator engine (MGE) forward and rear pipe duct air inlet, and room space
  - Boiler spaces, and GVU
  - Inert gas line
  - Emergency generator room
  - Gas Combustion Unit(GCU) Space & GVU Room
- Accommodation
  - Entrance to each accommodation deck
  - At air intakes (main, aux, gallery)
- Regasification plant (including regas module and suction drum module). Noting IR line of sight is also installed to supplement the IR point detectors.
- Vent mast for the regasification plant (alarm only)
- HP export manifold

- Gas Metering unit
- Cargo Machinery Room

In most cases, a 2ooN (where typically N≥3) voting configuration is adopted [47]. Detection by a single detector will trigger an alarm which will be investigated. When there is one failed or inhibited detector, the logic reverts to 1oo2. At locations where only one or two detectors are installed, single detection shall be treated as confirmed detection. Confirmed gas will activate alarms (visual and audible) at the CAAP (indicating location of gas detection) and an ESDL alarm on the IAS Operator Station (OS). A Total Process Shutdown (TPSD) is also initiated in the event of confirmed gas within the cargo machinery room. Blowdown of process segments of the regasification system containing gas may be initiated manually in case of confirmed gas leak in hazardous areas. The CAAP is located in the Cargo Control Room (CCR) and will be manned 24/7 while in FSRU mode while berthed at Port Kembla.

The fire detection system comprises a combination of heat, smoke and flame detectors. IR flame detectors and electric thermal fuse type fusible melt links are fitted for the following hazardous process areas:

- Regas Plant including suction drum
- HP export manifold.
- Gas Metering unit
- Cargo Machinery room
- Electric Motor room (non-hazardous area)

While fusible melt links of electric thermal fuse type are only provided in the following hazardous process areas:

- LNG loading manifold areas
- At each liquid dome
- At each gas dome

Like the gas detectors, in most cases, a 2ooN (where typically N≥3) voting configuration is adopted, with exception of the fusible melt links which generally only require a single plug to melt. Confirmed fire will activate alarms (visual and audible) at the CAAP (indicating location of fire detection) and an ESDL alarm on the IAS OS. A TPSD is also initiated, and the fire water and water spray pumps are automatically started. Noting application of the water spray system is manually activated (refer Section 6.1.5). Automatic blowdown is initiated in the event of confirmed fire in the regasification plant, gas metering or HP export manifold areas.

5.4.2 LNGC F&G System

The LNGC will have an ESD, and F&G system installed in compliance with DNV-RU-SHIP-Pt5Ch7 which has the following requirements:

- Permanently installed system of gas detection and audible and visual alarms shall be fitted in the following areas:
  - all enclosed cargo and cargo machinery spaces containing gas piping, equipment or consumers;
  - other enclosed or semi-enclosed spaces where cargo vapours may accumulate including interbarrier spaces and hold spaces for independent tanks other than type C;
  - airlocks;
  - the spaces in gas fired internal combustion engines;
  - ventilation hoods and gas ducts;
  - cooling / heating circuits, [including degassing tank if fitted];

- inert gas generator supply headers; and
- motor rooms for cargo handling machinery.

- Fire detection for protection of the weather decks of the cargo area and cargo machinery spaces. As a minimum, the method of detection used on the weather decks shall cover the liquid and vapour domes of the cargo tanks, the cargo manifolds and areas where liquid piping is dismantled regularly.

5.4.3 ORF F&G System

F&G detectors at the ORF are provided to facilitate early detection of a flammable gas release or subsequent fire. A Fire and Gas Detection Coverage Assessment has been carried out to support the design and ensure sufficient coverage is provided and further details the type, level settings and safety & reliability requirements of the F&G system [28].

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.

Personnel at immediate risk of harm are not afforded any additional protection through an automatically initiated shutdown system. Primarily, protection for these personnel is provided via the local sirens and beacons, which annunciate on confirmed fire and/or gas detection. Remote personnel may be at risk if they approach the berth with no awareness of the hazard. For this reason, sirens and beacons are provided for early warning. As previously detailed in Section 5.3, safe approach to the facility and notification of an incident will be documented in the facility's emergency response procedures which will be developed and approved prior to operation per the requirements of Infrastructure Approval [19] Schedule 3, Condition 23(a).

The berth is provided with flammable gas detectors and are located in areas where an accidental release of flammable gas can occur or where the presence of gas cannot be tolerated or at the boundaries of process areas to detect a leak migrating toward not rated electrical equipment. The following types and locations of flammable gas detectors are included

- Open path gas (line of sight (LOS)) detectors are to be located to monitor the migration of any gas release cloud into non process areas with non-rated equipment or offsite;
- Point gas detectors are to be used to monitor leakage from the MLA's, and at the odourant injection point; and
- Acoustic gas leak detectors are to be used to provide general area coverage and to complement conventional gas detection methods i.e. point and LOS.

Figure 5-2 shows the location of the gas detectors as determined in the ORF Fire and Gas Detection Coverage Assessment [28]. The detailed fire and gas layouts are provided in Appendix C. Noting, the location of the IR3 flame detectors in the process area is also shown. It is noted that the layout shows the provision for gas detection in the odourant package shipping container . However, AIE has confirmed (in consultation with others) they are not progressing with this design and only heat detection cable is being provided by the vendor. Confirmed fire (by melting of the cable) will result in an alarm only. The layouts will be "as-built" to capture this change.

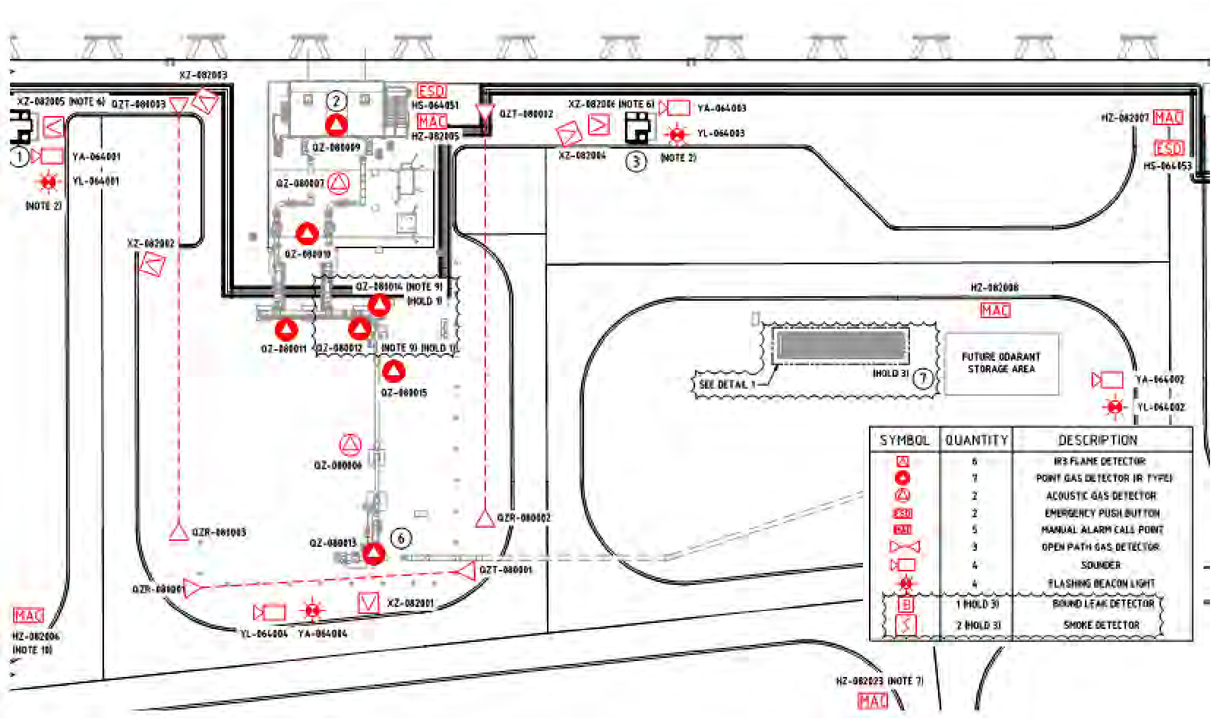

Figure 5-2 ORF Fire and Gas Detector Layout

Activation of a single detector shall initiate alarm system locally and in the Jemena EGP control room. On confirmed gas or fire detection (2ooN voting arrangement) the following executive actions are initiated:

- 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 (SDV-064007)**;**
- Stop odourant injection package; and
- Operator to use CCTV to investigate and ascertain if further mitigation actions are required.

Confirmed fire detection will also start the firewater pumps.

5.5 Emergency Shutdown System

ESD systems are provided onboard the FSRU and at the ORF to prevent escalation of and minimise the consequences of emergency situations. They do this through inventory isolation and blowdown of the regasification plant (if required) upon detection of an unsafe deviation from the process operating envelope, F&G detection (refer Section 5.4) or manual pushbutton initiation. The FSRU and ORF ESD systems are independent from one another. However, a hardwired link between the FSRU and ORF is provided for ORF ESD activation if required.

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) [47].

5.5.1 FSRU ESD Systems

The IAS ESD / PSD onboard the FSRU is divided into several levels, to form a shutdown hierarchy as presented in Figure 5-3. This allows non affected sections of the FSRU to remain operative. Each level of the ESD / PSD hierarchy is briefly described below. Noting, a shutdown initiated at any level shall initiate all lower levels, but not any higher levels.

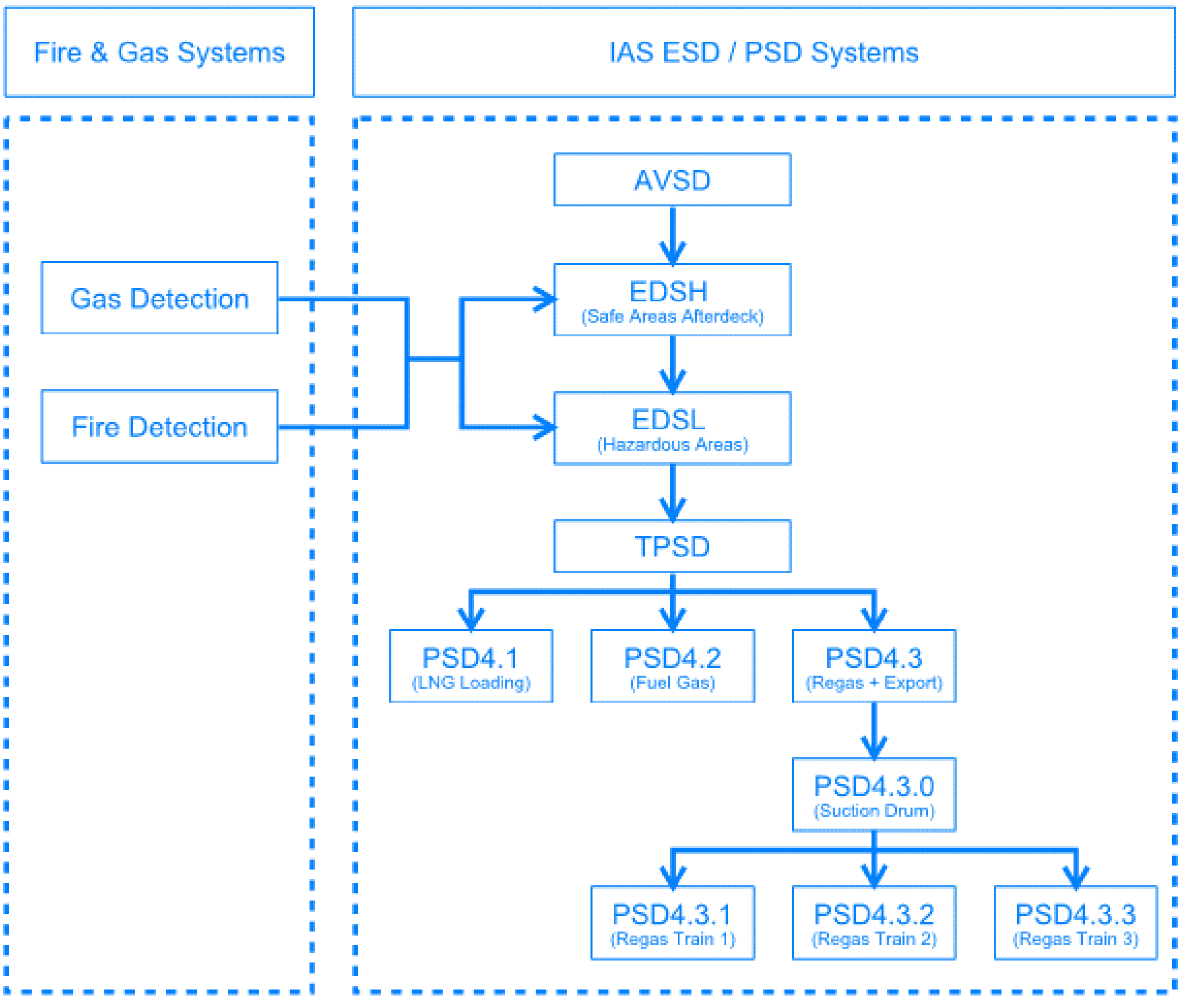

Figure 5-3: FSRU ESD / PSD Hierarchy [47]

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 a 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 shall be initiated manually if required (based on evaluation of the severity of the incident case by case).

<u>ESD Low (ESDL) (Hazardous Areas)</u>

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 logics will also automatically activate ESDL.

<u>Total PSD (TPSD)</u>

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 shall 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).

Noting 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.

As detailed above, 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). 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 shall activate the onboard alarm sounding, close the LNG transfer manifold valves (on LNGC and FSRU) and trip transfer machinery.

5.5.2 ORF ESD Systems

The ORF will have an Emergency Shutdown System which upon initiation the following executive actions are initiated [26]:

- 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 / SDV;
- Stop odourant injection package; and
- Operator to use CCTV to investigate and ascertain if further mitigation actions are required.

Noting, the MLA will be equipped with an emergency release system to allow the ship to leave the inner harbour in an emergency if required with no need for human activity in the ship's manifold area. The emergency release system will also activate if the MLAs operate close to their bounds of their physical operating envelope due to unexpected movement of the FSRU. This type of release will discharge the gas directly to atmosphere at a local vent located on the MLA. An MLA emergency release is likely to release a quantity of gas sufficient to form a flammable vapour cloud in the vicinity of the release point which will disperse primarily upwards and away from this point subject to atmospheric conditions. Depressurisation of the MLA emergency release system for maintenance will release gas through a local vent on the MLA arm away from the emergency release point.

During an emergency event at the ORF, the primary point of control will be via the Jemena EGP control room which will be manned 24/7. 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 including operation, steering and stream adjustment from fog nozzle to jet stream. Further details of this including back-up controls are provided in Section 6.2.5. Emergency response communication protocols will be documented in the facility's emergency response procedures which will be developed and approved prior to operation per the requirements of Infrastructure Approval [19] Schedule 3, Condition 23(a).

The berth emergency control room will normally be unattended and have power, general area lighting and emergency lighting provided. Lighting will also be provided externally above all access doors. Adequate ventilation and or air conditioning will also be provided. The structure will provide the operators (if onsite) with a clear unobstructed view of the berth's MLAs. Windows provided shall be laminated toughened safety glass [29].

The ORF F&G detection and alarm system will be incorporated into a dedicated F&G Detection and Alarm Panel installed within the berth emergency control room as shown in Figure 5-4. The F&G Detection and Alarm Panel will have an interface with the ORF fire pumps control panels to provide an indication of the status of each fire pump. The Panel will incorporate all required analogue addressable detection and alarm devices not associated with the F&G detection and alarm system. The Panel will also provide a telephonic or radio link to FRNSW in the event of an emergency. There is redundancy in the control system both by fibre with a wireless backup for critical systems. While the ORF Instrumented Safety Systems are on fully redundant platforms.

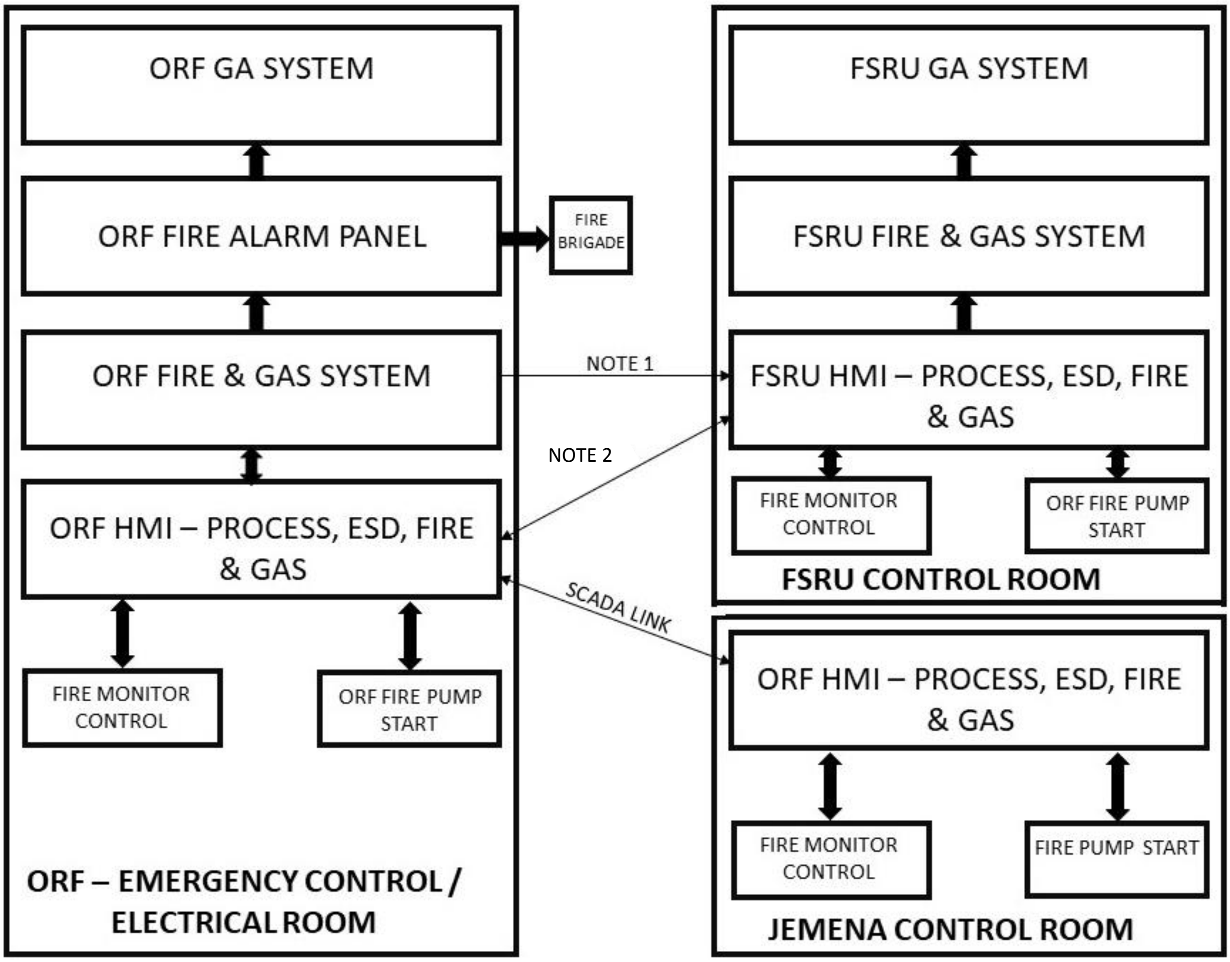

Figure 5-4: ORF / FSRU – F&G, and Fire Monitor Control Panel Logic [43]

Note 1: A hard wired link for ESD activation from the ORF to the FSRU. FSRU F&G status will be displayed on ORF HMI; and ORF F&G status will be made available on the FSRU.

Note 2: Soft Link – Modbus or similar agreed protocol.

The berth emergency control room will incorporate the HMI and CCTV visual display screens. The control system will employ visual display of the fire system functions on the HMI screen. The visual display will be enhanced via the CCTV system provided on the Berth. Indication of the FSRU F&G / ESD system status will also be provided within the berth emergency control room.

6. Fire Protection and Suppression Strategies

6.1 Ship-Based Active Fire Protection

The FSRU 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 Fire Control and Safety Plan is provided in Appendix B and presents the location of equipment on board the FSRU.

The FSRU ship-based firefighting system [49] 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 will be selected for ship-to-ship transfer to the FSRU. As such, it is expected that LNGC vessels will have fire protection equipment in compliance with requirements of DNV-RU-SHIP-Pt5Ch7 as outlined above and further detailed in the sections below.

6.1.1 Fire Water Demand

DNV-RU-SHIP-Pt6Ch4 Section 7 (Regasification Plant) requires the ship-based water spray system to be designed to cover the areas given below in addition to the areas specified in DNV-RU-SHIP-Pt5Ch7:

- Regasification units;
- Suction drum / recondenser;
- High-pressure send-out manifold;
- Process shutdown, emergency shutdown and blowdown valves;
- HIPPs valves and metering units, if fitted; and
- Storage tanks for propane or other flammable fluids, if fitted.

The system is capable of covering all areas mentioned above with a uniformly distributed water application rate of at least 10 litres /min/ m^2 for the largest projected horizontal surfaces and 4 litres /min/ m^2 for vertical surfaces. For structures having no clearly defined horizontal or vertical surface, the capacity of the water application shall not be less than the projected horizontal surface multiplied by 10 litres /min/ m^2. The Höegh Galleon Piping Diagram of Hull Part (Booklet) [45] includes a water spray demand calculation based on the above requirements and determines a total water demand of 26,314.1 LPM (1,578.85 m^3/hr). Water is applied via various spray nozzles. Appendix D includes the Höegh Galleon Water Spray System Specification Calculation which indicates the duty requirements of the water spray pumps. An excerpt from the Höegh Galleon Piping Diagram of Hull Part (Booklet) [45] is also provided in Appendix D which details the water spray pump specification.

In addition to the water spray system, fire water demand for the ship based ring main (hydrant) system, high expansion foam system and various other water curtains is determined in the Höegh Galleon Fire Pump Capacity Calculation provided in Appendix D. An excerpt from the Höegh Galleon Piping Diagram of Hull Part (Booklet) [45] is also provided in Appendix D which details the fire water pump specifications.

6.1.2 Foam Demand

On board the FSRU (and LNGC) potential fires in the engine room (including diesel generator, IGG room, purifier room) and steering gear room are intended where practical to be fought with a high expansion foam fire extinguishing system designed in accordance with DNV-RU-SHIP-Pt5Ch7. The Höegh Galleon foam system comprises the following [49]:

- A 6.2m^3 foam concentrate tank of steel construction with tar epoxy inside;
- High expansion foam concentrate.
- Two (2) foam pumps;
- A foam proportioner;
- Foam generators or foam distribution; and
- Piping, fittings isolating valves etc

An action has been raised by AIE confirm foam supplied on board the FSRU are compliant with Australian Standards and has 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. Subsequently, the foam used will not be PFAS type.

Sea water for the high expansion foam system is supplied from the emergency fire pump in the forward pump room. This case is included in the Höegh Galleon Fire Pump Capacity Calculation and is provided in Appendix D.

6.1.3 Fire Water Source

The ship-based firefighting system will be supplied by sea water.

6.1.4 Fire Water Pumps

The ship-based fire pump system is installed in the engine room floor deck, with an emergency fire pump installed in the emergency fire pump room under the steering gear room as indicated on the FSRU Fire Control and Safety Plan provided in Appendix B. These locations will have access, power, lighting, and ventilation as required to operate and maintain the pumps.

The water spray system is supplied via a 2x100% (i.e. duty / standby) arrangement. They are automatically started based on a confirmed fire event. Each water spray pump is electric motor driven and is capable of delivering ~28,333 LPM (1,700 m^3/hr) at 1000 kPag. An excerpt from the Höegh Galleon Piping Diagram of Hull Part (Booklet) [45] is also provided in Appendix D which details this water spray pump specification. Noting this is greater than the water spray demand as calculated in Section 6.1.1.

The ships fire water ring main line is also supplied via a 2x100% (i.e. duty / standby) arrangement. Noting these pumps (i.e. fire and general service pumps) can also be used for deck washing activities. Each fire and general service pump is electric motor driven and can deliver 160 m^3/hr at ~1130 kPa (115m head) and 180m^3/hr at ~900 kPa (90m head) respectively as detailed in the Höegh Galleon Fire Pump Capacity Calculation provided in Appendix D.

Pressurisation is achieved by an auto start / stop auxiliary jockey pump and hydrophore tank. In the event of the fire main line pressure dropping, a fire pump will automatically start. A local pressure gauge is installed on the fire main line to check system pressure if required. The ring main line is located through side passage way port and starboard. Branch lines from the fire ring main lead to the fire hydrants, water curtains for the side shell of cargo manifold, bilge eductors, anchor chain washing nozzles, and the regasification plant area.

6.1.5 Water Spray System

The FSRU water spray system provided for cooling, fire prevention and crew protection is installed in compliance with DNV-RU-SHIP-Pt5Ch7 and DNV-RU-SHIP-Pt6Ch4 Section 7 to cover:

- Exposed cargo liquid and vapour domes;
- Cargo manifold valves for loading and discharging;
- High pressure gas manifold;
- Cargo machinery room and electric motor room outside wall facing the cargo area (two layer water curtain);
- Essential cargo control valve;
- Front bulkhead and 3 m of side bulkheads from the front bulkhead of accommodation deck house (three layer water curtain);
- Lifeboats, life rafts and muster station facing the cargo area;
- Emergency escape routes; and
- LNG regasification plant.

Application of the water spray system is achieved by starting the FSRU water spray pumps and opening the water spray header isolation valves. Water can be delivered separately to the deck area(s) or the accommodation or it can be supplied to both areas simultaneously. The FSRU water spray pumps may be operated from the fire control station, bridge emergency console (start only), locally in the engine room, cargo control console and the main switchboard group starter panel. However, they will automatically start on confirmed fire on board the FSRU. The water spray header isolation valves to the deck area(s) or the accommodation area are remotely actuated by an operator.

The LNGC will have a water spray system installed in compliance with DNV-RU-SHIP-Pt5Ch7 and are expected to cover the same areas detailed above (with exception of the LNG regasification plant which are not installed on LNGC).

6.1.6 Hydrants

Fire hydrants on the FSRU are installed such that at least two jets of water can reach any part of the deck in the cargo area and those portions of the cargo containment system and tank covers that are above the deck as indicated on the FSRU Fire Control and Safety Plan provided in Appendix B, noting the two jets shall not emanate from the same hydrant. The necessary number of fire hydrants are located to satisfy the above arrangements in accordance with DNV-RU-SHIP-Pt5Ch7.

Hydrant hose cabinets are located as indicated on the FSRU Fire Control and Safety Plan provided in Appendix B. Each cabinet will contain hose lengths as summarised in Table 6-1 and a jet / fog hose each with a working pressure in accordance with DNV-RU-SHIP-Pt5Ch7.

Table 6-1: FSRU Hydrant Cabinets and Hoses (Extract from FSRU Specification Chapter 4.4 [49])

Location		Hydrant Valve	Fire Hose	Nozzle		Hose Storage
				Tip	CONN.	
Accommodation	Enclosed	DN50	20m	12mm	-	Steel box recessed in the Bulkhead
	Weather	DN50	20m	12mm	-	FRP Box
Engine Room	All	DN50	15m	19mm	-	Steel (Reel type)
Hull	Enclosed	DN50	20m	19mm	-	Steel (Reel type)
	Weather	DN50	25m	19mm	-	FRP Box

The LNGC will also have a hydrant system installed in compliance with DNV-RU-SHIP-Pt5Ch7.

6.1.7 Carbon Dioxide Extinguishing System

A high pressure CO_2 fire extinguishing system is provided for protection of the FSRU cargo machinery room, electric motor room, cargo switch board rooms, emergency generator room, emergency switchboard room, main S/W board room, engine control room, convertor room, regasification switchboard room and forward pump room and is installed in accordance with DNV-RU-SHIP-Pt5Ch7 (which refers to the IGC Code and Chapter II-2 of SOLAS).

CO_2 bottles are arranged in a separated room which is located at a safe and readily accessible location as indicated on the FSRU Fire Control and Safety Plan provided in Appendix B. The CO_2 room is provided with mechanical ventilation.

DNV-RU-SHIP-Pt5Ch7 requires the system to be able to discharge 85% of the gas into the space within 2 minutes.

The LNGC will have a CO_2 extinguishing system (or equivalent) installed in compliance with DNV-RU-SHIP-Pt5Ch7 to protect enclosed spaces.

6.1.8 Dry Powder Extinguishing System

The FSRU fixed dry powder system is provided for the purpose of firefighting on the deck in the cargo area and the regasification plant area is installed in accordance with DNV-RU-SHIP-Pt5Ch7 and DNV-RU-SHIP-Pt6Ch4 Section 7.

The powder is stored at atmospheric pressure in two (2) separate containers, one each on the port and starboard. The dry powder containers have capacities of approximately 2000 kg. The powder expellant shall be nitrogen which is stored in high pressure cylinders. Each powder container is furnished with a distribution manifold consisting of pneumatically operated distribution valves for the relevant hose stations and monitors.

Two (2) sets of monitors are provided as indicated on the FSRU Fire Control and Safety Plan provided in Appendix B. Each monitor is fitted with nozzles with manual stop and with remote start at the CCR and fire control station. The monitors are manually controlled.

Dry powder hose stations are also located as indicated on the FSRU Fire Control and Safety Plan provided in Appendix B. They are arranged to reach any part of the cargo and regasification area and each hose station is furnished with a flexible hose of 33m length ending up in a powder pistol and be housed in Glass Reinforced Plastic (GRP) cabinets. One hose station is provided at each port and starboard side on the end of the cargo area facing the accommodation and readily available from the accommodation.

The LNGC will have a dry powder extinguishing system installed in compliance with DNV-RU-SHIP-Pt5Ch7.

6.1.9 Portable Fire Fighting Equipment

Portable fire extinguishers are located in accordance with DNV-RU-SHIP-Pt5Ch7 as indicated on the FSRU Fire Control and Safety Plan provided in Appendix B.

The LNGC will have portable fire extinguishers located in compliance with DNV-RU-SHIP-Pt5Ch7.

6.2 Shore-Based (ORF) Active Fire Protection

Active fire protection and suppression systems are provided for liquid fires and gas fires in compliance with International and Australian Standards as required. The berth general arrangement plan, escape route layouts and ORF fire service layouts are provided in Appendix C**.**

Primary firefighting strategy for gas fires (including liquefied gas fires) is to cool adjacent equipment to prevent escalation events due to mechanical or structural failure and to enable personnel evacuation.

Primary firefighting for small liquid spill fires will be by portable fire extinguishers if and when safe to do so.

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.

Foam use is minimised as far as practical in order to avoid environmental spill of firefighting foam. Noting that the foam used shall not be Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS).

During an emergency event at the ORF, the primary point of control will be via the Jemena EGP control room which will be manned 24/7. 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 including operation, 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.

6.2.1 Fire Water Demand

Shore-based firefighting system design is based on AS 3846 which states *"Shore-based firefighting resources should be in accordance with Appendix G unless otherwise determined by risk assessment"*. Appendix G is "Informative" providing information and guidance only.

The guidance of Appendix G4 details the shore-based firefighting resources for flammable gas tanker berths (i.e. FSRU vessel) and includes provision for fire protection of the ship/shore manifold area and to combat tanker fires themselves.

As previously detailed, the FSRU is a DNV Class vessel subject to the relevant Rules for Classification including the additional Regas Notation [1, 2]. Marine Order 15 (Construction — fire protection, fire detection and fire extinction) [7] 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 [7] and no further modifications to the FSRU are required. AIE consider the fire protection, fire detection and fire extinction systems provided onboard are sufficient. Therefore, the design case for the shore-based firefighting system is to protect the ship/shore manifold area (i.e. MLAs).

Based on the extrapolation of AS 3846 Table G4, the ship/shore manifold area for tankers of 85,000 DWT may be provided a fire water flow rate based on an application rate of 4 litres/min/m^2 equating to ~11,100 LPM (670 m^3/hr). This is equivalent to protecting an area of ~2,775 m^2. Conservatively, the footprint of the ship/shore manifold area is 400 m^2. Based on an application rate of 4 litres/min/m^2 and applying a 50% adverse weather factor in compliance with Section 10.7.6 (a) of AS 3846 a fire water flow rate of 2,400 LPM (144 m^3/hr) is required. It is considered the fire water demand determined using AS 3846 Table G4 is in excess of what is required to protect the area. Therefore, the project has determined a total demand of ~12,812 LPM (770 m^3/hr). In compliance with Section G4.2 of Appendix G4, appropriate appliances (tower mounted fire water monitors) are provided to adequately cover the ship/shore manifold area and supply the fire water. The additional fire water capacity over and above the requirements of Section 10.7.6 (a) of AS 3846 and the location of the monitor towers provides some coverage of the FRSU if required in a fire event and is consistent with a "defence in depth" approach to mitigating the impacts of a major accident event.

Two fire monitors based on a flow rate of 6,406 LPM (384.4 m^3/hr) will be provided on the berth to provide the required protection to the ship/shore manifold area. All fire monitors will operate simultaneously as required.

Appendix E includes the PKGT Fire Water Hydraulic Calculation which indicates the duty requirements of the fire water pumps. The datasheets for the pumps selected to be installed are also provided.

In accordance with AS 2419 [11] and Section 19.5.3 of the International Safety Guide for Oil Tankers and Terminals (ISGOTT) [4] at least 4 hours of fire water supply will be available for the shore-based firefighting system. This is based on continuous use at the maximum design capacity which is operation of the tower mounted fire water monitors. This supply time provides a safety factor of 2 (based on advice from Höegh the minimum FSRU mobilisation is 2 hours) should the FRSU choose to leave the port as mitigation against a long duration fire event.

6.2.2 Foam Demand

On the shore, there are no storage quantities that require fixed foam systems. Potential fires from odourant storage vessels, hydraulic oil, from vehicles and miscellaneous non-process are intended where practical to be fought with portable (foam) fire extinguishers. The ORF safety equipment layout is provided in Appendix C and presents the location of the foam extinguishers provided. The foam used will not be PFAS type. The sizes of the potential fires were estimated as:

- 12 m^2 (unconfined) odourant fires during SBC changeout;
- 20 m^2 sump fire for hydraulic oil at the MLAs; and
- 11 m^2 spill fire for vehicle spills on the road.

6.2.3 Fire Water Source

The shore-based firefighting system will be supplied by a static water supply comprising two fire water tanks in compliance with requirements of AS 1940. Each tank will have a minimum operational capacity of 1537m^3 and will be design in compliance with AS 2304 [10]. The total fire water storage at the ORF will be 3075m^3. As previously detailed, this is based on continuous use at the maximum design capacity which is 4 hours operation of the tower mounted fire water monitors. The supply duration of 4 hours is recommended in AS 2419.1 [11] and the ISGOTT [4].

The fire water tanks will supply the distribution system. The fire water ring main will be designed in compliance with AS 2419.1 [11] and will be sized such that any section can be isolated without affecting the performance of the overall system. Readily accessible manually operated isolation valves will be installed within the fire main to allow for isolation of any damaged sections or for general maintenance activities. The fire water ring main and distribution pipe work will be routed in a way such that they will not be affected by any fire incident on the berth or vehicle impact.

Water supply to the PKGT is not directly from the Sydney Water mains, rather it is via the PKCT under a contractual arrangement [22]. Following a fire event, in compliance with requirements of AS 2419.1 the supply to a water storage tank shall be capable of refilling 50% of the effective capacity of the tank within 24 hours. There are known constraints within the current water supply. In order to manage the risk associated with a fire water tank refill rate which does not meet the requirements of AS 2419.1, AIE commits to ensuring the site and the FSRU will shut down and not operate until the level in the fire water tanks has been restored to an acceptable level. This operational constraint will be documented in the facility's emergency response procedures which will be developed and approved prior to operation per the requirements of Infrastructure Approval [19] Schedule 3, Condition 23(a).

An international ship to shore emergency fire water connection has been provided on the berth to provide mutual aid between the FRSU fire main and berth fire protection system in compliance with requirements of AS 3846. The connections will be provided with isolation valves and hose connections.

No provision for an emergency fire water connection has been provided for the LNGC. During the Firefighting Support Ships risk assessment workshop [40] the LNGC onboard active fire protection systems were considered to be reliable with sufficient redundancies. In the event of an emergency the LNGC can come off berth if required.

6.2.4 Fire Water Pumps

The shore-based fire water pumps at the north-east of the berth are in an accessible location, and are outside of the 25mm flammable dispersion and thermal radiation contours. FRNSW access to the berth including potential emergency services staging area will be documented in the facility's emergency response procedures which will be developed and approved prior to operation per the requirements of Infrastructure Approval [19] Schedule 3, Condition 23(a).

The pumps are provided shelter and have access, power, and lighting as required to operate and maintain the pumps. Each of the pumps is house within individual enclosures in compliance with AS 2941 [13]

In compliance with requirements of AS 2941 [13] and AS 2419.1 [11] a 3x50% arrangement is provided (i.e. duty / standby). Each firewater pump will be capable of delivering 50% of the total demand of ~12,812 LPM (770 m^3/hr). The datasheets for the pumps selected to be installed are provided in Appendix E.

Fire Pump controls shall comply with AS 2941 [13] and start the pumps automatically on drop in pressure. Manual controls to start the pumps will also be provided in the FSRU control room and at the firewater pump local control panel (adjacent to each firewater pump). Firewater pumps, once started, will run until manually stopped at the firewater pump local control panels.

The jockey pump is designed to permanently pressurize the firewater network to 700 kPag at the most hydraulically remote points. When the jockey pump is out of service and the fire water ring main pressure drops below the setpoint the fire water pumps will start and maintain the system pressure and fire water readiness / availability.

6.2.5 Shore-based Fire Water Monitors

Fire protection for the ship/shore manifold area is to be delivered via two oscillating monitors of equal size located on a tower to the north and south within 30m of the area. Each monitor has a minimum straight stream throw in still air of 70m and a design flow rate of 6,406 LPM (384.4 m^3/hr) (refer Section 6.2.1).

Monitors are remotely actuated and can be controlled from multiple locations. The EGP control room will have full control of the berth tower mounted fire water monitors including operation, 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. CCTV or a similar tool (with 2 hours fire rated cables) is available for feedback for the remote operator.

6.2.6 Hydrants

Fire Hydrants will be arranged to provide coverage of the Berth general area from two different directions. The shore-based fire-fighting system is designed based on the largest fire water demand which is to protect the ship/shore manifold areas. Therefore, it is expected the fire hydrants will be able to deliver in excess of the minimum specified in AS 3846 [14] Section G4 (b) and AS 2419.1 of 10 L/s.

Hydrants will be located in a ring around the MLAs nominally 30 m from the nearest MLA, or as required to allow two hose streams to be brought to bear on any fire incident within the ship/shore manifold area in accordance with AS 3846 Section G4.2 (b). The ORF fire water equipment and ring main layouts are provided in Appendix C.

A hydrant hose cabinet will be located next to each hydrant unless agreed with by FRNSW that these are not required (refer Section 6.5), noting that the ORF site is unmanned. It will be manufactured from GRP or epoxy coated steel construction and suitable for being secured on top of the Jetty structure. Each cabinet will contain 2 x 30 meters lengths of 65 mm lay flat hose and a jet / fog hose nozzle with a minimum flow rate of 10 L/s at a working pressure not less than 700 kPag.

6.2.7 Portable Fire Fighting Equipment

AS 3846 requires two powder-type portable fire extinguishers of 30B(E) capacity, in accordance with AS/NZS 1841.5 [8] to be provided at the berth, within 30 m of the ship/shore manifold area. Note that these extinguishers are primarily to fight non-process fires (for example vehicular fires) which could escalate to the process.

In accordance with AS 2444 [12], extinguisher are located in a conspicuous and readily accessible location. Where practicable, extinguishers are located along normal paths of travel and near exits. The ORF firefighting and safety equipment layouts are provided in Appendix C**.**

6.3 Fire Fighting Support Ships

AS 3846 requires a minimum of two Class A Firefighting Support Ships (firefighting tugs) to be available for the PKGT FSRU. However, it is noted that this may be varied by risk assessment. As such, a risk assessment workshop was held at the AIE Office in Wollongong and via Microsoft Teams on the 12th July 2022 [40]. The workshop team consisted of a range of experienced personnel from various engineering, project and operations groups including the Port Kembla Harbour Master and representatives from the tug operator, Svitzer.

The findings of the risk assessment are documented in the workshop report [40]. However, the workshop team concluded:

- Tugs with additional firefighting capability are not required to be permanently on stand-by at Port Kembla. The firefighting capabilities of the tugs currently servicing Port Kembla are sufficient for providing support should primary protection systems fail and support is specifically requested. However, the FRSU (and LNGC) onboard active fire protection systems were considered to be reliable with sufficient redundancies.
- Should an existing firefighting tug be occupied at the time an emergency arises (i.e. in towage), they shall only be available to provide support when the vessel under towage is confirmed to be in a safe state. This is estimated to take up to 90 minutes. The majority of towage in Port Kembla requires at least two tugs where towage operations are undertaken approximately 25-30% of the time. When firefighting tug are not in operation, they are typically on a two hour stand-by (i.e. time crew required to be onsite within). However, at best a crew could be available for firefighting support in 30 minutes.
- Should an existing firefighting tug be taken temporarily out of service (e.g. for maintenance) there is no specific requirement for a replacement tug to have equivalent firefighting capability.
- Due to the cost associated with storage, periodic testing, and replacement of foam concentrate and the associated potential environmental concerns associated with release, it was not considered that tugs were required to carry foam stocks.
- A single fire scenario was identified (i.e. escalation of an accommodation fire) where the FiFi Class 1 vessel is required. However, it was agreed by the workshop that this would be a protracted scenario and there would be sufficient time to mobilise an alternate FiFi Class 1 vessel to Port Kembla, if the permanently stationed Svitzer Ruby were not available. The nearest FiFi Class 1 vessel is located at Port Botany approximately 6 hours away. This response to this scenario is consistent with existing vessels in Port Kembla.
- Port Kembla currently has a FiFi Class 1 vessel (Svitzer Ruby) with two electric / remote operated fire monitors each capable of supplying 1200m^3/hr of fire water. This exceeds the “Class A” firefighting

requirements presented in AS 3846. A noted deviation from the "Class A" requirements is a specified monitor height of 17m. The Svitzer Ruby only has a monitor height of 7.5m. However, this is more than compensated by the additional throw capacity (approximately 120m). It was noted by Svitzer that the 17m monitor height is not commonly applied as it creates difficulties when approaching vessels, due to flare booms etc.

6.4 Passive Fire Protection

A Passive Fire Protection Requirement Assessment has been conducted for the ORF [39] to determine areas of the facility 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.

No PFP is required for the FSRU by DNV-RU-SHIP-Pt5Ch7 or DNV-RU-SHIP-Pt6Ch4.

6.5 Fire Authority Consultation

FRNSW is the statutory firefighting authority for the PKGT ORF. The previous revision (Revision 1) of this report was issued to FRNSW for consultation. A meeting was held via Microsoft Teams on the 15th March 2023 and attended by representatives from FRNSW, AIE and Worley to clarify comments which have subsequently been addressed in this revision of the report. Noting consultation with FRNSW will be ongoing in order to develop the facility's emergency response arrangements per the requirements of Infrastructure Approval [19] Schedule 3, Condition 23(a).

7. FSRU Fire Detection and Prevention Measures

The following safety philosophy for the FSRU has been provided by Höegh [50] 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*

Mandatory rules and regulations are complied with unless approved waivers are achieved."

As identified during the DNV HAZID and HAZOP studies, LOC events from the process are mitigated through the FSRU storage and regasification design and application of the hierarchy of controls. The FSRU is intended to be designated as a Major Hazard Facility (MHF) and as such will be subject to the requirements outlined in the NSW Work Health and Safety Regulation 2017 (WHS Regulation).

The potential release scenarios detailed in Table 4-7 that originate from the FSRU include Scenario 1-5, and Scenarios 10-11. The likelihood of these events occurring is documented as part of a detailed frequency analysis in the PKGT Final Hazard Analysis [41]. This section reviews the fire prevention strategies for each of the release scenarios which originate from the FSRU itself. A high-level summary of the detection and protection measures is provided for each scenario, while detailed summaries of the fire detection and protection measures can be found in Section 5 and Section 6. In all cases of confirmed gas or fire, alarms (visual and audible) will be activated in the CCR which will be manned by FSRU personnel 24/7 while in FSRU mode while berthed at Port Kembla. Any firefighting response onboard the FSRU is expected to be performed by the FSRU crew who are trained in compliance with the IMO International Convention of Standards of Training, Certification and Watchkeepers (STCW) for Seafarers [6] which includes advanced firefighting. This was communicated during the Firefighting Support Ships risk assessment workshop [40]. Crews onboard the LNGC vessels are also expected to have the same certifications. The FSRU F&G status will be displayed on ORF HMI in the Berth Emergency Control Room which is also linked to the Jemena EGP control room (refer Figure 5-4, Section 5.5.2).

In addition, this section reviews potential impacts on the following areas:

- FSRU Muster Points (MPs);
- Gangway between FSRU and shore;
- FSRU accommodation decks;
- Berth infrastructure including MLAs and Emergency Shut Down Valves (ESD valves);
- Berth MPs;
- Berth fire water storage tanks and pumps; and
- Berth electrical and instrument building (containing emergency control room).

Impacts to people are based on the 4.7 kW/m^2 thermal radiation level and the 7 kPa explosion overpressure level while impacts to equipment and structures are based on the 23 kW/m^2 thermal radiation level and the 14 kPa explosion overpressure level. As previously detailed, equipment impacted by the 12.6kWm^2 thermal radiation level is not considered due to equipment materials of construction on the FSRU. The 3 kW/m^2 radiant heat level contours are provided for information in compliance with AS 1940.

Should a LOC occur, the extent of unignited LNG or gas dispersion, flash fire impacts and estimated fire durations have been determined and are provided in Appendix A. The maximum flash fire impact distance emanating from the FSRU results from a release of LNG at the regasification booster pumps discharge conditions (Scenario 4). The berth fire water storage tanks and pumps, and electrical and instrument room (containing emergency control room) are located outside all of the FSRU maximum 25mm hole size unignited LNG or gas dispersion impact distances. The FSRU has fire and gas detection provided in accordance with DNV-RU-SHIP-Pt5Ch7 and DNV-RU-SHIP-Pt6Ch4 Section 7 (refer Section 5.4.1) and it is expected that LNG releases on the FSRU will be detected and isolated.

As detailed in Section 4.4.1.1, flash fire are short duration events in which a flame rapidly passes through the fuel without generating damaging overpressures and burns for an insufficient duration to cause structural and equipment damage [58]. The ensuing jet fires are reviewed in the following sections and as it has larger lasting impact, flash fire impacts are not considered further.

7.1 Scenario 1 - BOG from cargo tanks via vapour header to cargo machinery room (compressor suction conditions)

Vaporised gas generated from LNG in the storage tanks is called Boil-off-gas (BOG). BOG is collected in a vapour header that extends the majority length of the vessel (on the port/berth side) and delivered to the cargo machinery room compressors. The cargo machinery room is located on the FSRU starboard (refer Figure 2-1, Section 2.1). This scenario is also expected to apply to an LNGC vessel, it is assumed an equivalent fire prevention strategy and controls will be adopted in compliance with requirements of DNV-RU-SHIP-Pt5Ch7. A high level summary of the detection and protection measures is provided in Table 7-1.

Table 7-1: Scenario 1 LP BOG – Fire and gas detection and protection measures

Material	Location	Detection Type	Executive Action (protection)
Boil-off gas	Cargo machinery room	• IR point gas detectors (2oo3 voting)	• ESDL alarms on CAAP and IAS OS • Initiates TPSD
		• Electric thermal fuse type fusible melt links (requires single plug to melt) • IR flame detectors (2oo11 voting)	• ESDL alarms on CAAP and IAS OS • Initiates TPSD • Water spray pump automatically start and application of water spray (cargo deck and regasification plant) for exposure protection activated manually • CO_2 extinguishing system activated manually
	Deck (vapour "dome" area)	• Electric thermal fuse type fusible melt links (requires single plug to melt)	• ESDL alarms on CAAP and IAS OS • Initiates TPSD • Water spray pump automatically start and application of water spray (cargo deck and regasification plant) for exposure protection activated manually

The FSRU cargo machinery room and cargo deck has F&G detection provided in accordance with DNV-RU-SHIP-Pt5Ch7 (refer Section 5.4.1). Confirmed gas in the cargo machinery room will activate an alarm and buzzer at the CAAP (also indicating location of gas detection) and an ESDL alarm on the IAS OS. It will also initiate a TPSD which will isolate the available inventory (refer Section 5.5.1). There is no gas detection provided along the vapour header. However, leak sources have been minimised through welded connections.

Should the LOC go undetected, immediately ignited releases from this area of the process will be low pressure and are expected to result in relatively localised jet fires (i.e. will not impact further than the FSRU deck). Figure 7-1 presents the immediately ignited jet fire impacts from a 25mm hole size release. The inner solid line represents the impacts of a single release, whereas the outer solid line represents the extent of the impacts in other directions. The dashed line shows impacts should the release emanate from another location along the vapour header (or within the cargo machinery room).

Figure 7-1: Scenario 1, 25mm Jet Fire Thermal Radiation Impacts at FSRU (14m above grade) – Initial Conditions

Confirmed fire (via fusible melt links and/or IR flame detectors) in these areas will also activate alarms (visual and audible) at the CAAP (indicating location of fire detection) and an ESDL alarm on the IAS OS. A TPSD is also initiated which isolates the gas inventory, de-energises machinery and automatically starts the water spray system pump. Once the pump has started, water spray can be applied to the cargo deck to provide cooling to adjacent inventories and primary structures by opening the cargo deck water spray header isolation valve which supplies all of the spray nozzles. This valve is remotely actuated by an FSRU operator and is included in the Höegh Fire Contingency Plan [51] for ignited liquid releases on the deck. In addition, the cargo machinery room is also provided with a high pressure CO_2 extinguishing system.

Once the gas inventory has been isolated the fire duration for a 25mm hole size release in these areas is estimated to be 4.5 minutes. Fire durations for other hole size releases are provided in Table A- 1 (refer Appendix A).

Table 7-2 indicates this scenario is not expected to impact any of the onsite receptors identified. Personnel onboard the FSRU are expected to be able to safely muster and await instruction should additional firefighting response be required. The FSRU Fire Control and Safety Plan Layout (refer Appendix B) indicates the location of escape routes which show multiple means of egress both from the cargo machinery room and along the header piperack (i.e. if one is impaired, the crew can egress via an alternate route). As previously detailed, a 25mm hole size release is not expected to be sustained for more than 5 minutes.

Table 7-2: Scenario 1 LP BOG – Potential impacts to onsite sensitive receptors

Fire Event	FSRU MP	FSRU Accom.	Gangway	Berth FW Monitors	Berth MLA	Berth Buildings
25mm Jet Fire (Initial)	N	N	N	N	N	N

Should a release in the cargo machinery room go undetected there is potential for flammable vapours to accumulate which are ignited may result in an explosion. Explosion scenarios are further detailed in Section 7.8.

7.2 Scenario 2 - LNG from cargo tank via liquid header to regasification plant

LNG is pumped up from the cargo tanks into a suction drum located toward the bow the vessel. Like the BOG header, the LNG header extends the majority length of the vessel (on the port/berth side). This scenario is also expected to apply to an LNGC vessel (when transferring product via liquid LNG header). Noting the LNGC does not have a suction drum. It is assumed an equivalent fire prevention strategy and controls will be adopted in compliance with requirements of DNV-RU-SHIP-Pt5Ch7. A high level summary of the detection and protection measures is provided in Table 7-3.

Table 7-3: Scenario 2 LNG Liquid Header – Fire and gas detection and protection measures

Material	Location	Detection Type	Executive Action (protection)
LNG	Deck (liquid “dome” area)	• Electric thermal fuse type fusible melt links (requires single plug to melt)	• ESDL alarms on CAAP and IAS OS • Initiates TSPD • Water spray pump automatically start and application of water spray (cargo deck, regasification plant and accommodation) for exposure protection activated manually
	Suction Drum (not applicable to LNGC)	• IR point gas detectors (2oo3 voting)	• ESDL alarms on CAAP and IAS OS • Ability to activate blowdown of regasification plant is provided (requires manual activation on confirmed gas)
		• Electric thermal fuse type fusible melt links (requires single plug to melt) • IR flame detectors (2oo11 voting)	• ESDL alarms on CAAP and IAS OS • Initiates TSPD and automatic blowdown of high pressure gas from regasification plant and export manifold • Water spray pump automatically start and application of water spray (cargo deck, regasification plant and accommodation) for exposure protection activated manually

There is no gas detection provided along the liquid LNG header. However, leak sources have been minimised through welded connections. Gas detection is provided in the suction drum area in accordance with DNV-RU-SHIP-Pt6Ch4 Section 7 (refer Section 5.4.1). Confirmed gas in the suction drum area will activate an alarm and buzzer at the CAAP (also indicating location of gas detection) and an ESDL alarm on the IAS OS. It will also initiate a TPSD which will isolate the available inventory (refer Section 5.5.1). Blowdown of the regasification system can be manually activated if required.

Should the LOC go undetected, immediately ignited releases from this area of the process may result in large liquid spray fires as presented in Figure 7-2. Liquid spray fires are typically larger than gas jets (for the same pressure and hole size) because the mass release rate is higher. The inner solid line represents the impacts of a single release, whereas the outer solid line represents the extent of the impacts in other directions. The dashed line shows impacts should the release emanate from another location along the liquid header.

Figure 7-2: Scenario 2, 25mm Jet Fire Thermal Radiation Impacts at FSRU (14m above grade) – Initial Conditions

Confirmed fire (via fusible melt links) in the vicinity of the liquid domes (tank outer structure) will activate alarms (visual and audible) at the CAAP (indicating location of fire detection) and an ESDL alarm on the IAS OS. A TPSD is also initiated which isolates the inventory, de-energises machinery (i.e. pumps) and automatically starts the water spray system pump. Once the pump has started, water spray can be applied to the cargo deck and accommodation (simultaneously) to provide cooling to adjacent inventories and primary structures by opening the cargo deck water spray header isolation valve and accommodation water spray isolation valve which supplies all of the spray nozzles. These valves are remotely actuated by an FSRU operator and is included in the Höegh Fire Contingency Plan [51] for ignited liquid releases on the deck. Impacts of a liquid release from the system will reduce quickly once the pressure source (i.e. pumps) are tripped.

Once the inventory has been isolated, the fire duration for a 25mm hole size release along the liquid LNG header may be sustained for greater than 1 hour. Fire durations for other hole size releases are provided in Table A- 1 (refer Appendix A). Although this fire event may be sustained for a long duration, the initial flame length is 43m. 5 minutes after detection and isolation this reduces to 30m and will continue to reduce with time. The resultant liquid spray fire 5 minutes post release is presented in Figure 7-3. The Jemena EGP control room will be notified of confirmed fire on the FSRU (refer Figure 5-4, Section 5.5.2) and will have the ability to start the ORF fire water system and apply cooling to the MLAs or FSRU gangway via the tower mounted fire water monitors.

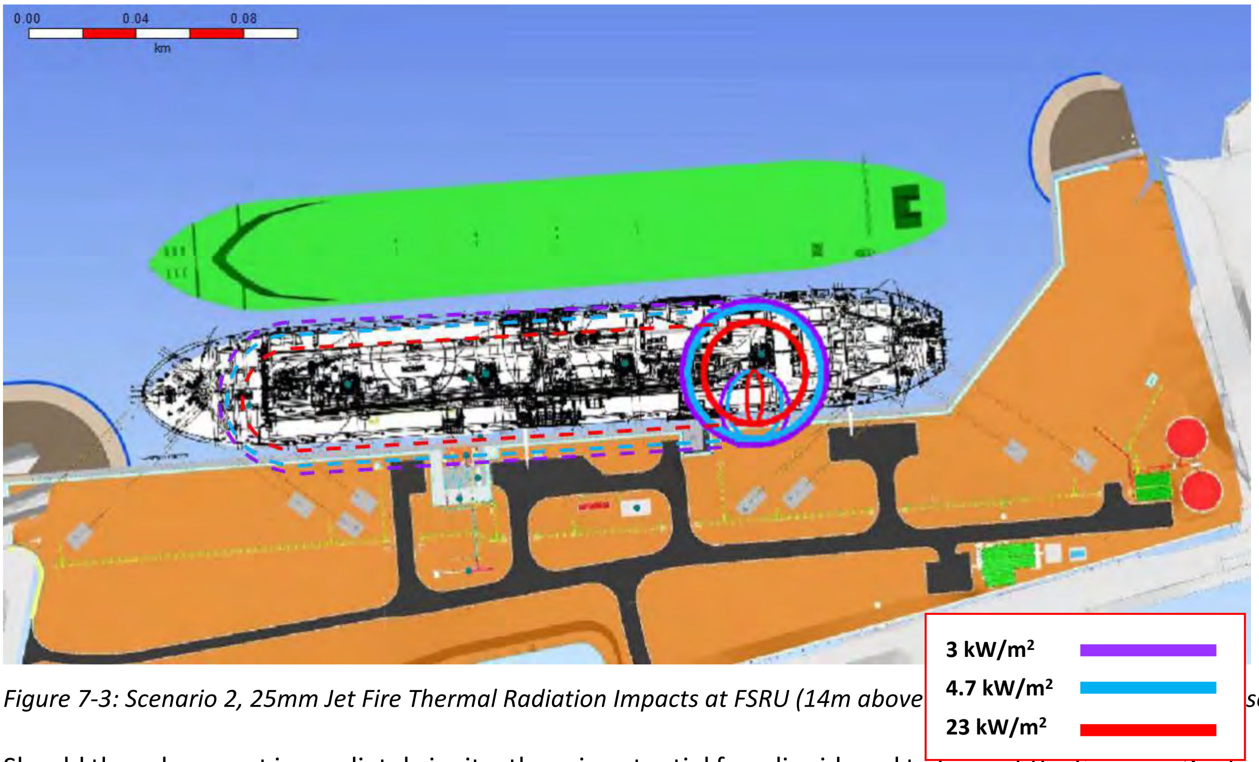

Figure 7-3: Scenario 2, 25mm Jet Fire Thermal Radiation Impacts at FSRU (14m above ... se

Should the release not immediately ignite, there is potential for a liquid pool to form at the Scenario 2 release conditions. If the liquid pool ignites, an LNG pool fire will ensue. Potential pool fire impacts resulting from a 25mm release are presented in Figure 7-4. The solid line represents the extent of the impacts in all directions. The dashed line shows impacts should the release emanate from another location along the liquid header. The extent of the pool fire is represented in yellow.

Figure 7-4: Scenario 2, 25mm Pool Fire Thermal Radiation Impacts at FSRU (14m above grade)

The same response to a pool fire applies as the jet fire scenario, where confirmed fire (via fusible melt links) in the vicinity of the liquid domes (tank outer structure) will isolate the inventory, stop the pumps and will activate alarms at the CAAP. The Höegh Fire Contingency Plan [51] also indicates that for ignited liquid releases on the deck the FSRU water spray is applied for the deck and cargo area is to provide cooling to adjacent inventories and primary structures. Depending on the location of the pool fire, FSRU water spray can also be applied to the accommodation deck. The pool fire will continue to burn until the inventory (fuel source) has been consumed.

Table 7-4 indicates that this scenario may impact onsite (FSRU or ORF) receptors with high levels of radiant heat, depending on the initial conditions, release orientation and where the release occurs along the liquid LNG header. It should be noted that releases emanating near the Tank 3 and Tank 4 structures (i.e. closest to the accommodation) are more likely to impact the FSRU gangway and accommodation. The FSRU has controls to detect this fire event, remove the pressure source and isolate the inventory, which in most instances will mitigate impacts. As previously detailed the FSRU water spray pumps will be automatically started on confirmed fire and cooling can be applied to the accommodation deck. The Jemena EGP control room will be notified of confirmed fire on the FSRU and will have the ability to start the ORF fire water system and apply cooling to the MLAs or FSRU gangway via the tower mounted fire water monitors.

The FSRU Fire Control and Safety Plan Layout (refer Appendix B) indicates the location of escape routes which show multiple means of egress along the header piperack (i.e. if one is impaired, the crew can egress via an alternate route) to allow for safe egress of personnel to the muster point located at the lifeboat station or the fire control stations in the accommodation. Crew are able to refuge for as long as required in these locations and await instruction should additional firefighting response be required. Primary escape from the FSRU is specified as being via the gangway. However, the Höegh Contingency Fire plans [51] specify to muster for a fire event. Evacuation of the FSRU is only implemented as a result of activation of the abandon vessel shutdown by the FSRU captain. Alternate means of escaping the vessel via ladders / embarkation stations, davit launched life rafts and a rescue boat are also indicated on the FSRU Fire Control and Safety Plan.

Table 7-4: Scenario 2 LNG Liquid Header – Potential impacts to onsite sensitive receptors

Fire Event	FSRU MP	FSRU Accom.	Gangway	Berth FW Monitors	Berth MLA	Berth Buildings
25mm Jet Fire (Initial)	N	Yes 23kW/m^2	Yes 23kW/m^2	Yes 23kW/m^2	Yes 23kW/m^2	N
25mm Jet Fire (5 mins)	N	Yes 23kW/m^2	Yes 4.7kW/m^2 (Tank 3&4)	N	N	N
25mm Pool Fire	N	Yes 23kW/m^2	Yes 4.7kW/m^2 (Tank 3&4)	N	N	N

7.3 Scenario 3 - BOG from LD Compressors for fuel gas or to BOG cooler for reliquefication

In the cargo machinery room, compressors increase the pressure of the BOG for use as fuel gas for the on-board generators for the operation of pumps and other equipment used on the FSRU vessel or to be reliquefied by the BOG coolers. The generators are located in the engine room located on the FSRU below the main deck. This scenario is also expected to apply to an LNGC vessel, it is assumed an equivalent fire prevention strategy and controls will be adopted in compliance with requirements of DNV-RU-SHIP-Pt5Ch7. A high level summary of the detection and protection measures is provided in Table 7-5.

Table 7-5: Scenario 3 Discharge BOG – Fire and gas detection and protection measures

Material	Location	Detection Type	Executive Action (protection)
Boil-off gas	Cargo machinery room	• IR point gas detectors (2oo3 voting)	• ESDL alarms on CAAP and IAS OS • Initiates TPSD
		• Electric thermal fuse type fusible melt links (requires single plug to melt) • IR flame detectors (2oo11 voting)	• ESDL alarms on CAAP and IAS OS • Initiates TSPD • Water spray pump automatically start and application of water spray (cargo deck and regasification plant) for exposure protection activated manually • CO_2 extinguishing system activated manually
	Deck (vapour "dome" area)	• Electric thermal fuse type fusible melt links (requires single plug to melt)	• ESDL alarms on CAAP and IAS OS • Initiates TSPD • Water spray pump automatically start and application of water spray (cargo deck and regasification plant) for exposure protection activated manually

As with Scenario 1, the FSRU has F&G detection provided within the cargo machinery room in accordance with DNV-RU-SHIP-Pt5Ch7 (refer Section 5.4.1). Confirmed gas in the cargo machinery room will activate an alarm and buzzer at the CAAP and an ESDL alarm on the IAS OS. It will also initiate a TPSD which will isolate the available inventory (refer Section 5.5.1). There is no gas detection provided along the vapour header. However, leak sources have been minimised through welded connections.

Should the LOC go undetected, immediately ignited releases from this area of the process are expected to result in relatively localised jet fires (i.e. will not impact further than the FSRU deck). Figure 7-5 presents the immediately ignited jet fire impacts from a 25mm hole size release. The inner solid line represents the impacts of a single release, whereas the outer solid line represents the extent of the impacts in other directions. The dashed line shows impacts should the release emanate from another location along the vapour header (or within the cargo machinery room).

Figure 7-5: Scenario 3, 25mm Jet Fire Thermal Radiation Impacts at FSRU (14m above grade) – Initial Conditions

Confirmed fire (via fusible melt links and/or IR flame detector) in these areas will also activate alarms (visual and audible) at the CAAP (indicating location of fire detection) and an ESDL alarm on the IAS OS. A TPSD is also initiated which isolates the inventory, de-energises machinery and automatically starts the water spray system pump. Once the pump has started, water spray can be applied to the cargo deck to provide cooling to adjacent inventories and primary structures by opening the cargo deck water spray header isolation valve which supplies all of the spray nozzles. This valve is remotely actuated by an FSRU operator and is included in the Höegh Fire Contingency Plan [51] for ignited liquid releases on the deck. In addition, the cargo machinery room is also provided a high pressure CO_2 extinguishing system.

Once the gas inventory has been isolated the fire duration for a 25mm hole size release in these areas is estimated to be 16.5 minutes. Fire durations for other hole size releases is provided in Table A- 1 (refer Appendix A). The initial flame length is 10m while 5 minutes after detection and isolation this reduces to 8m and will continue to reduce with time.

Table 7-6 indicates this scenario is not expected to impact any of the onsite receptors identified. Personnel onboard the FSRU are expected to be able to safely muster and await instruction should additional firefighting response be required. The FSRU Fire Control and Safety Plan Layout (refer Appendix B) indicates the location of escape routes which show multiple means of egress both from the cargo machinery room and along the header piperack (i.e. if one is impaired, the crew can egress via an alternate route) to allow for safe egress of personnel to the muster point located at the lifeboat station or the fire control stations in the accommodation.

Table 7-6: Scenario 3 Discharge BOG – Potential impacts to onsite sensitive receptors

Fire Event	FSRU MP	FSRU Accom.	Gangway	Berth FW Monitors	Berth MLA	Berth Buildings
25mm Jet Fire (Initial/ 5 Mins)	N	N	N	N	N	N

Should a release in the cargo machinery room or engine room go undetected there is potential for flammable vapours to accumulate which are ignited may result in an explosion. Explosion scenarios are further detailed in Section 7.8.

7.4 Scenario 4 - LNG from Regasification Booster Pumps

LNG from the suction drum is then directed to the LNG booster pumps. Each individual regasification train is equipped with 2 identical parallel, submerged, pot mounted LNG booster pumps (i.e. in total 6 x LNG Booster Pumps installed). The booster pumps increase the LNG pressure from approximately 5.5 barg to 120 barg. A high level summary of the detection and protection measures is provided in Table 7-7.

Table 7-7: Scenario 4 LNG Regas Plant – Fire and gas detection and protection measures

Material	Location	Detection Type	Executive Action (protection)
LNG	Regasification plant	• LOS and IR point gas detectors (2oo16 voting)	• ESDL alarms on CAAP and IAS OS • Ability to activate blowdown of regasification plant is provided (requires manual activation on confirmed gas)
		• Electric thermal fuse type fusible melt links (requires single plug to melt) • IR flame detectors (2oo6 voting)	• ESDL alarms on CAAP and IAS OS • Initiates TSPD and automatic blowdown of high pressure gas from regasification plant and export manifold • Water spray pump automatically start and application of water spray (cargo deck, regasification plant and accommodation) for exposure protection activated manually

Gas detection is provided in the regasification plant in accordance with DNV-RU-SHIP-Pt5Ch7 and DNV-RU-SHIP-Pt6Ch4 Section 7 (refer Section 5.4.1). Confirmed gas in the regasification plant area will activate an alarm and buzzer at the CAAP, and an ESDL alarm on the IAS OS. Blowdown of the regasification system can be manually activated if required.

Should the LOC go undetected, immediately ignited releases from this area of the process may result in large liquid spray fires as presented in Figure 7-6. The inner solid line represents the impacts of a single release, whereas the outer solid line represents the extent of the impacts in other directions.

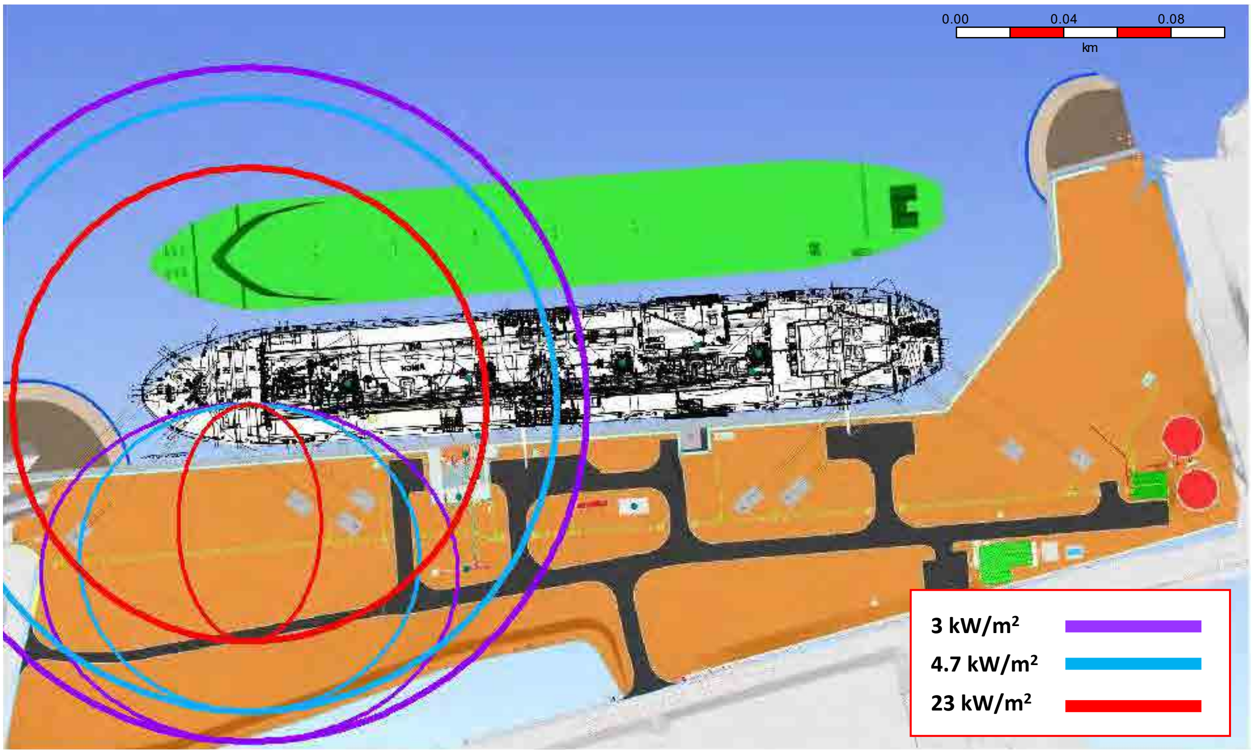

Figure 7-6: Scenario 4, 25mm Jet Fire Thermal Radiation Impacts at FSRU (14m above grade) – Initial Conditions

Confirmed fire (via fusible melt links and/or IR flame detectors) in the regasification plant area will isolate the inventory, stop the booster pumps, activate alarms (visual and audible) at the CAAP (indicating location of fire detection), initiate a TPSD and automatically blowdown the regasification plant and high pressure export pipework. Like the other fire scenarios, TPSD will isolate the inventory, de-energise machinery (i.e. the booster pumps) and automatically start the water spray system pump. Once the pump has started, water spray can be applied to the cargo deck (including regasification plant) to provide cooling to adjacent inventories and primary structures by opening the cargo deck water spray header isolation valve which supplies all of the spray nozzles. This valve is remotely actuated by an FSRU operator and is included in the Höegh Fire Contingency Plan [51] for ignited liquid releases on the deck.

Impacts of a liquid spray fire release from the system will reduce quickly once the pressure source (i.e. pump) is de-energised and blowdown is initiated. Blowdown of the regasification plant and HP manifold is designed to take 15 minutes. The initial flame length is 69m while 5 minutes after detection and isolation this reduces to 11m and will continue to reduce with time. The resultant liquid spray fire 5 minutes post release is presented in Figure 7-7 which shows the reduction in the radiant heat impacts. Critical ORF structures including the MLAs and the tower mounted fire water monitors will not be impacted by thermal radiation levels greater than 23 kW/m^2.

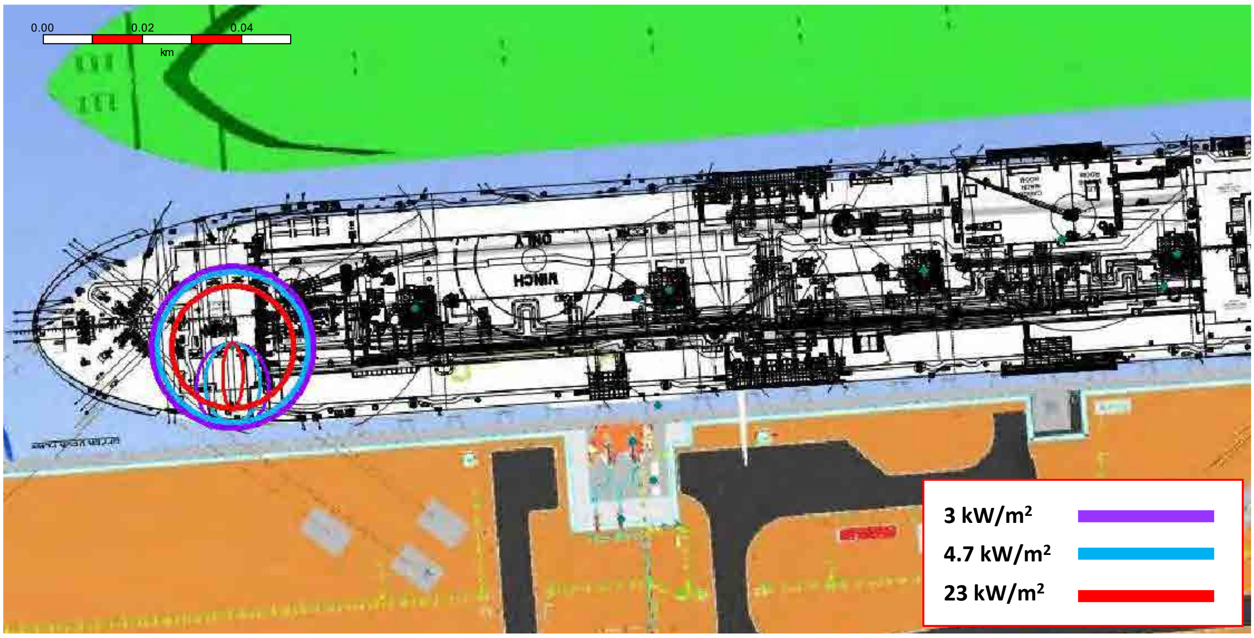

Figure 7-7: Scenario 4, 25mm Jet Fire Thermal Radiation Impacts at FSRU (14m above grade) – 5 minutes post release

Should the release not immediately ignite, there is potential for a liquid pool form at the Scenario 4 release conditions for 100mm and greater hole size releases. For 50mm hole size releases and less, the formation of a liquid pool is not expected due to vapourisation of the pressurised (pumped) LNG. A drip tray is installed underneath regasification plant area. The drip tray is made of stainless steel, and provided with drains that divert possible liquids overboard to reduce risk of pool fires. However, if the drip tray fills and the liquid pool ignites, a LNG pool fire may ensue. Potential pool fire impacts resulting from a 100mm release are presented in Figure 7-8 and Table 7-8. Noting the 100mm hole size is not the design case and is shown for information only. This release has an equivalent pool fire diameter of the drip tray. The extent of the pool fire is represented in yellow.

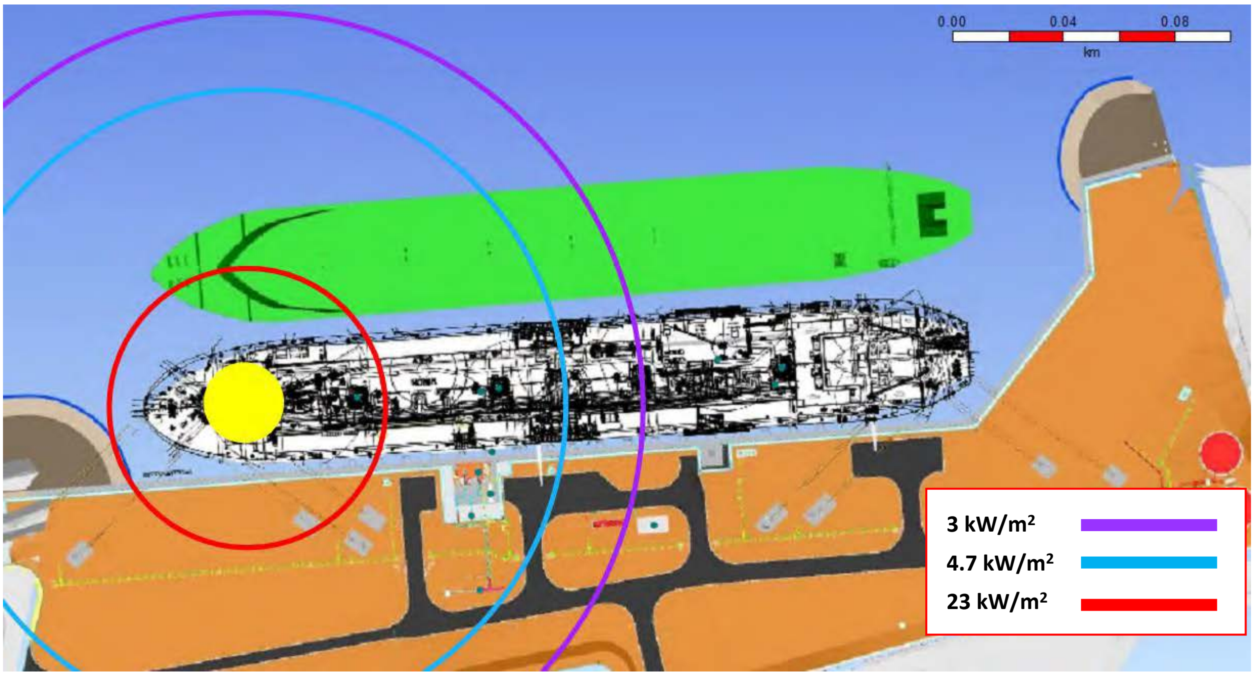

Figure 7-8: Scenario 4, 100mm Pool Fire Thermal Radiation Impacts at FSRU (14m above grade) – Fire in Regas Drip Pan

The same response to a pool fire applies as the jet fire scenario, where confirmed fire (via fusible melt links and/or IR flame detectors) in the regasification plant area will isolate the inventory, de-energise the booster pumps, activate an activate alarms (visual and audible) at the CAAP (indicating location of fire detection), initiate TPSD and automatically blowdown the regasification system and high pressure export pipework. Like the other fire scenarios, TPSD will isolate the inventory, de-energise machinery (i.e. the booster pumps) and automatically start the water spray system pump. Once the pump has started, water spray can be applied to the cargo deck (including regasification plant) to provide cooling to adjacent inventories and primary structures by opening the cargo deck water spray header isolation valve which supplies all of the spray nozzles. This valve is remotely actuated by an FSRU operator and is included in the Höegh Fire Contingency Plan [51] for ignited liquid releases on the deck. The pool fire will continue to burn until the inventory (fuel source) has been consumed. The Jemena EGP control room will be notified of confirmed fire on the FSRU (refer Figure 5-4, Section 5.5.2) which will also be manned 24/7. The Jemena EGP control room will have the ability to start the ORF fire water system and apply cooling via the tower mounted fire water monitors.

Table 7-8 indicates that based on initial release conditions, this scenario may impact onsite receptors with high levels of radiant heat. The FSRU has controls to detect this fire event, remove the pressure source, isolate the inventory and blowdown the system which removes the majority of the onsite impacts.

The FSRU Fire Control and Safety Plan Layout (refer Appendix B) shows multiple means of egress from the regasification plant (i.e. if one is impaired, the crew can egress via an alternate route) to allow for safe egress of personnel to the muster point located at the lifeboat station or the fire control stations in the accommodation. Like other scenarios, crew are able to refuge for as long as required in this location and await instruction should additional firefighting response be required.

Table 7-8: Scenario 4 LNG Regas Plant – Potential impacts to onsite sensitive receptors

Fire Event	FSRU MP	FSRU Accom.	Gangway	Berth FW Monitors	Berth MLA	Berth Buildings
25mm Jet Fire (Initial)	N	N	N	Yes 23kW/m^2	Yes 23kW/m^2	N
25mm Jet Fire (5 mins)	N	N	N	N	N	N
100mm Pool Fire (Not design case)	N	N	N	N	N	N

7.5 Scenario 5 - NG from Regasification Module to FSRU Discharge ESD Valve

From the booster pumps, LNG is then pumped through a series of heat exchangers, which utilise seawater as a source of natural heat differential to warm up the LNG. However, most of the duty required to heat the LNG to NG at ambient conditions is done in the vapouriser. From the regasification trains, the natural gas goes through the gas metering system and is then delivered to the ORF through 2 x 12” MLAs. There are ESD valves on the FSRU at the HP export manifold. A high level summary of the detection and protection measures is provided in Table 7-9.

Table 7-9: Scenario 5 HP Gas on FSRU – Fire and gas detection and protection measures

Material	Location	Detection Type	Executive Action (protection)
HP NG	Regasification plant	• LOS and IR point gas detectors (2oo16 voting)	• ESDL alarms on CAAP and IAS OS • Ability to activate blowdown of regasification plant is provided (requires manual activation on confirmed gas)
		• Electric thermal fuse type fusible melt links (requires single plug to melt) • IR flame detectors (2oo6 voting)	• ESDL alarms on CAAP and IAS OS • Initiates TSPD and automatic blowdown of high pressure gas from regasification plant and export manifold • Water spray pump automatically start and application of water spray (cargo deck, regasification plant and accommodation) for exposure protection activated manually
	Deck (HP manifold, gas metering)	• IR point gas detectors (2oo3 voting in both HP manifold and gas metering locations)	• ESDL alarms on CAAP and IAS OS • Ability to activate blowdown of regasification plant is provided (requires manual activation on confirmed gas)
		• Electric thermal fuse type fusible melt links (requires single plug to melt) • IR flame detectors (2oo3 voting in both HP manifold and gas metering locations)	• ESDL alarms on CAAP and IAS OS • Initiates TSPD and automatic blowdown of high pressure gas from regasification plant and export manifold • Water spray pump automatically start and application of water spray (cargo deck, regasification plant and accommodation) for exposure protection activated manually

The regasification plant area has gas detection provided in accordance with DNV-RU-SHIP-Pt5Ch7 and DNV-RU-SHIP-Pt6Ch4 Section 7 (refer Section 5.4.1). Confirmed gas in the regasification plant area, gas metering or HP export manifold will activate an alarm and buzzer at the CAAP (also indicating location of gas detection) and an ESDL alarm on the IAS OS. Blowdown of the regasification system can be manually activated if required.

Should the LOC go undetected, immediately ignited releases from this area of the process are expected to result in large gaseous jet fires. Figure 7-9 presents the immediately ignited jet fire impacts from a 25mm hole size release. The inner solid line represents the impacts of a single release, whereas the outer solid line represents the extent of the impacts in other directions. The dashed line shows impacts should the release emanate from another location along the NG export header.

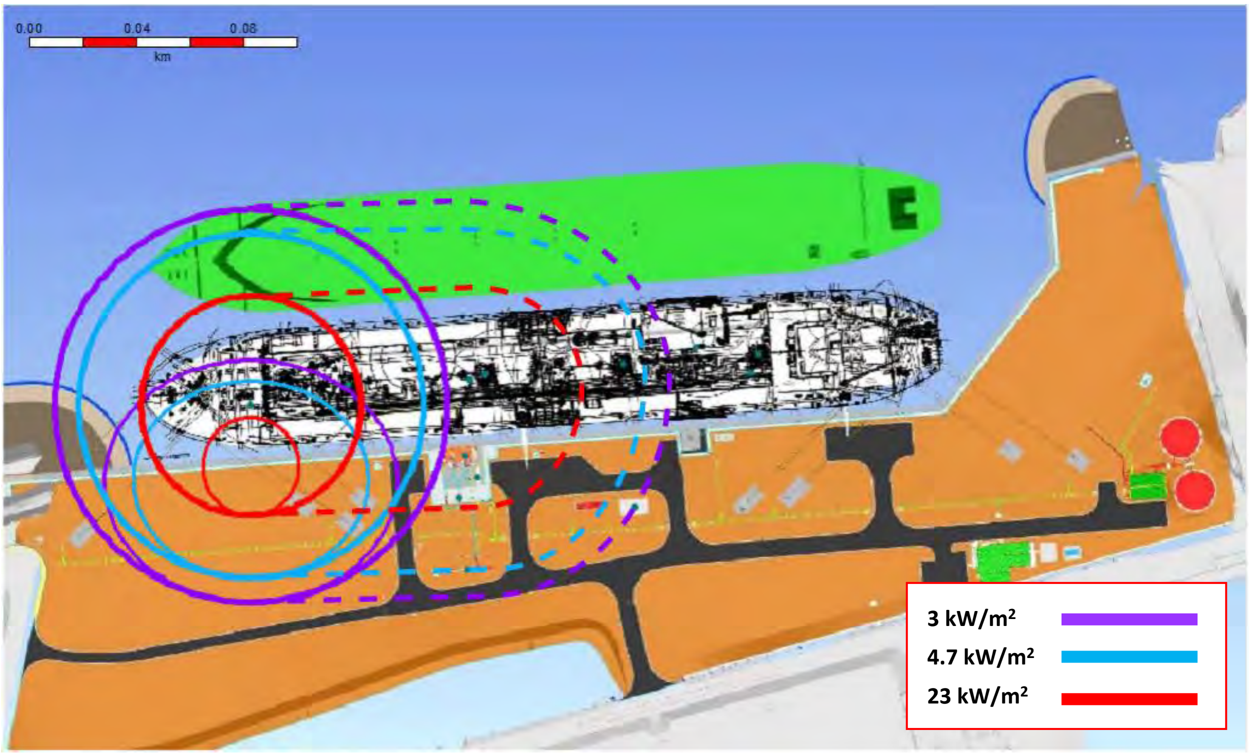

Figure 7-9: Scenario 5, 25mm Jet Fire Thermal Radiation Impacts at FSRU (14m above grade) – Initial Conditions

Confirmed fire (via fusible melt links and/or IR flame detectors) in the regasification plant area, HP manifold or gas metering area will isolate the inventory, stop the pumps, activate alarms (visual and audible) at the CAAP (indicating location of fire detection), initiate TPSD and automatically blowdown the regasification plant and high pressure export pipework. Like the other fire scenarios, TPSD will isolate the inventory, de-energise machinery and automatically start the water spray system pump. Once the pump has started, water spray can be applied to the cargo deck (including regasification plant) to provide cooling to adjacent inventories and primary structures by opening the cargo deck water spray header isolation valve which supplies all of the spray nozzles. This valve is remotely actuated by an FSRU operator and is included in the Höegh Fire Contingency Plan [51] for ignited liquid releases on the deck.

Impacts of a high pressure gaseous release from the system is expected to reduce as a result of inventory depletion and blowdown. Blowdown of the regasification plant and HP manifold is designed to take 15 minutes. The initial flame length is 46m while 5 minutes after detection and isolation this reduces to 36m and will continue to reduce with time. The resultant jet fire 5 minutes post release is presented in Figure 7-10 which shows the reduction in the radiant heat impacts.

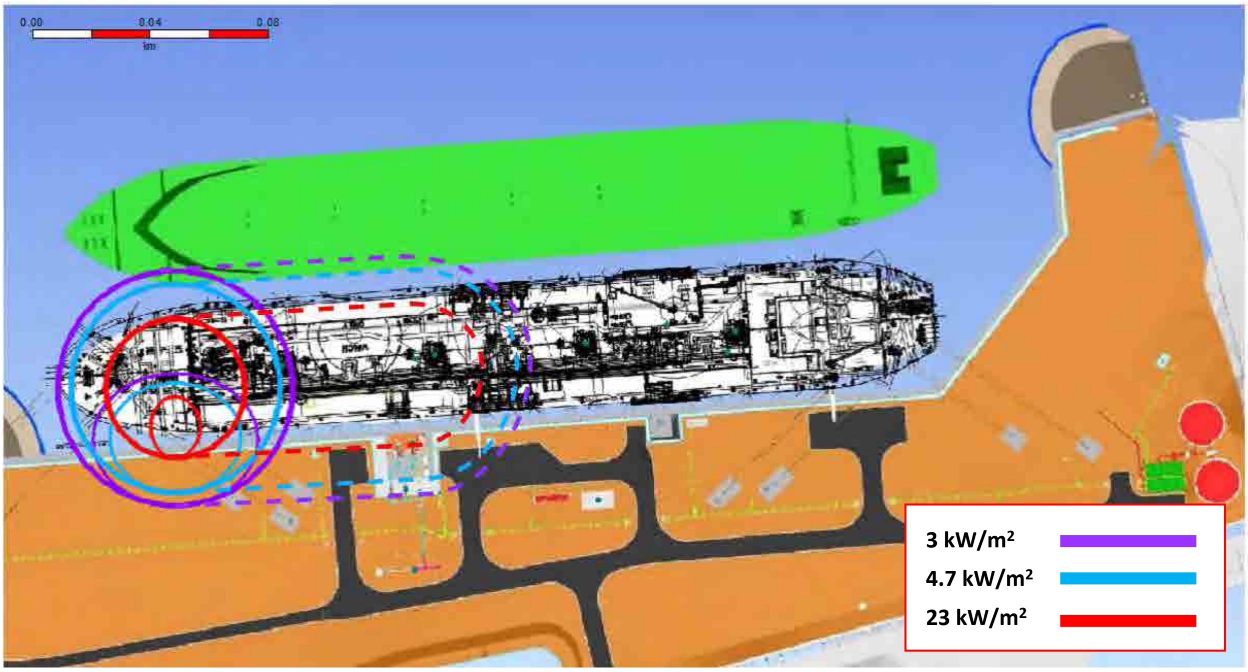

Figure 7-10: Scenario 5, 25mm Jet Fire Thermal Radiation Impacts at FSRU (14m above grade) – 5 minutes post release

Depending on the release orientation and location along the HP export header, the MLAs and one of the tower mounted fire water monitors may be impacted by thermal radiation levels greater than 23 kW/m^2. The requirement for additional protection for these structures as a result of this scenario was considered in the PKGT Passive Fire Protection Requirement Assessment Technical Note [39] which concluded:

- Only the top section of the south fire water monitor tower can be impacted for greater than 5 minutes. However, this is not likely to compromise the integrity of the entire structure. It is also not likely for both of the tower mounted fire water monitors to be impacted simultaneously i.e. there are redundant monitors. Water from the monitor will provide cooling for equipment within the impact zone of the fire and/or the monitor itself.
- Both MLA structures and associated pipework can be impacted for greater than 5 minutes resulting in potential failure and escalation. However, the Jemena EGP control room will be notified of confirmed fire on the FSRU (refer Figure 5-4, Section 5.5.2) which will also be manned 24/7. The Jemena EGP control room will have the ability to start the ORF fire water system and apply cooling to the MLAs via the tower mounted fire water monitors. It is not likely that a fire event will impact the MLAs and the fire water monitors simultaneously.
- The above ground ORF pipework and PKP section will not be impacted by this scenario.

Table 7-10 indicates that based on initial conditions, this scenario may impact onsite receptors with high levels of radiant heat. The FSRU has controls to detect this fire event, remove the pressure source and isolate the inventory, which removes the majority of the onsite impacts. As detailed above, requirement for PFP to be applied to the berth MLA and FW monitor was considered [39]. However, it was concluded that PFP was not required as the MLA structures are protected by the fire water monitors and fires from the FSRU impacting the monitor towers will damage the top section of the towers but structural failure and escalation is not expected.

The FSRU Fire Control and Safety Plan Layout (refer Appendix B) shows multiple means of egress from the regasification plant (i.e. if one is impaired, the crew can egress via an alternate route) to allow for safe egress of personnel to the muster point located at the lifeboat station or the fire control stations in the accommodation. Like other scenarios, crew are able to refuge for as long as required in this location and await instruction should additional firefighting response be required.

Table 7-10: Scenario 5 HP Gas on FSRU – Potential impacts to onsite sensitive receptors

Fire Event	FSRU MP	FSRU Accom.	Gangway	Berth FW Monitors	Berth MLA	Berth Buildings
25mm Jet Fire (Initial)	N	N	N	Yes 23kW/m^2 (Tower 1)	Yes 23kW/m^2	N
25mm Jet Fire (5 mins)	N	N	N	Yes 23kW/m^2 (Tower 1)	Yes 23kW/m^2	N

Should a release in the regasification plant area go undetected there is potential for flammable vapours to accumulate which are ignited may result in an explosion. Explosion scenarios are further detailed in Section 7.8.

7.6 Scenario 10 - 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 FSRU / LNGC double hull design provides some inherent protection depending on the size of vessel and the speed prior to impact. Vessel speed and movements within the inner harbour are controlled by Port Authority.

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 tugs (reducing potential impact speeds) 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.

The "A Quantitative Risk Analysis Approach to Port Hydrocarbon Logistics" technical paper and TNO Purple Book [59, 60] presents calculation methods to determine representative spill sizes. For vessel collision incidents with FSRU / LNGC in the Port Kembla harbour leading to spillage, two scenarios are considered. 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. The LNG is expected to vapourise quickly resulting in flammable dispersion from 81.7m (minor spill) to 266.1m downwind (major spill).

During the firefighting support ships risk assessment (refer Section 6.3) it was agreed an unignited release is expected to be managed by water police / port security. Noting that recreational craft (potential ignition sources) are not permitted within the inner harbour. However, should the LNG pool ignite radiant heat levels of 23kW/m^2 may impact up to 51m downwind from the pool (at sea level). Figure 7-11 presents the major spill pool fire impacts of a ship collision (should the event occur within "The cut" – a ship collision event may occur anywhere within the harbour).

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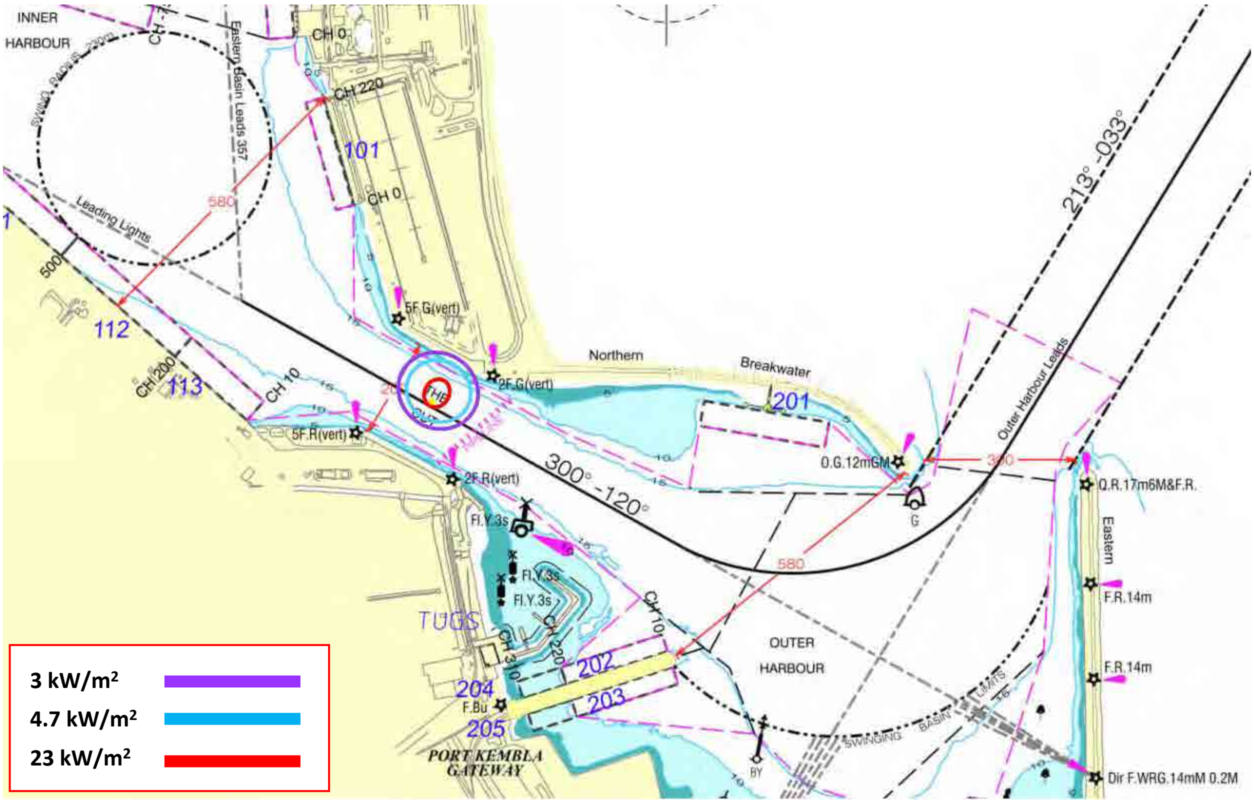

Figure 7-11: Scenario 10, Major Spill, Pool Fire Thermal Radiation Impacts at Sea Level (1m above sea)

7.7 Scenario 11 – Ship-to-ship Loading Hose Failure

LNGCs shall deliver LNG approximately every 1 to 2 weeks to the FSRU. The 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. 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. This system is supplied via the fire main system separate to the water spray system. The intent of the water spray system is to mitigate cold temperature embrittlement of the loading hoses. Only approved LNGC vessels in accordance with DNV Rules for Classification shall be selected for ship-to-ship transfer to the FSRU. LNGC shall also have water spray system in accordance with International Association of Classification Societies (IACS).

Failure of or unintended decoupling of transfer hose(s) may result in a LNG release on the surface of the water which has the potential to result in rapid phase transition as previously detailed in Section 4.4.4. 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 further detailed in Section 7.8.

Immediate ignition of a release from a ship-to-ship loading hose may results in large liquid spray fires as presented in Figure 7-12.

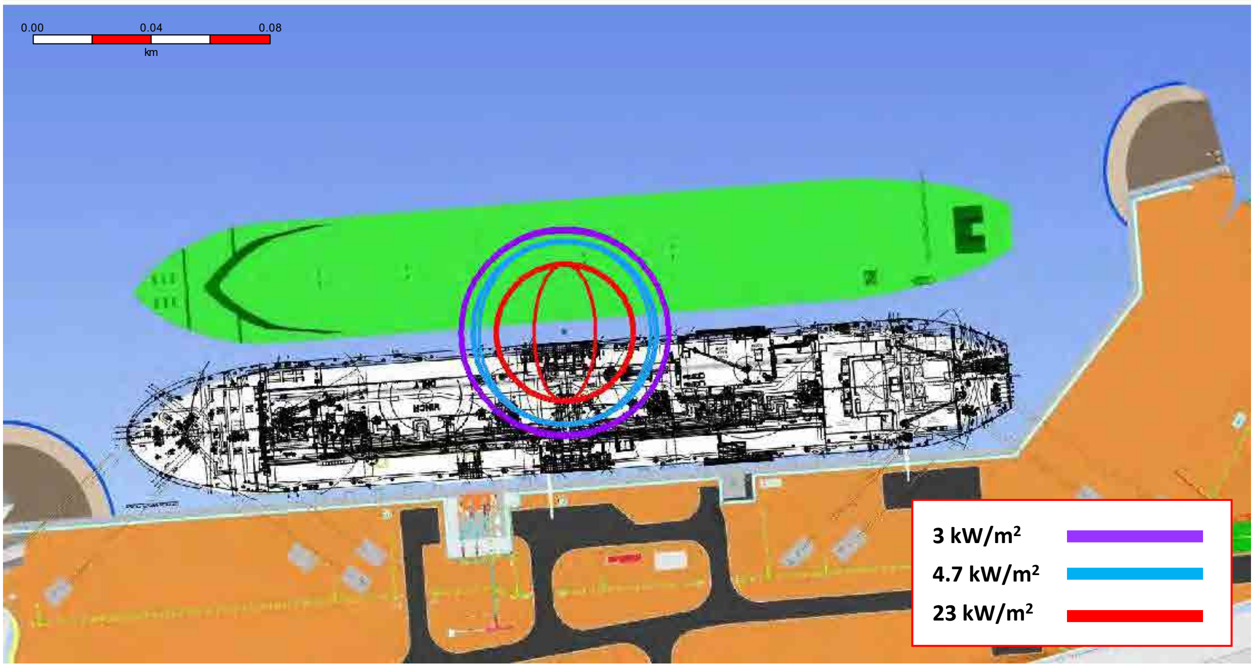

Figure 7-12: Scenario 11, 25mm Jet Fire Thermal Radiation Impacts at FSRU (14m above grade) – Initial Conditions

Confirmed fire (via fusible melt links) in the LNG cargo manifold area will activate alarms (visual and audible) at the CAAP (indicating location of fire detection) and an ESDL alarm on the IAS OS. A TPSD is also initiated which isolates the cargo inventory, de-energises machinery (i.e. pumps) and automatically starts the water spray system pump. Once the pump has started, water spray can be applied to the cargo deck and accommodation (simultaneously) to provide cooling to adjacent inventories and primary structures by opening the cargo deck water spray header isolation valve and accommodation water spray isolation valve which supplies all of the spray nozzles. These valves are remotely actuated by an FSRU operator and is included in the Höegh Fire Contingency Plan [51] for ignited liquid releases on the deck. Impacts of a liquid release from the system are expected to reduce quickly once loading hose emergency release couplings activated to isolate the inventory from the LNGC. It is expected the LNGC vessel will have an equivalent fire prevention strategy and controls.

Table 7-11 indicates this scenario is not expected to impact any of the onsite receptors identified. The FSRU Fire Control and Safety Plan Layout (refer Appendix B) shows multiple means of egress (i.e. if one is impaired, the crew can egress via an alternate route) to allow for safe egress of personnel to the muster point located at the lifeboat station or the fire control stations in the accommodation. Like other scenarios, crew are able to refuge for as long as required in this location and await instruction should additional firefighting response be required. It is expected the LNGC will also have multiple escape routes to their muster point locations. However, the exact locations of these are unknown.

Table 7-11: Scenario 11 Ship-to-ship Loading Hose Failure – Potential impacts to onsite sensitive receptors

Fire Event	FSRU MP	FSRU Accom.	Gangway	Berth FW Monitors	Berth MLA	Berth Buildings
25mm Jet Fire	N	N	N	N	N	N

7.8 Explosion Escalation Scenarios

Releases from the above FSRU scenarios have the potential to accumulate in congested / enclosed areas which if are ignited have the potential for a VCE. Details of the explosion modelling included in the FEED PHA [31] consequence analysis are summarised in Section 4.5.2.4. A high level summary of the detection and protection measures in each of the locations identified (if applicable) is provided in Table 7-12.

Table 7-12: Explosion Scenario Gas detection and protection measures

Location	Detection Type	Executive Action (protection)
Cargo machinery room	• IR point gas detectors (2oo3 voting)	• ESDL alarms on CAAP and IAS OS • Initiates TPSD
Suction Drum (not applicable to LNGC)	• IR point gas detectors (2oo3 voting)	• ESDL alarms on CAAP and IAS OS • Ability to activate blowdown of regasification plant is provided (requires manual activation on confirmed gas)
Regasification plant (not applicable to LNGC)	• LOS and IR point gas detectors (2oo16 voting)	• ESDL alarms on CAAP and IAS OS • Ability to activate blowdown of regasification plant is provided (requires manual activation on confirmed gas)

Worst case explosion overpressures generated from VCEs originating from LNG cargo tank pipework (single explosion only), cargo machinery room, suction drum module or regasification plant module based on worst case stoichiometric flammable masses are presented in Figure 7-13, Figure 7-14, Figure 7-15, and Figure 7-16 respectively.

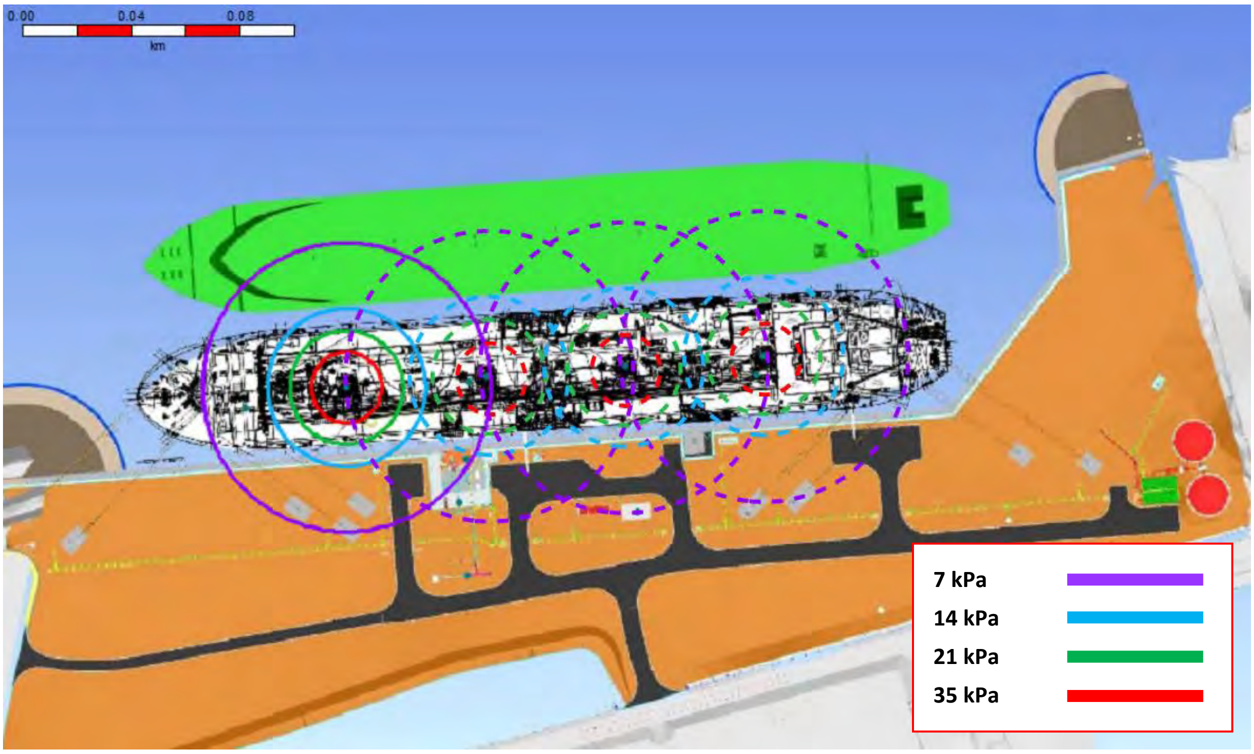

Figure 7-13: LNG Cargo Tank 1-4 Piping VCE

The solid line in Figure 7-13 represents the impacts of a single explosion (i.e. cargo tank 1 and associated pipework). While the dashed line shows impacts should the release emanate from another location (i.e. cargo tank 2-4 associated pipework). It is not expected that explosion events from the cargo tank piping will occur at the same time as this requires simultaneous LOC from multiple locations.

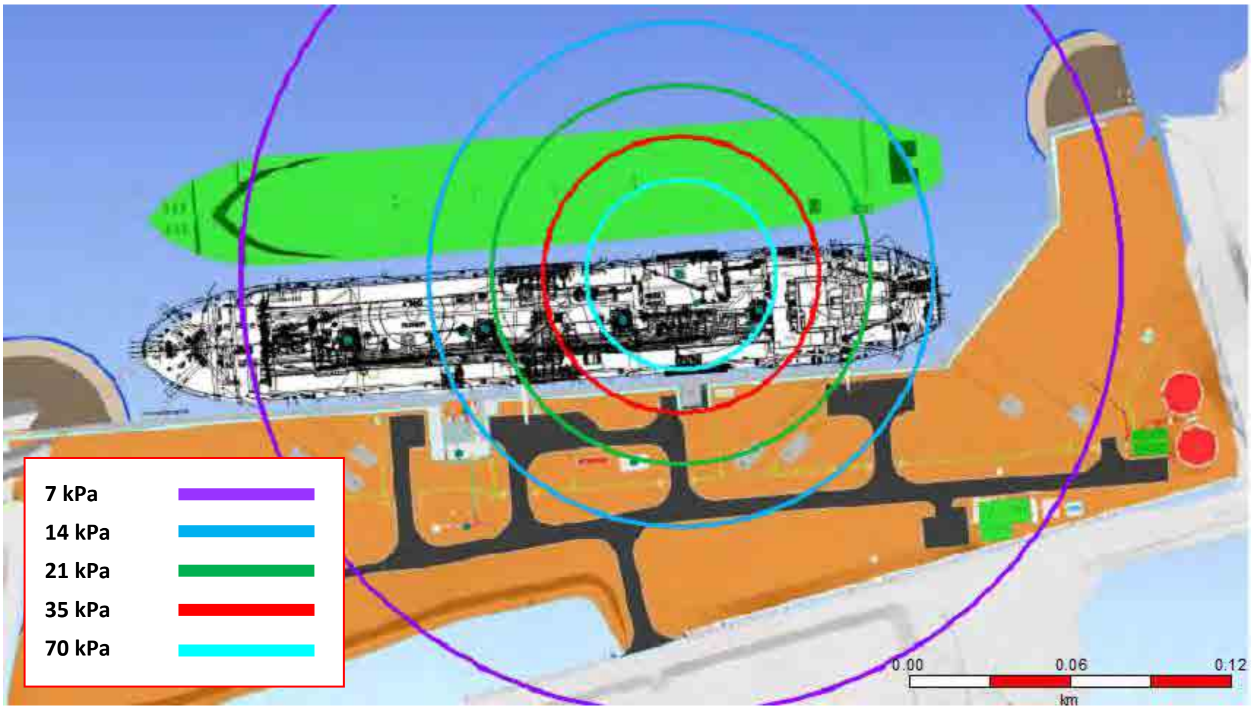

Figure 7-14: Cargo machinery room VCE

An explosion in the cargo machinery room is the worst case explosion scenario on the FSRU vessel as it generates the highest peak overpressure. However, it has gas detection provided, where on confirmed gas in the cargo machinery room will activate an alarm at the CAAP and isolate the gas inventory. It is the only location on the FSRU where TPSD is activated on confirmed gas. The cargo machinery room is also provided with high pressure CO_2 extinguishing system which is manually activated [49]. This is to ensure personnel are not located within the cargo machinery room when the CO_2 is released. A 25mm hole size release in the cargo machinery room would require going undetected for at least five minutes to achieve the stoichiometric flammable mass capable of producing the explosion overpressures presented in Figure 7-14.

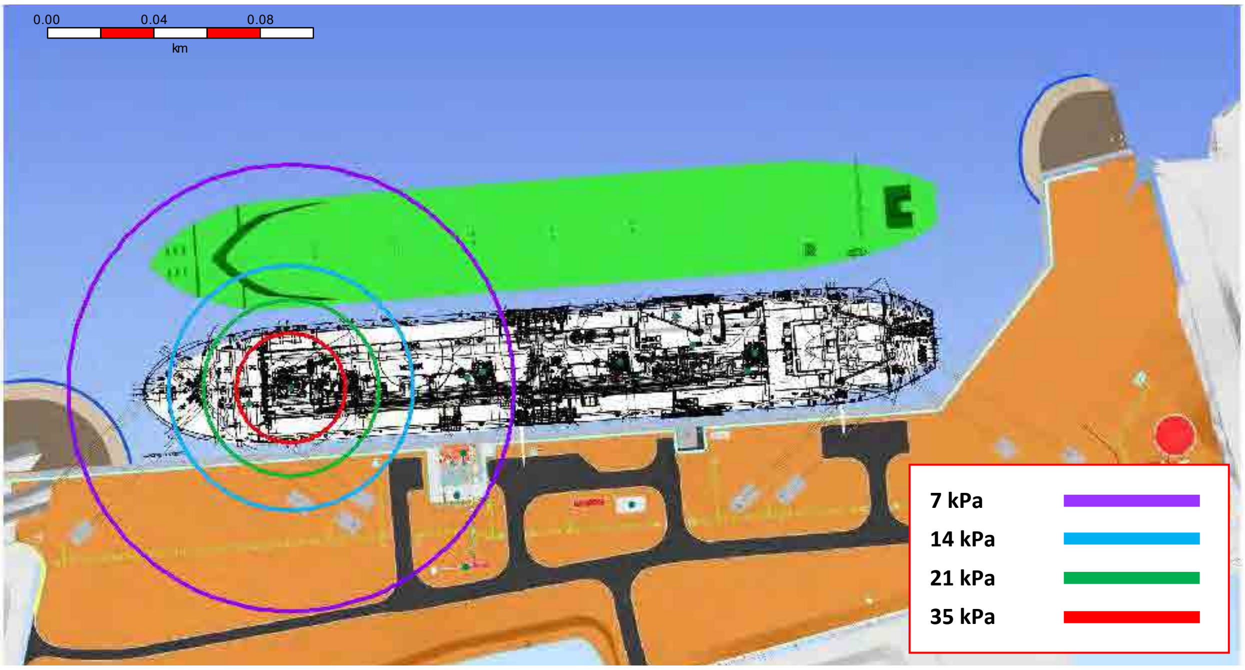

Figure 7-15: Suction Drum Module VCE

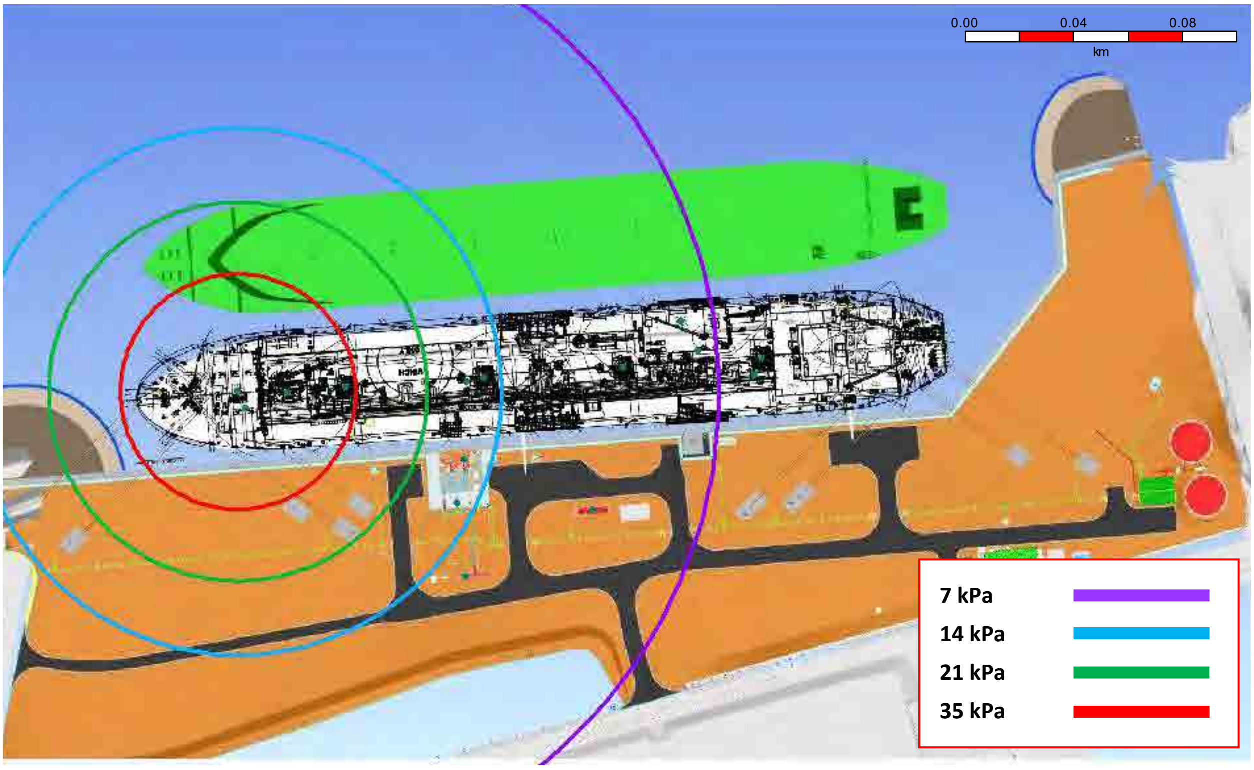

Figure 7-16: Regasification module (top half) VCE

Table 7-13 indicates that based the stoichiometric flammable mass, there are explosion scenarios that may impact various onsite sensitive receptors. The FSRU has multiple escape routes (i.e. if one is impaired, the crew can egress via an alternate route). Escape routes impacted by explosion overpressure levels of 7kPa are not expected to be impaired and personnel in these areas have a 10% probability of injury. Injury risk was calculated in Addendum 2 to the FEED PHA [33] and PKGT Final Hazard Analysis [41] and is detailed further below. An explosion in the cargo room generates the worst case explosion overpressures. Noting, these do not take into account the onboard F&G detection, and isolation systems on board the FSRU.

Table 7-13: FSRU Explosion impacts to onsite sensitive receptors

Explosion Event	FSRU MP	FSRU Accom.	Gangway	Berth FW Monitors	Berth MLA	Berth Buildings
LNG Cargo Tank 1-4 Piping	N	Yes 14kPa (Tank 4)	Yes 7kPa (Tank 3&4)	N	N	N
Cargo Machinery Room	Yes >7kPa	Yes >14kPa	Yes >14kPa	Yes 14kPa (FM101)	N	Yes >7kPa
Suction Drum Module	N	N	N	Yes 14kPa (FM102)	N	N
Regasification Module (Bottom Half)	N	N	N	Yes >14kPa (FM102)	Yes 14kPa	N
Regasification Module (Top Half)	N	N	Yes 7kPa	Yes >14kPa (FM102)	Yes 14kPa	N

Propagation and injury risk was calculated in the PKGT Final Hazard Analysis [41] and is presented in Figure 7-17 and Figure 7-18 respectively. Noting the dashed red line is representative of the buried PKP route.

Figure 7-17: Property Damage (5E-05 pa) from 14 kPa Explosion Overpressure Levels

Figure 7-18: Injury Risk (5E-05 pa) from 7 kPa Explosion Overpressure Levels

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, is located 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 7-18 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. Personnel onboard the FSRU are expected to egress to the muster point located at the lifeboat station or the fire control stations in the accommodation and aren't typically expected to be located in this area.

8. ORF Fire Detection and Prevention Measures

The potential release scenarios detailed in Table 4-7 that originate from the ORF include Scenario 6-9. The likelihood of these events occurring is documented as part of a detailed frequency analysis in the PKGT Final Hazard Analysis [41]. This section reviews the fire prevention strategies for each of the release scenarios which originate from the ORF. A high level summary of the detection and protection measures is provided for each scenario, while detailed summaries of the fire detection and protection measures are provided in Section 5 and Section 6. In all cases of confirmed gas or fire, alarms will be activated in the Jemena EGP Control Room which will be manned 24/7. As previously detailed in Section 5.3, safe approach to the facility and notification of an incident will be documented in the facility's emergency response procedures which will be developed and approved prior to operation per the requirements of Infrastructure Approval [19] Schedule 3, Condition 23(a).

In addition, potential impacts on the following areas have been included:

- Gangway between FSRU and shore;
- Berth infrastructure including MLAs and ESD valves;
- Berth MPs; and
- Berth fire water storage tanks and pump; and
- Berth electrical and instrument building (containing emergency control room).

Impacts to people are based on the 4.7 kW/m^2 thermal radiation level and the 7 kPa explosion overpressure level while impacts to equipment and structures are based on the 23 kW/m^2 thermal radiation level and the 14 kPa explosion overpressure level. As previously detailed, equipment impacted by the 12.6kWm^2 thermal radiation level is not considered due to equipment materials of construction onsite. The berth fire water storage tanks, fire water pumps, and electrical and instrument room (containing emergency control room) are located outside all of the other ORF maximum 25mm hole size ignited jet fire impact distances. The 3 kW/m^2 radiant heat level contours are provided for information in compliance with AS 1940.

Should a LOC occur, the extent of unignited gas dispersion and flash fire impacts have been determined and are provided in Appendix A. The maximum flash fire impact distance emanating from the ORF results from a release of natural gas from the PKP (Scenario 8). This release has the potential to impact the ORF and other berth infrastructure. However, gas detection is provided in the main process areas where an accidental release of flammable gas can occur or where the presence of gas cannot be tolerated or at the boundaries of process areas to detect a leak migrating toward not rated electrical equipment (refer Section 5.4.3). It is expected that flammable gas dispersion will be detected and isolated quickly. The berth fire water storage tanks, and fire water pumps are located outside all of the other ORF maximum 25mm hole size unignited gas dispersion impact distances.

As detailed in Section 4.4.1.1, flash fires are short duration events in which a flame rapidly passes through the fuel without generating damaging overpressures and burns for an insufficient duration to cause structural and equipment damage [58]. The ensuing jet fires are reviewed in the following sections and as it has larger lasting impact, flash fire impacts are not considered further.

8.1 Scenario 6 – NG from FSRU ESD Valve to ORF (up to SDV-064001 / SDV-064002) including MLA

The 2 x 12" MLA's used to transfer high pressure natural gas from the FSRU to the ORF are designed by Emco Wheaton. Fail closed ESD valves (RCG705, RCG706) are provided for each MLA on the FSRU itself and an additional ESD valve is also provided within the Emco Wheaton MLA package. A high level summary of the detection and protection measures is provided in Table 8-1.

Table 8-1: Scenario 6 HP Gas at MLAs – Fire and gas detection and protection measures

Material	Location	Detection Type	Executive Action (protection)
NG	MLA	• Acoustic and point gas detectors (2ooN)	• Initiate total terminal shutdown
		• IR flame detectors (2ooN)	• Initiate total terminal shutdown and start ORF firewater pumps

Acoustic and point gas detection is provided in the vicinity of the MLAs (refer Section 5.4.3). The detailed fire and gas layouts as provided in Appendix C. Confirmed gas shall initiate the alarm system locally and in the Jemena EGP control room and initiate ESD. Emergency response arrangements including safe approach to the facility and notification of an incident will be documented in the facility's emergency response procedures which will be developed and approved prior to operation per the requirements of Infrastructure Approval [19] Schedule 3, Condition 23(a).

Should the LOC go undetected, immediately ignited releases from this area of the process are expected to result in large gaseous jet fires. Figure 8-1 presents the immediately ignited jet fire impacts from a 25mm hole size release. The inner solid line represents the impacts of a single release, whereas the outer solid line represents the extent of the impacts in other directions.

Figure 8-1: Scenario 6, 25mm Jet Fire Thermal Radiation Impacts at ORF (1m above grade) – Initial Conditions

Confirmed fire (via IR flame detectors) in the MLA / ship-to-shore manifold area will send ESD signals to the FSRU and MLA packages, isolate the inventory, stop the odourant injection package and start the firewater pumps. Impacts of a high pressure gaseous release from the system is expected to reduce as a result of inventory depletion.

Once the gas inventory has been isolated the fire duration for a 25mm hole size release in this area is estimated to be 7.5 minutes. Fire durations for other hole size releases is provided in Table A- 1 (refer Appendix A). The initial flame length is 46m while 5 minutes after detection and isolation this reduces to 13m. The resultant jet fire 5 minutes post release is presented in Figure 8-2.

Figure 8-2: Scenario 6, 25mm Jet Fire Thermal Radiation Impacts at ORF (1m above grade) – After 5 Minutes

Failure of the MLA (i.e. due to extreme vessel movements) may result in full-bore failure. The detailed consequence modelling results are provided in Appendix A. The MLA will be equipped with an emergency release system and will activate if the MLAs approach the limits of their physical operating envelope (refer Section 5.5.2).

Depending on the release orientation and location, the MLA structures and associated pipework may be impacted by thermal radiation levels greater than 23 kW/m^2 for greater than 5 minutes. The requirement for additional protections for these structures as a result of this scenario was considered in the PKGT Passive Fire Protection Requirement Assessment Technical Note [39] which concluded:

- The MLA structures and associated pipework can be impacted by this scenario for greater than 5 minutes resulting in potential failure and escalation. However, the Jemena EGP control room will be notified of a confirmed fire event at the ORF. Confirmed fire at the ORF will automatically start the fire water system and the Jemena EGP control room will have the ability apply cooling to the MLAs via the tower mounted fire water monitors. This scenario will not impact the fire water monitors.
- The above ground PKP section will not be impacted by this scenario for greater than 5 minutes.

indicates that based on initial conditions, this scenario may impact onsite receptors at the ORF with high levels of radiant heat. The ORF has controls to detect this fire event, remove the pressure source and isolate the inventory. As detailed above, the requirement for PFP to be applied to the berth MLA and FW monitor was considered by the project [39]. However, it was concluded that PFP was not required as the MLA structures and associated pipework which contain a small inventory and can be protected by the fire water monitors. As detailed in Section 6.2.5, controls for the tower mounted fire water monitors are provided in multiple locations including a mobile unit which is available on the FSRU. The FSRU CCR is manned 24/7.

This scenario will not impact egress or muster on the FSRU. Should a fire event occur on the berth, the FSRU crew can remain on the ship unless it becomes unsafe. The ORF has multiple escape routes the allow for safe egress of personnel to the muster point located outside the eastern fence line of the ORF.

Table 8-2: Scenario 6 HP Gas at MLAs – Potential impacts to onsite sensitive receptors

Fire Event	FSRU MP	FSRU Accom.	Gangway	Berth FW Monitors	Berth MLA	Berth Buildings
25mm Jet Fire (Initial)	N	N	Yes 3kWm/^{2}	Yes >23kW/m^2	Yes >23kW/m^2	N
25mm Jet Fire (5 mins)	N	N	N	N	Yes >23kW/m^2	N

8.2 Scenario 7 - ORF Pipework (from SDV-064001 / SDV-064002 to SDV-064007)

Once the gas has been transferred to the shore via the MLAs, a small amount of above ground pipework with odourant injection is provided. A high level summary of the detection and protection measures is provided in Table 8-3.

Table 8-3: Scenario 7 HP Gas at ORF – Fire and gas detection and protection measures

Material	Location	Detection Type	Executive Action (protection)
NG	ORF	• LOS, acoustic and point gas detectors (2ooN)	• Initiate total terminal shutdown
		• IR flame detectors (2ooN)	• Initiate total terminal shutdown and start ORF firewater pumps

The ORF process area has gas detection provided (refer Section 5.4.3). The detailed fire and gas layouts as provided in Appendix C. Confirmed gas detection in this area shall initiate the alarm system locally and in the Jemena EGP control room and initiate ESD. Emergency response arrangements including safe approach to the facility and notification of an incident will be documented in the facility's emergency response procedures which will be developed and approved prior to operation per the requirements of Infrastructure Approval [19] Schedule 3, Condition 23(a).

Should the LOC go undetected, immediately ignited releases from this area of the process are expected to result in large gaseous jet fires. Figure 8-3 presents the immediately ignited jet fire impacts from a 25mm hole size release. The inner solid line represents the impacts of a single release, whereas the outer solid line represents the extent of the impacts in other directions.

Figure 8-3: Scenario 7, 25mm Jet Fire Thermal Radiation Impacts at ORF (1m above grade) – Initial Conditions

Confirmed fire (via IR flame detectors) in the ORF will send ESD signals to the FSRU and MLA packages, isolate the inventory, stop the odourant injection package and start the firewater pumps. Impacts of a high pressure gaseous release from the system is expected to reduce as a result of inventory depletion.

Once the gas inventory has been isolated the fire duration for a 25mm hole size release in this area is estimated to be 6.5 minutes. Fire durations for other hole size releases is provided in Table A- 1 (refer Appendix A). The initial flame length is 46m while 5 minutes after detection and isolation this reduces to 10m. The resultant jet fire 5 minutes post release is presented in Figure 8-4.

Figure 8-4: Scenario 7, 25mm Jet Fire Thermal Radiation Impacts at ORF (1m above grade) – After 5 Minutes

Depending on the release orientation and location the MLA structures and associated pipework and the above ground section of the PKP may be impacted by thermal radiation levels greater than 23 kW/m^2 for greater than 5 minutes. The requirement for additional protections for these structures as a result of this scenario was considered in the PKGT Passive Fire Protection Requirement Assessment Technical Note [39] which concluded:

- The MLA structures and associated pipework can be impacted by this scenario for just greater than 5 minutes resulting in potential failure and escalation. However, the Jemena EGP control room will be notified of a confirmed fire event at the ORF. Confirmed fire at the ORF will automatically start the fire water system and the Jemena EGP control room will have the ability apply cooling to the MLAs via the tower mounted fire water monitors. This scenario will not impact the fire water monitors.
- The above ground PKP section can be impacted by this scenario for just greater than 5 minutes resulting in potential failure and escalation. As this is a relatively large isolatable inventory, a passive fire protection coating will be applied to above ground pipework from the above ground / below ground interface to SDV-064007 to provide further mitigations against a fire event. Confirmed fire at the ORF will automatically start the fire water system and the Jemena EGP control room will have the ability apply cooling to the MLAs via the tower mounted fire water monitors.

Table 8-3 indicates that based on initial conditions, this scenario may impact onsite receptors at the ORF with high levels of radiant heat. The ORF has controls to detect this fire event, remove the pressure source and isolate the inventory. As detailed above, the requirement for PFP to be applied to the berth MLA and FW monitor was considered by the project [39]. It was concluded that passive fire protection coating will be applied to above ground pipework from the above ground / below ground interface to SDV-064007. However, it was considered that PFP was not required for the MLA structures and associated pipework which contain a much smaller inventory and can be protected by the fire water monitors. As detailed in Section 6.2.5, controls for the tower mounted fire water monitors are provided in multiple locations including a mobile unit which is available on the FSRU. The FSRU CCR is manned 24/7.

This scenario will not impact egress or muster on the FSRU. Should a fire event occur on the berth, the FSRU crew can remain on the ship unless it becomes unsafe. The ORF has multiple escape routes the allow for safe egress of personnel to the muster point located outside the eastern fence line of the ORF.

Table 8-4: Scenario 7 HP Gas at ORF – Potential impacts to onsite sensitive receptors

Fire Event	FSRU MP	FSRU Accom.	Gangway	Berth FW Monitors	Berth MLA	Berth Buildings
25mm Jet Fire (Initial)	N	N	N	Yes >23kW/m^2	Yes >23kW/m^2	N
25mm Jet Fire (5 mins)	N	N	N	N	Yes >23kW/m^2	N

8.3 Scenario 8 - PKP (from SDV-064007 to MLV-064011)

Odourised, high pressure gas is then delivered to 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 KGMS. However, a boundary isolation valve (MLV-064011) is installed approximately 300m from the pipeline aboveground / below ground transition. This is also considered as the boundary of the FSS scope.

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. A Pipeline Safety Management Study has been carried out for the Jemena PKP [24] 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 which starts at the ORF). 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 [62]. Small leaks from the buried section of PKP operated by Jemena will rely on noise and smell while large leaks will be detected via change of pressure monitoring.

A high level summary of the detection and protection measures available at the ORF for a LOC in the above ground section of the PKP is provided in Table 8-5. Noting the above ground section of the PKP will be provided with a passive fire protection coating. It will be fully welded downstream of the ESD valve and in clean dry service. As such, significant corrosion is not expected.

Table 8-5: Scenario 8 HP Gas at ORF (above ground section of PKP) – Fire and gas detection and protection measures

Material	Location	Detection	Executive Action (protection)
NG	ORF (above ground section of pipeline)	• LOS, acoustic and point gas detectors (2ooN)	• Initiate total terminal shutdown
		• IR flame detectors (2ooN)	• Initiate total terminal shutdown and start ORF firewater pumps

The ORF process area has gas detection provided (refer Section 5.4.3). The detailed fire and gas layouts as provided in Appendix C. Confirmed gas detection in this area shall initiate alarm system locally and in the Jemena EGP control room and initiate ESD. Safe approach to the facility and notification of an incident will be documented in the facility's emergency response procedures which will be developed and approved prior to operation per the requirements of Infrastructure Approval [19] Schedule 3, Condition 23(a).

Like Scenario 6 and Scenario 7, should the LOC go undetected, immediately ignited releases from this area of the process are expected to result in large gaseous jet fires. Figure 8-5 presents the immediately ignited jet fire impacts from a 25mm hole size release. The inner solid line represents the impacts of a single release, whereas the outer solid line represents the extent of the impacts in other directions.

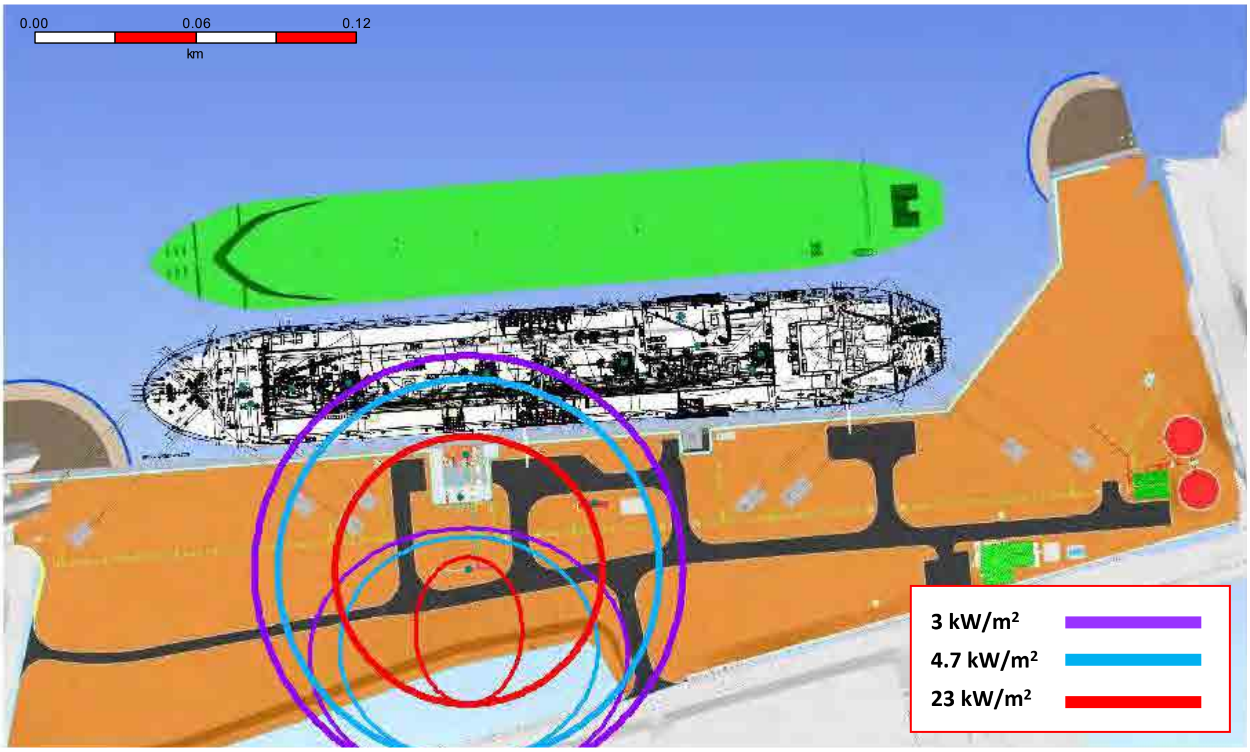

Figure 8-5: Scenario 8, 25mm Jet Fire Thermal Radiation Impacts at ORF (1m above grade) – Initial Conditions

Confirmed fire (via IR flame detectors) in the ORF will send ESD signals to the FSRU and MLA packages, isolate the inventory, stop the odourant injection package and start the firewater pumps. Impacts of a high pressure gaseous release from the system is expected to reduce as a result of inventory depletion.

Once the gas inventory has been isolated the fire duration for a 25mm hole size release from the above ground section of the PKP may be sustained for greater than 1 hour. Fire durations for other hole size releases is provided in Table A- 1 (refer Appendix A). Although this fire event may be sustained for a long duration, the initial flame length is 46m. 5 minutes after detection and isolation this reduces to 36m and will continue to reduce with time. The resultant jet fire 5 minutes post release is presented in Figure 8-6. In addition, the PKGT Final Hazard Analysis [41] calculated the overall fire frequency for all hole sizes in the above ground section of the PKP be 1.92E-05 pa considering the full range of hole sizes. For smaller hole size releases (i.e. 25mm and smaller) the fire frequency is 6.20E-06 pa. This is less than the industry criteria for escalation of 1E-04 pa.

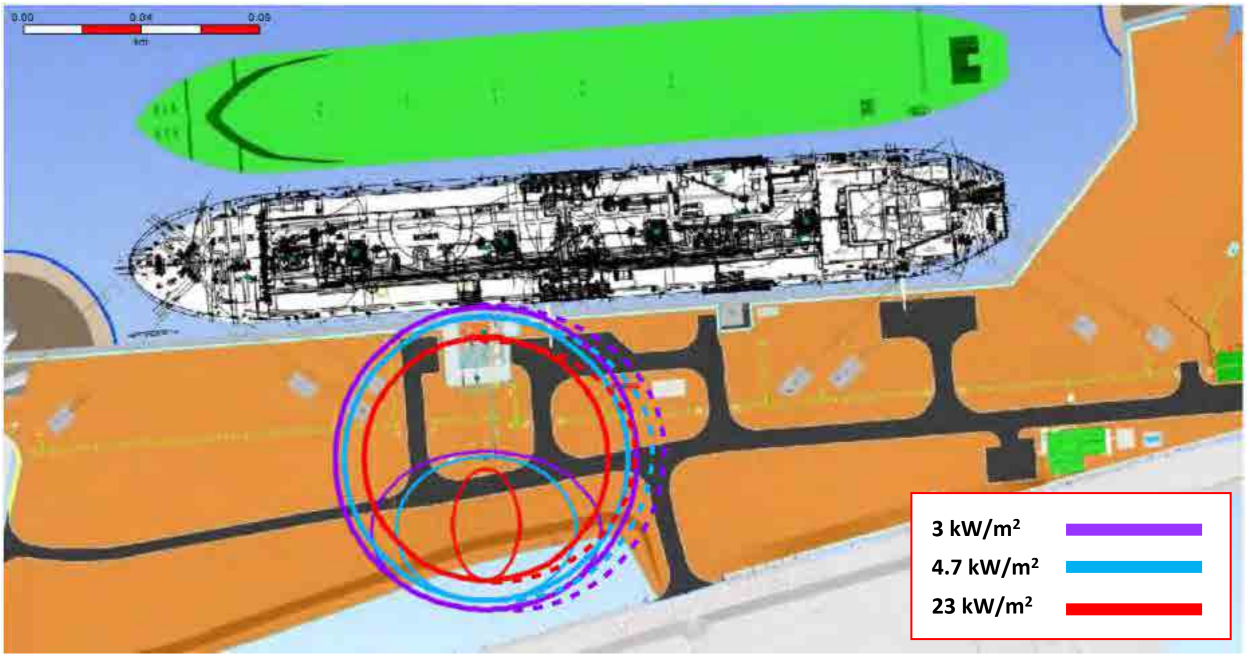

Figure 8-6: Scenario 8, 25mm Jet Fire Thermal Radiation Impacts at ORF (1m above grade) – After 5 Minutes

Depending on the release orientation and location the MLA structures and associated pipework may be impacted by thermal radiation levels greater than 23 kW/m^2 for greater than 5 minutes. The requirement for additional protections for these structures as a result of this scenario was considered in the PKGT Passive Fire Protection Requirement Assessment Technical Note [39] which concluded:

- The MLA structures and associated pipework can be impacted by this scenario for greater than 5 minutes resulting in potential failure and escalation. However, the Jemena EGP control room will be notified of a confirmed fire event at the ORF. Confirmed fire at the ORF will automatically start the fire water system and the Jemena EGP control room will have the ability apply cooling to the MLAs via the tower mounted fire water monitors. This scenario will not impact the fire water monitors.

Table 8-4 indicates that based on initial conditions, this scenario may impact onsite receptors at the ORF with high levels of radiant heat. The ORF has controls to detect this fire event, remove the pressure source and isolate the inventory. As detailed above, the requirement for PFP to be applied to the berth MLA and FW monitor was considered by the project [39]. However, it was concluded that PFP was not required as the MLA structures and associated pipework which contain a small inventory and can be protected by the fire water monitors. As detailed in Section 6.2.5, controls for the tower mounted fire water monitors are provided in multiple locations including a mobile unit which is available on the FSRU. The FSRU CCR is manned 24/7.

This scenario will not impact egress or muster on the FSRU. Should a fire event occur on the berth, the FSRU crew can remain on the ship unless it becomes unsafe. The ORF has multiple escape routes the allow for safe egress of personnel to the muster point located outside the eastern fence line of the ORF.

Table 8-6: Scenario 8 HP Gas at ORF (above ground section of PKP) – Potential impacts to onsite sensitive receptors

Fire Event	FSRU MP	FSRU Accom.	Gangway	Berth FW Monitors	Berth MLA	Berth Buildings
25mm Jet Fire (Initial)	N	N	N	Yes >23kW/m^2	Yes >23kW/m^2	N

Fire Event	FSRU MP	FSRU Accom.	Gangway	Berth FW Monitors	Berth MLA	Berth Buildings
25mm Jet Fire (5 mins)	N	N	N	N	N	N

8.4 Scenario 9 - Odourant Storage & Pipework

Odourant is stored onsite in two 500L SBCs housed within a shipping container. The container has internal bunding and provision for a third SBC. The shipping container will also contain the injection packages. 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 odourant shipping container will have an activated carbon filter system provided by the vendor. A high level summary of the detection and protection measures is provided in Table 8-7.

Table 8-7: Scenario 9 Odourant Storage and Pipework – Fire and gas detection and protection measures

Material	Location	Detection Type	Executive Action (protection)
Odourant	ORF	• Acoustic and point gas detector (2ooN)	• Initiate total terminal shutdown
		• IR flame detectors (2ooN)	• Initiate total terminal shutdown and start ORF firewater pumps
	Odourant shipping container	• Heat detection cable	• Raise alarm in control room

The detailed fire and gas layouts as provided in Appendix C. Appendix C also provides the ORF safety equipment layout and presents the location of the foam fire extinguisher provided. It is noted the fire and gas layout for the odourant package shows point gas detection. However, AIE has confirmed (in consultation with others) they are not progressing with this design and only heat detection cable is being provided by the vendor. Confirmed fire (by melting of the cable) will result in an alarm only. The layouts will be "as-built" to capture this change.

During normal operation if a LOC occurs at the storage conditions (refer Scenario 9a, Table 4-7), unignited releases, jet fire and pool fire events are expected to be contained within the shipping container. Should a release in the odourant shipping container go undetected there is potential for flammable vapours to accumulate which are ignited may result in an explosion. Explosion scenarios are further detailed in Section 8.5.

Although the odourant injection pressure is high, harmful consequences of a LOC at the odourant injection conditions (refer Scenario 9b, Table 4-7) are either very localised or not produced due to the low flow rates limited by the injection pump. The odourant tubing from the container to the injection point shall be fully welded. Point gas detection is provided at the injection point [28].

As SBC changeout is expected to occur frequently with the long side of the container adjacent to the road being open and accessible, unignited release (toxic), jet fire and pool fire impacts have been assessed at the storage conditions (refer Scenario 9a, Table 4-7).

Figure 8-7 and Figure 8-8 presents the potential jet fire and pool fire impacts from a 25mm hole size release. The inner solid line represents the impacts of a single release, whereas the outer solid line represents the extent of the impacts in other directions. The extent of the pool fire is represented in yellow. Noting pool fires modelled in DNV PHAST are circular based on the expected pool fire area.

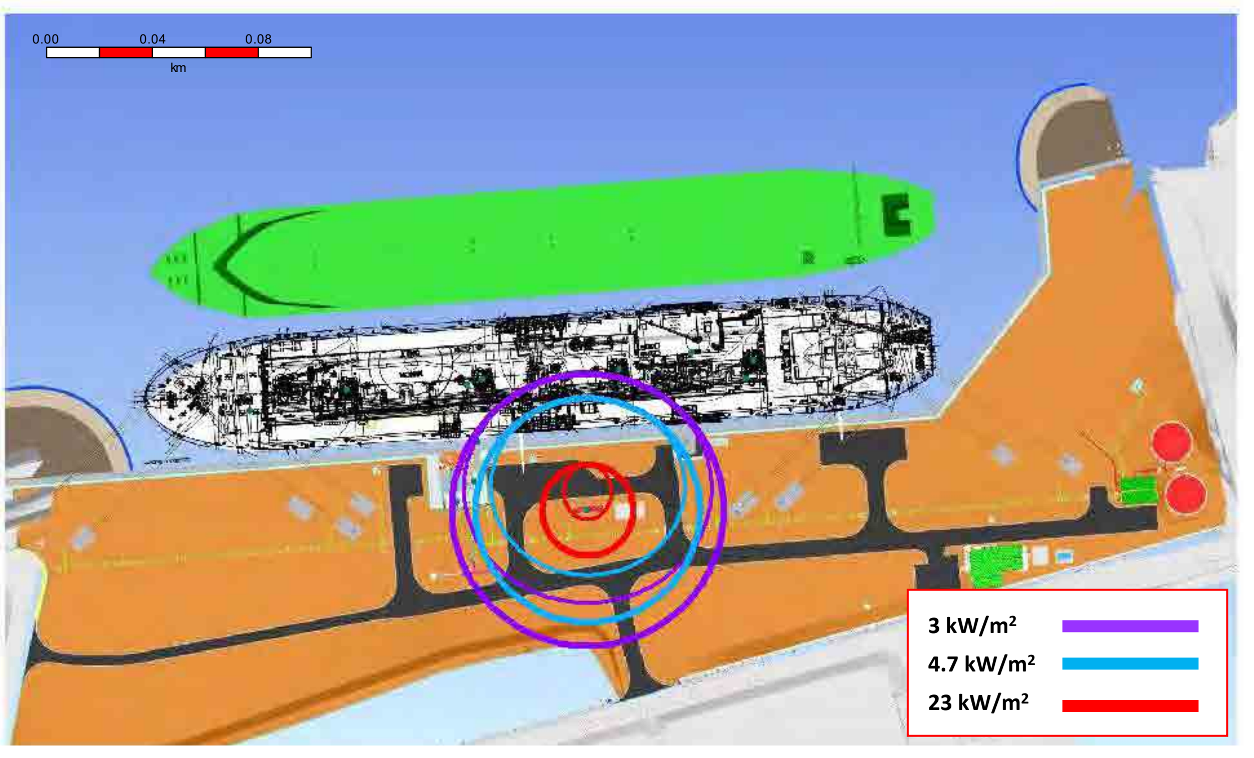

Figure 8-7: Scenario 9a, 25mm Jet Fire Thermal Radiation Impacts at ORF (1m above grade) – Initial Conditions

Figure 8-8: Scenario 9a, 25mm Pool Fire Thermal Radiation Impacts at ORF (1m above grade) – Initial Conditions

Figure 8-9 presents the unignited (toxic) dispersion impacts from a 25mm hole size release. The inner solid line represents the impacts of a single release, whereas the outer solid line represents the extent of the impacts in other directions. Noting due to the extent of the 6ppm dispersion (furthest impact is ~2.48km downwind), the outer solid line (effect zone) is not shown. Figure 8-10 presents the location of the nearest residential neighbours which may be impacted by 6 ppm concentrations (effects are not disabling and are transient and reversible upon cessation of exposure) during SBC changeout.

Safe entry procedures for any activity that involves entry to the shipping container will be developed.

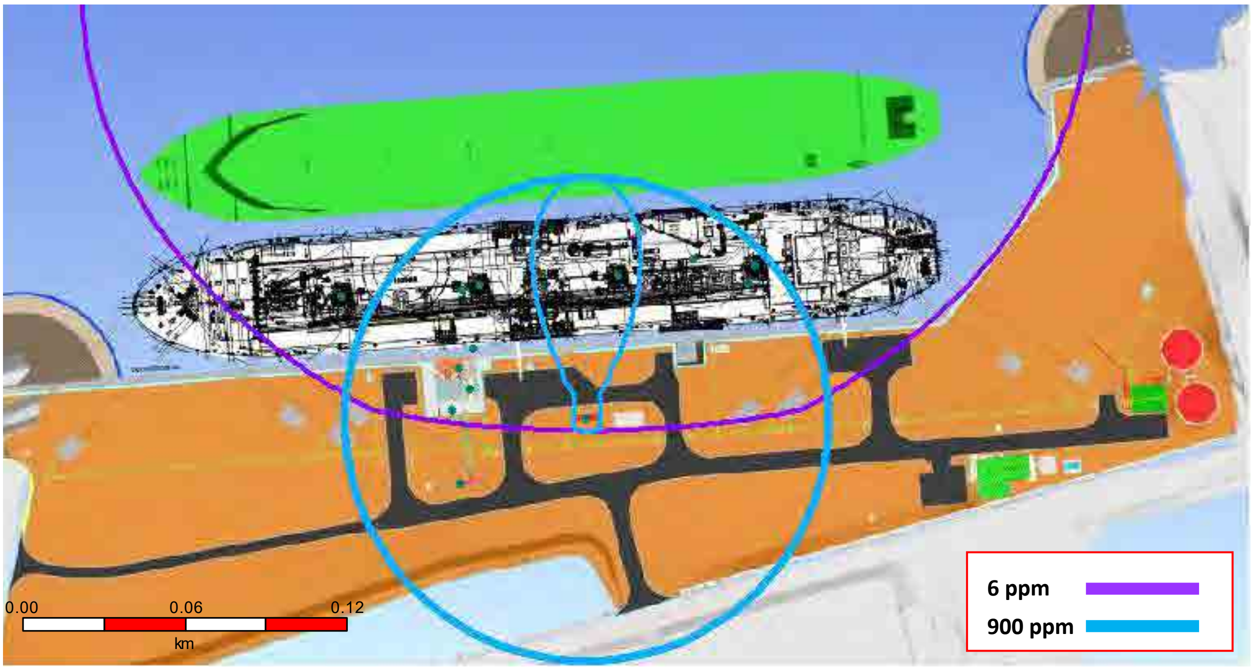

Figure 8-9: Scenario 9a, 25mm Toxic Dispersion Impacts during SBC changeout at ORF (1m above grade)

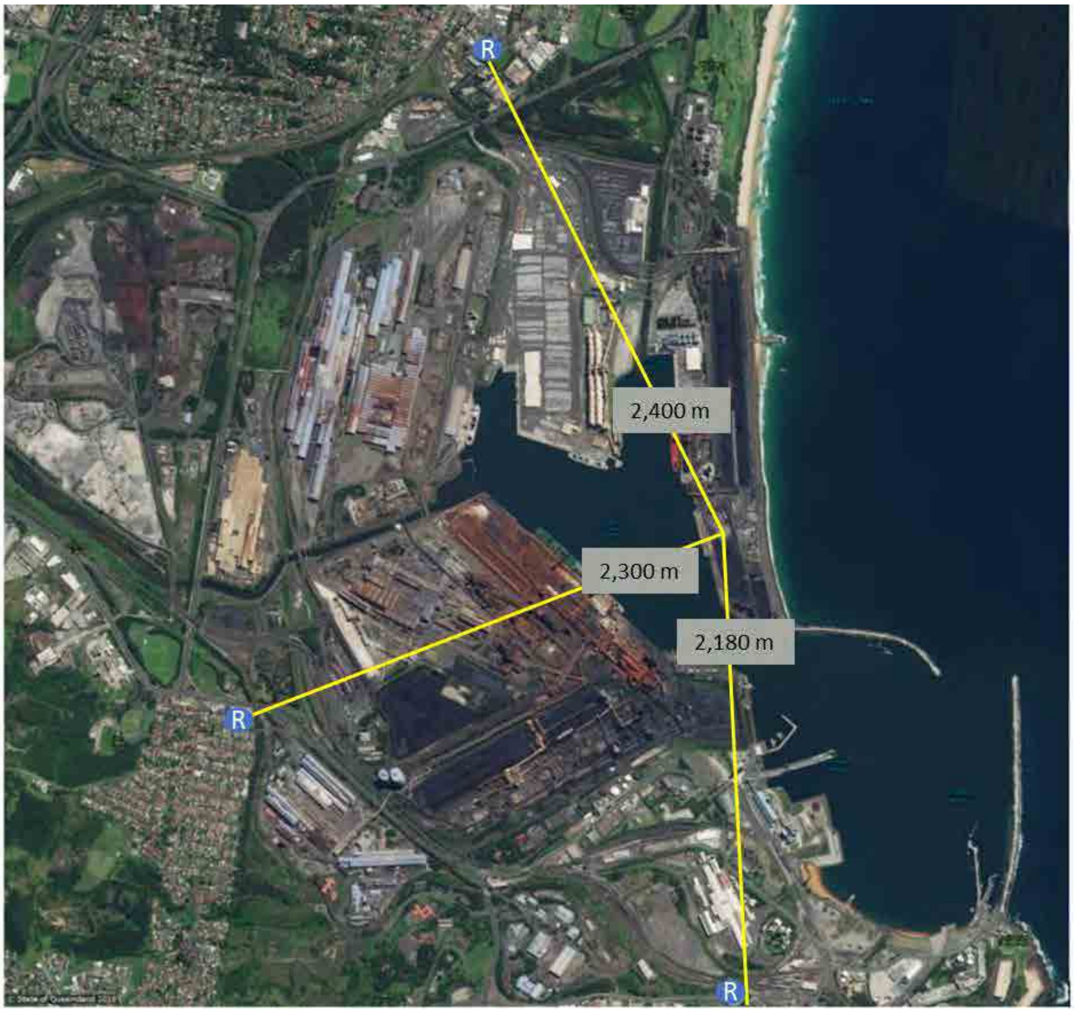

Figure 8-10: Neighbouring Residential Areas

Injury risk resulting from toxic exposure was determined in the PKGT Final Hazard Analysis [41] and has been reproduced in Figure 8-11 and Figure 8-12. It was concluded that no residential and sensitive land users in the vicinity of the PKGT that will be exposed to injury risks greater than the criteria specified in HIPAP4. Figure 8-11 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 8-12 shows the 1E-05 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 8-11: Injury Risk (5E-05 pa) – Minor injury due to toxic exposure (AEGL 1, 30 min)

Figure 8-12: Injury Risk (1E-05 pa) - Serious injury due to toxic exposure (AEGL 2, 30 min)

Table 8-5 indicates this scenario is not expected to impact any of the onsite receptors identified. Should a fire event occur on the berth, the FSRU crew are not expected to evacuate the ship. During SBC changeout activities, a LOC may impact onsite areas. However, toxic dispersion impacts at the height of the FSRU are not reached.

Table 8-8: Scenario 9 Odourant Storage and Pipework – Potential impacts to onsite sensitive receptors

Fire / Toxic Event	FSRU MP	FSRU Accom.	Gangway	Berth FW Monitors	Berth MLA	Berth Buildings
25mm Jet Fire (Initial / 5 Mins)	N	N	N	N	N	N
25mm Pool Fire	N	N	Yes 3kW/m^2	N	N	N
25mm Toxic Dispersion	N	N	N	N	N	N

8.5 Explosion Escalation Scenarios

AIE has confirmed (in consultation with others) there is no provision for gas detection within the shipping container. Releases of Spotleak1005 have the potential to accumulate inside the enclosed odorant package shipping container which if ignited may have the potential for a VCE. Details of the explosion are summarised in Section 4.5. Noting PHAST does not account for attenuation provided by structures such as the odourant shipping container.

Worst case explosion overpressures generated from a VCE originating from the odorant package shipping container based on worst case stoichiometric flammable masses are presented in Figure 8-13. The odourant shipping container explosion is not expected to impact any onsite sensitive receptors.

Figure 8-13: Odorant Package Shopping Container VCE

9. Contaminated Material Containment

The safety philosophy for the FSRU provided by Höegh [50] details that open deck fire-fighting water would generally go overboard, although parts of it may also be diverted to bilge tanks. As detailed in Section 7 of this FSS, the FSRU open deck fires are generally gas fires (including liquefied gas fires). Fire-fighting water below the deck (i.e. engine room) or for the accommodation decks shall be collected in the bilge tanks.

Used fire water from the shore-based fire-fighting system will flow into the normal stormwater drains [25]. The civil works general arrangements showing the stormwater drainage are provided in Appendix C. It is not expected that fire water will be contaminated due to the nature of the materials onsite (i.e. flammable gas). On the ORF, the only liquid chemical is the odourant. The odourant shall be stored in SBC's located within a shipping container. It is not expected that fire-fighting water or a fixed foam system is required for this.

10. First Aid Fire Protection Arrangements and Equipment

Höegh have Fire Contingency Plans for various scenarios onboard the vessel [51]. During the Firefighting Support Ships risk assessment workshop [40] it was communicated that all FSRU crew are trained in STCW [6] which includes advanced firefighting. It is expected they will perform any firefighting activities onboard the vessel if required. The FSRU vessel fire control station is located on the upper deck in the accommodation with access from both the deck and the accommodation as indicated on the FSRU Fire Control and Safety Plan provided in Appendix B. In addition to the hydrant systems (refer Section 6.1.6 and Section 6.1.8) and portable firefighting equipment (refer 6.1.9), necessary provision for fire control is provided at the fire control station and include the following [49]:

- CO_2 release boxes;
- Dry chemical powder release box for cargo tank area;
- Engine room vent fan stopping and closing of the flaps;
- Oil supply pump stopping in accordance with DNV-RU-SHIP-Pt5Ch7;
- Oil transfer pump stopping in accordance with DNV-RU-SHIP-Pt5Ch7;
- Fire alarm repeater panel;
- Accommodation fans stopping and closing of flaps;
- Remote start of emergency fire pump;
- Remote start/stop of fire pumps;
- On/off button for water spay main isolating valves;
- Activation of water spray system; and
- High expansion foam release.

On board the FSRU, firefighting outfits consisting of the following are provided and located on Accommodation Deck A and B:

- Fire protective clothing
- Boots and gloves
- Rigid helmet
- An electric safety lamp
- An axe
- A breathing apparatus having a capacity of at least 1,800 litres of free air with fireproof lifeline and a snap hook.

The following safety equipment will also be provided [49]:

- Two (2) self-contained breathing apparatus of the same type as above having a capacity of at least 1,200 litres of free air and spare cylinders having a total capacity of 6,000 litres.
- Protective clothing, boots, gloves and tight-fitting goggles
- Steel cored rescue line with belt
- Explosion proof lamp
- Medical first aid equipment including oxygen resuscitation equipment and antidotes, and a stretcher are located in the hospital / treatment room on Accommodation Deck B.

At the berth, a hydrant system (refer Section 6.2.6) and portable firefighting equipment (refer Section 6.2.7) are provided. However, FRNSW are the statutory firefighting authority for the PKGT ORF. As previously detailed, consultation with FRNSW will be ongoing in order to develop the facility's emergency response arrangements per the requirements of Infrastructure Approval [19] Schedule 3, Condition 23(a).

11. Key Findings and Conclusions

The fire prevention, detection and protection measures for the PKGT project are largely focused on safety in design measures and reducing potential for events to escalate. The general key findings are summarised in Table 11-1. Only approved LNGC vessels in accordance with DNV Rules for Classification shall be selected for ship-to-ship transfer to the FSRU.

Table 11-1: PKGT Summary of fire prevention, detection and protection measures

Strategy	FSRU	ORF
Minimisation of Leak Sources	Known common leakage sources (i.e. flanges, pumps, valves) have been minimised in the design. Drip trays locally mounted at flanged connections in low pressure LNG lines (ensure cryogenic liquids are collected and vapourise in drip tray) and a stainless steel drip tray installed beneath regasification trains with drains to reduce potential for LNG pooling (pool fire).	Known common leakage sources (i.e. flanges, pumps, valves) have been minimised in the design. The PKP piping is fully welded downstream of the ESD valve.
Minimisation of inventory	Isolatable inventories include: • LNG liquid and vapour headers; and • Regas plant (from suction drum to FSRU discharge ESD valves). The regasification plant has the largest inventory onboard the FSRU. However, this system is provided with automatic blowdown in accordance with DNV-RU-SHIP-Pt6Ch4 Section 7 (Regas Plant) such that the inventory can be depressured via a dedicated cold vent on board the FSRU within 15 minutes.	Isolatable inventories include: • MLAs; • ORF pipework; and • PKP tie-in facilities. The PKP tie-in has the largest inventory at the ORF with approximately 300 m of pipeline available. The above ground section is provided with PFP to protect against potential FSRU and ORF jet fire impacts and reduce escalation risk [39].
Layout	FSRU layout arranged to separate hazardous and non-hazardous areas.	ORF layout arranged to separate hazardous and non-hazardous areas. Ancillary equipment (i.e. fire water pumps and tanks) are located outside of the 25mm (design case) flammable dispersion and thermal radiation contours. Berth emergency control room (located in the electrical and instrument building) is located outside of the 25mm (design case) thermal radiation contours. Sirens and beacons are provided for early warning to remote personnel attending the site of potential LOC events if they have occurred.
Control of ignition sources	Per the hazardous area zoning requirements of DNV-RU-SHIP-Pt5Ch7.	Per the hazardous area zoning requirements of AS 60079.10.1.

Strategy	FSRU	ORF
Fire and gas detection	Fire and gas system provided in compliance with DNV-RU-SHIP-Pt5Ch7 and DNV-RU-SHIP-Pt6Ch4 Section 7 (Regasification Plant). Consists of point gas detection, IR flame detectors and electric thermal fuse type fusible melt links.	Consists of acoustic, LOS and point gas detection, odourant detection, IR flame detectors and heat detection cable.
Emergency shutdown	ESD system on board FSRU is divided into several levels, to form a shutdown hierarchy to allow non affected sections of the FSRU to remain operative. Confirmed gas and/or fire in hazardous areas (i.e. cargo or process) or failure of the F&G system initiates ESDL and implements the following actions: • Activates alarms on IAS OS and CAAP; • Initiate TPSD (shutdown all cargo related processes and regasification); • Initiate alarms; • Close FSRU ESD valves and main gas valves; • Initiate blowdown (automatically on confirmed fire in the regasification plant, gas metering or HP export manifold areas only, otherwise requires manual remote activation); • Send gas trip signal to main engines and boilers control system (confirmed fire only); • Start fire water spray pump (automatically on confirmed fire only); • Start fire water pump (automatically on confirmed fire only). The Jemena EGP control room will be notified of confirmed fire on the FSRU which will also be manned 24/7. The Jemena EGP control room will have the ability to start the ORF fire water system and apply cooling via the ORF tower mounted fire water monitors. 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). 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 shall activate the onboard alarm sounding, close the LNG transfer manifold valves (on LNGC and FSRU) and trip transfer machinery.	Activation of ORF ESD system implements the following actions: • 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/ SDV; • Stop odourant injection package; and • Operator to use CCTV to investigate and ascertain if further mitigation actions are required. Confirmed fire will also start the firewater pumps. During an emergency event the primary point of control will be via the Jemena EGP control room. However, an emergency control room is provided on the berth at a safe distance from the facilities. A hard wired link is also provided for ESD activation from the ORF to the FSRU. FSRU F&G status will be displayed on ORF HMI; and ORF F&G status will be made available on the FSRU.

Strategy	FSRU	ORF
Fire protection system	Active fire protection and suppression provided in compliance with DNV-RU-SHIP-Pt5Ch7 and DNV-RU-SHIP-Pt6Ch4 Section 7 (Regasification Plant) which includes: • Fire water pumps to distribute water via a ring main system with hydrants; • Water spray pumps to distribute water to the water spray system; • Emergency fire pump; • High expansion foam system for firefighting in the engine room and steering gear room; • CO2 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; and • Dry powder extinguishing system for firefighting on the deck in the cargo area and the regasification plant. Appendix D includes the Höegh Galleon Water Spray System Specification and Hydraulic Calculation Sheet and the Höegh Galleon Fire Pump Capacity Calculation.	Active fire protection provided in compliance with Australian Standards which includes: • Fire water storage tanks; • Fire water pumps to distribute water via a ring main system with hydrants. • Remotely activated tower mounted fire water monitors Appendix E includes the PKGT Fire Water Hydraulic Calculation which indicates the duty requirements of the fire water pumps. The datasheets for the pumps selected to be installed are also provided. Procedures will be developed to ensure the site and the FSRU will shut down and not operate until the level in the fire water tanks has been restored to an acceptable level.
Contaminated Material Containment	Open deck fire-fighting water will generally go overboard, although parts of it may also be diverted to bilge tanks. Noting, FSRU open deck fires are generally gas fires (including liquefied gas fires). Fire-fighting water below the deck (i.e. engine room) or for the accommodation decks shall be collected in the bilge tanks.	Used fire water from the shore-based fire-fighting system will flow into the normal stormwater drains [25]. It is not expected that fire water shall be contaminated due to the nature of the materials onsite (i.e. flammable gas).
First Aid Fire Protection Arrangements	Höegh have Fire Contingency Plans for various scenarios onboard the vessel [51]. It is expected the FSRU crew will perform any firefighting activities onboard the vessel if required. In addition to the hydrant system and portable fire-fighting equipment, necessary provision for fire control is provided on board the FSRU in compliance with DNV-RU-SHIP-Pt5Ch7.	FRNSW are the statutory firefighting authority for the PKGT ORF. At the time of issue of this revision of the FSS, the Emergency Response arrangements with PANSW and FRNSW for the ORF are yet to be determined. Noting consultation with FRNSW will be ongoing in order to develop the facility's emergency response arrangements per the requirements of Infrastructure Approval [19] Schedule 3, Condition 23(a).

Explosion escalation events have also been considered in this study. An explosion in the cargo machinery room onboard the FSRU is the worst case explosion scenario. However, it has gas detection provided, where on confirmed gas in the cargo machinery room will activate an alarm at the CAAP and isolate the gas inventory. The cargo machinery room is also provided with high pressure CO_2 extinguishing system which is manually activated. Propagation and injury risk was calculated in PKGT Final Hazard Analysis [41] which meets the criteria specified by HIPAP4.

The facility's emergency response procedures will be developed in consultation with FRNSW and PANSW and approved prior to operation per the requirements of Infrastructure Approval [19] Schedule 3, Condition 23(a). Throughout this report, specific elements required to be included in the emergency response procedures have been documented and are summarised below:

- On detection of a LOC of hydrocarbons or odourant, site PAGA and flashing beacons to be activated, including a flashing beacon to be provided and located near the entry of the ORF to alert personnel approaching the site of a potential LOC of hydrocarbons;
- Define communication protocols between Jemena EGP Control Room, FSRU personnel, and third-party contractors (i.e. security). The Jemena EGP Control Room is the primary point of control during an emergency event;
- Define communication protocols between primary point of control and FRNSW for notification of an incident;
- Define FRNSW access to the berth including potential emergency services staging area and hydrant block plan;
- Include operational constraints within the current fire water supply. In order to manage the risk associated with a fire water tank refill rate which does not meet the requirements of AS 2419.1, AIE commits to ensuring the site and the FSRU will shut down and not operate until the level in the fire water tanks has been restored to an acceptable level.
- Consideration of public access to Seawall Road during normal operation and emergency events.