Proposed Elgas LPG Depot, Kooragang, NSW
Preliminary Hazard Analysis

For Elgas Ltd

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Notation

Abbreviation	Description
API RP	American Petroleum Institute Recommended Practice
AS	Australian Standard
BLEVE	Boiling Liquid Expanding Vapour Explosion
CCPS	Center for Chemical Process Safety
DG	Dangerous Good
DOP&E	Department of Planning & Environment
EIS	Environmental Impact Statement
ESD	Emergency Shutdown
FIP	Fire Indicator Panel
F-N Curve	Log-log plot of cumulative frequency F at which given number of fatalities N is exceeded
HAZID	Hazard Identification
HAZOP	Hazard and Operability Study
HIPAP	Hazardous Industry Planning Advisory Paper
ISC	Internal Self Closing
kg	kilograms
kL	Kilo-Litres
kPa	Kilo-Pascals
kPag	Kilo-Pascals gauge
kW/m^2	Kilo-Watts per square metre
L	Litres
LFL	Lower Flammability Limit
LPG	Liquefied Petroleum Gas
m	Metres
m^2	Square metres
m^3	Cubic metres

Abbreviation	Description
mm	Millimetres
OGP	Oil & Gas Producers Association
OH&S	Occupational Health & Safety
P&ID	Piping and Instrumentation Diagram
p.a.	Per annum
PHA	Preliminary Hazard Analysis
PLC	Programmable Logic Controller
pmpy	Per Million Per Year
PSV	Pressure Safety Valve
PWCS	Port Waratah Coal Services (1)
QRA	Quantitative Risk Assessment
s	Seconds
SDV	Shutdown Valve
SEPP	State Environmental Planning Policy
TMS	Technical Maintenance System
UK HSE	United Kingdom Health & Safety Executive
UPS	Uninterrupted Power Supply
V	Volts
VCE	Vapour Cloud Explosion
WHS	Workplace Health & Safety

1 INTRODUCTION

1.1 Background

Elgas Limited (Elgas) is the leading Liquefied Petroleum Gas (LPG) supplier and distributor throughout Australia and New Zealand with over 250,000 customers. Elgas is a member of The Linde Group, a world leading gases and engineering company with almost 48,000 employees working in more than 100 countries worldwide.

Elgas Ltd proposes to operate a Liquefied Petroleum Gas (LPG) storage and cylinder filling loading facility at Part of 130 Cormorant Road (Corner of Egret Street), Kooragang, NSW. The facility will be developed by Sovechles Developments Pty Ltd.

The proposed site falls within the leased land in Kooragang, managed by the Port of Newcastle. Under the NSW Three Ports State Environmental Planning Policy (SEPP) (2), the Minister for Planning is the determining authority for the development.

Elgas commissioned Arriscar Pty Ltd to undertake a Preliminary Hazard Analysis (PHA) in accordance with Hazardous Industry Planning Advisory paper (HIPAP) No.6 (3). This report incorporates both the PHA and a Quantitative Risk Assessment (QRA) in a single document.

1.2 Objectives of the study

The objectives of the present study are to:

1. Conduct a preliminary hazard analysis of the proposed Elgas Kooragang LPG depot. The PHA is to follow HIPAPNo.6, ”Guidelines for Hazard Analysis” (4).
2. Incorporate the quantitative risk assessment (QRA) into the hazard analysis report.
3. Compare the risk levels with the risk criteria for land use safety, specified in HIPAP No.4, “Risk Criteria for Land Use Safety Planning” (5).
4. Development recommendations for risk reduction, where applicable, for compliance with the risk criteria.
5. Prepare a PHA/QRA report to accompany the Development Application.

1.3 Scope of the Study

The scope of the study covers the following:

- One 100 kL (water capacity) LPG tank, fireproofed with Fendolite coating for protection against flame impingement.
- LPG loading/ unloading point (B-Double road tanker delivery and bobtail tanker loading)
- LPG pump supplying cylinder filling plant
- Cylinder filling and storage, loadout on flat top trucks.
- Overnight parking of laden bobtail tankers (1 x 6 tonne and 1 x 9 tonne) in a dedicated area

2 SITE LOCATION AND SURROUNDING LAND USES

2.1 Site Location

The proposed Elgas LPG depot is located on part of 130, Cormorant Road, Kooragang, NSW (Part Lot 1, DP 1195449). The site covers approximately 7500 m^2 (55 metres x 138 metres).

There is an existing service station (gasoline and diesel) retail outlet and a car wash facility on Part of 130 Cormorant Road. The proposed site is on the northern part of 130, Cormorant Road, with vehicle access and exit to be located on Egret Street.

The proposed site and the existing service station together constitute Lot 1, DP 1195449, and both leased from the Port of Newcastle by Sovechles Developments. Elgas will sub-lease part of Lot 1 from Sovechles Developments (the proponent) for the proposed Depot, and operate the Depot.

A location map is shown in Figure 1.

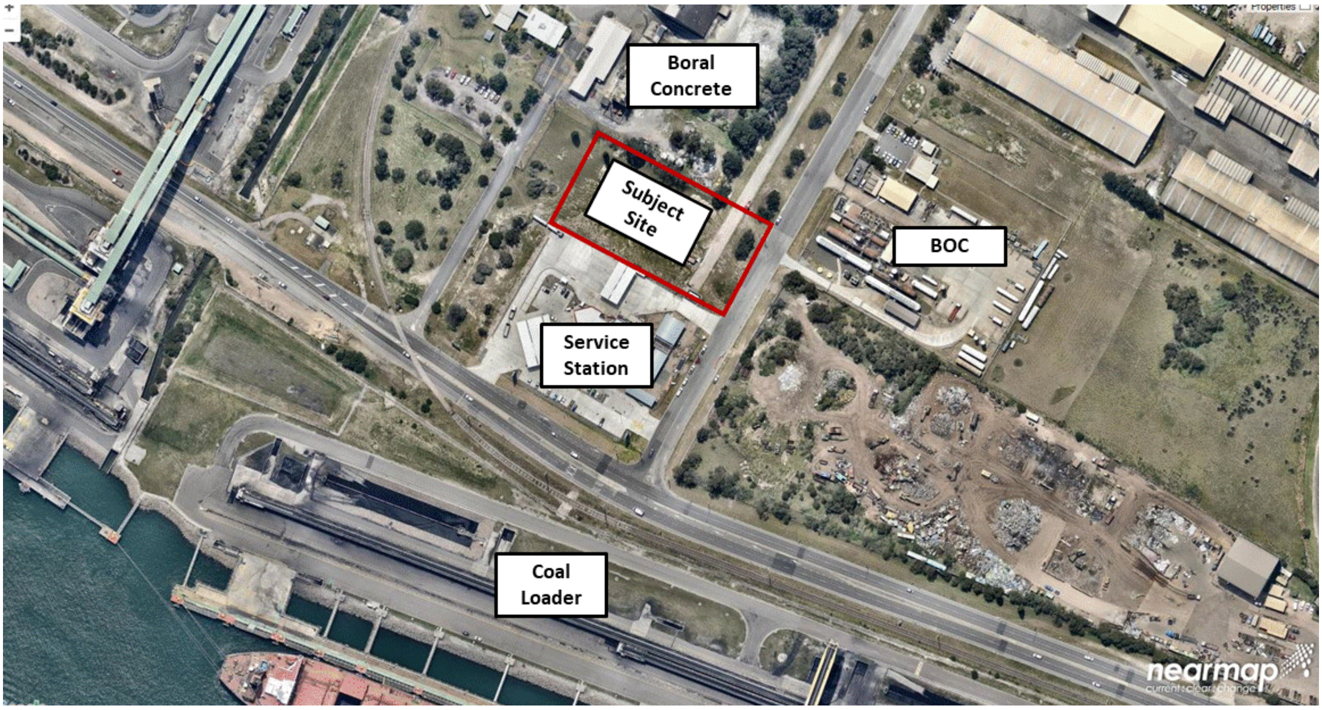

Figure 1: Elgas Kooragang LPG Depot Location Map

2.2 Surrounding Land Uses

The subject site is to the North of Cormorant Road with vehicle entry and exit from Egret Street (on the East).

The land is zoned SP1 - Special Activities (pub. 2014-05-31), where the proposed development is permissible with consent. The determining authority is the NSW Department of Planning & Environment (DoPE).

Surrounding facilities are:

North:

- Boral concrete. A substation belonging to Boral is on the border between the Elgas site and the Boral site.

South:

- Shell service station and truck wash facility (operated by Sovechles Developments, the leaseholder for Lot 1, DP 1195449 on 130 Cormorant Road). The facility services the vehicles involved in port related activities.
- South of the service station across Cormorant Road is the south channel of the Hunter River and the Port Waratah Coal loading terminal.

East:

- Across Egret Street the BOC facility for industrial gases.

West:

- Vacant land leased by Boral Concrete

The land use planning map is shown in

Figure 2.

The nearest residential area is located in Stockton, approximately 1400 metres from Egret Street.

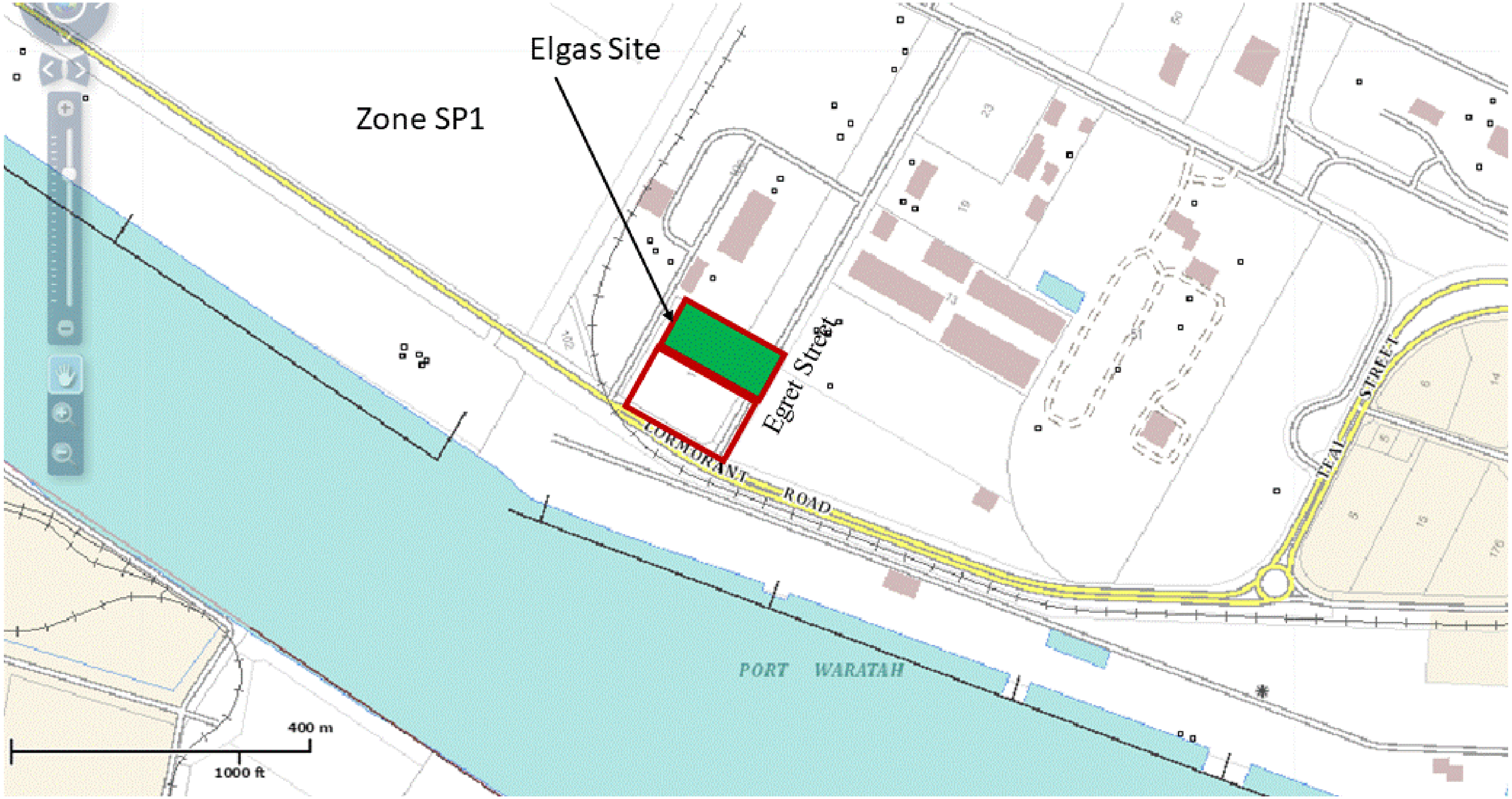

Figure 2: Land Use Map showing Elgas Site

2.3 Meteorology

The meteorological data for the study was based on the data for Williamtown Weather Station, this being one of the closest to the Kooragang site. The meteorological data for the study obtained from the Bureau of Meteorology was processed into representative wind speed/ weather stability classes.

Details are given in Appendix C. The process data is summarised in **Table 1**.

Table 1: Meteorological Data for Kooragang site (Williamtown Weather Station)

Wind Direction (from)	Wind speed/ Weather Stability Class						
	B	DH	DL	DM	E	F	Total
Speed m/s	1.86	8.13	0.83	4.03	3.1	0.58	
N	0.007	0.0004	0.0168	0.013	0.0022	0.0137	0.0531
NNE	0.0045	0.0012	0.0111	0.0157	0.0029	0.0109	0.0463
NE	0.0044	0.0076	0.0118	0.0322	0.0044	0.0111	0.0715
ENE	0.0029	0.014	0.0101	0.0224	0.0032	0.0096	0.0622
E	0.0034	0.014	0.0104	0.0249	0.002	0.0087	0.0634
ESE	0.0037	0.0136	0.0052	0.0202	0.0008	0.0034	0.0469
SE	0.0057	0.0176	0.0052	0.0217	0.0008	0.0035	0.0545
SSE	0.0039	0.0231	0.0055	0.0198	0.0006	0.0034	0.0563
S	0.0024	0.0345	0.0071	0.0259	0.0012	0.0042	0.0753
SSW	0.0012	0.0109	0.0037	0.0116	0.0005	0.0021	0.03
SW	0.001	0.006	0.0037	0.0095	0.0006	0.0024	0.0232
WSW	0.0016	0.0045	0.0053	0.0137	0.001	0.0043	0.0304
W	0.0042	0.0196	0.0127	0.0326	0.0036	0.0119	0.0846
WNW	0.007	0.0599	0.0197	0.0579	0.0087	0.0188	0.172
NW	0.0082	0.0115	0.0157	0.0346	0.0062	0.0164	0.0926
NWW	0.0075	0.0013	0.0089	0.0111	0.0016	0.0076	0.038
Total	0.0686	0.2397	0.1529	0.3668	0.0403	0.132	**1.000**

The data indicates that unstable weather conditions prevail for approximately 7% of the time, neutral stability for over 76% of the time, and stable conditions for 17% of the time. This means that a gas release would disperse more readily.

Wind from West/ Northwest direction dominates the wind (26% of the time). The wind direction probabilities are nearly uniformly distributed in the rest of the 16 directions selected.

2.4 Site Layout

The layout of the facility is shown on **Error! Reference source not found.**.

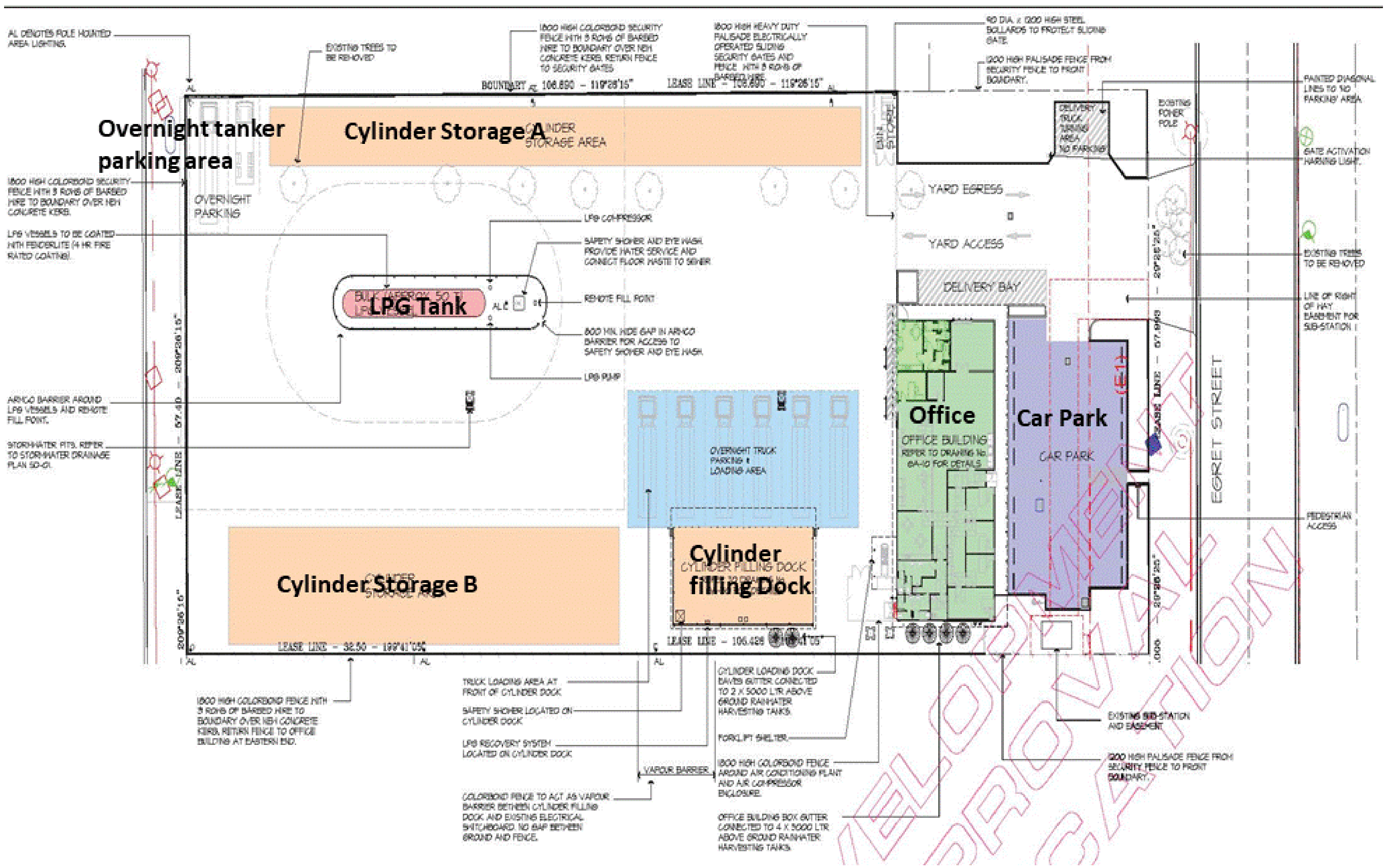

Figure 3: Site Layout

3 REGULATORY REQUIREMENTS

The following regulations apply to the proposed development:

1. NSW State Environmental Planning Policy (Three Ports), 2013 (2)

   Under this policy, the proposed development in land zoned SP1 (Special uses) is permissible with consent. The Development Application shall be lodged with NSW Department of Planning & Environment (Consent Authority)

2. NSW State Environmental Planning Policy (SEPP) No.33, "Hazardous and Offensive Developments" (6). A Preliminary Hazard Analysis (PHA) shall accompany the Development Application.

3. Environmental Planning & Assessment Regulations 2000 (7)

   Under the Environmental Planning & Assessment Regulation 2000, Schedule 3, Part 1.10, the following requirements apply:

   Chemical storage facilities:

   (a) that store or package chemical substances in containers, bulk storage facilities, stockpiles or dumps with a total storage capacity in excess of:

      (i) 20 tonnes of pressurised gas, or

      (ii) 200 tonnes of liquefied gases, or

      (iii) 2,000 tonnes of any chemical substances, or

   (b) that are located:

      (i) within 40 metres of a natural waterbody or wetland, or

      (ii) in an area of high water table or highly permeable soil, or

      (iii) in a drinking water catchment, or

      (iv) on a floodplain.

   If any of the conditions are satisfied, then the development may be deemed a designated development.

   The proposed development will contain less than 200 tonnes of liquefied gas. However, the subject land is in an area of high water table, and therefore deemed to be a designated development by NSW Planning & Environment and hence an EIS is required. It has been assessed in Ref.6 that an LPG release would not have adverse effect on the groundwater.

4. There are a number of standards and guidelines applicable to the facility. These are listed below:

   - Applying SEPP 33 (8)
   - Hazardous Industry Planning Advisory Paper (HIPAP) No.6, "Hazard Analysis Guidelines" (3).
   - Hazardous Industry Planning Advisory Paper (HIPAP) No.4, "Risk Criteria for Land Use Safety Planning" (9).

- Standards Australia, AS 1596-2014: LP Gas Code (10)
- AS/NZS 60079.10.1 - 2009: Classification of Areas – Explosive Gas Atmospheres (11)
- AS 2419.1- 2005: Fire hydrant installations System design, installation and commissioning (12)

4 DESCRIPTION OF PROPOSED OPERATIONS

4.1 Overview of Operations

The following operations are proposed to be performed at the LPG Depot:

- LPG (propane) is delivered by single or B-double road tankers from the Elgas Cavern facility in Port Botany to Kooragang Depot. The average temperature of propane is 18°C (generally slightly below ambient).
- The product is unloaded from an unloading bay into the storage tank using a gas compressor.
- LPG from the storage tank is loaded onto 6-9 tonne road tankers (Bobtails), using the Depot pump.
- Cylinder filling occurs for delivery to customers (8.5, 15, 18, 45 kg cylinders).
- 5 x B Double Linehaul loads of S'n'G Cylinders for distribution

4.2 LPG Storage Vessel

The main LPG storage vessel is approximately 20m long with 2.6m outside diameter, with a water capacity of 100 kL. It will contain odourised LPG and has the following piping connections:

- 50mm nozzle for liquid flow to cylinder filling
- 50mm nozzle for liquid flow to tanker loading bay
- 50mm nozzle for vessel draining
- 4 x 50mm nozzles for relief valve connection
- 1 x 50mm nozzles for vapour return line from tanker loading bay.

The protection systems provided on the storage vessel comprise the following:

- Fendolite M11 (cementitious fireproofing material) coating in storage vessel
- Multiport pressure relief valves located on top of the vessel
- Excess flow valves and back check valves for primary shutoff
- Manual ball valves for secondary shutoff
- Air operated fire safe isolation valves for tertiary shutoff, with remote emergency isolation provision.
- High level protection shutdown (set at 88% tank level)
- In the cylinder testing/inspection section, the recovered gas in a manifold is returned directly to the main storage tank using a small Haskel pump (compressed air driven pump). There is no storage.

4.3 Tanker Loading and Unloading

LPG (propane) is received from the Elgas Cavern in Port Botany via road tankers to the Kooragang Depot. The road tankers are routed to the LPG load-out facility, and unloaded by the driver, using the site compressor (Corken Model FD 491). The storage tanks level is first noted prior to unloading to ensure that there is adequate ullage in the tank to receive the full road tanker load.

There is a single loading bay for loading and unloading of the LPG (propane) out of the bulk road tankers. B-double tankers are unloaded one tank at a time.

The system is designed for driver loading/ unloading. Loading of LPG occurs in small tankers (6-9 tonnes), known as Bobtails, using the site compressor. The loading is controlled by the PLC. Manual loading is controlled by observing the rotogauge on the Bobtail. A high level switch in the tanker would automatically shut down loading when set level is reached.

The delivery hose and the vapour return lines are connected to the road tanker. The Depot's hoses are used.

The driver opens the fixed ullage gauge on the tanker (rotogauge set at 85%) and once LPG starts to release through this valve, loading is stopped. When loading is complete, the tanker driver uncouples the loading hoses and the scully. Once the driver has complied with all the necessary safety steps, the road tanker is driven out of the loading bay.

The main features of the tanker loading bay are:

- The tanker must be earthed (Scully Ground Hog – Vehicle Static Grounding System) to ensure that there is no static build up. The prime-mover battery on the road tanker will be isolated, thus the tanker may not be moved. The site air-lines are connected to the truck to provide pneumatics to enable the tanker internal self-closing (ISC) control valve to be opened.
- Liquid fill and vapour return piping manifold with manual isolation and air operated isolation valves.
- Loading pump stop/ start station from loading bay.
- Mechanical brake interlock system on all road tankers that prevent the movement of the road tanker should any transfer hoses still be connected.
- The LPG loading and unloading piping at the load-out facility is fitted with breakaway couplings. Thus, in the event the tanker moves from its load-out position with the loading pipes/hoses still connected, no product release would occur.
- Emergency shutdown buttons (site-wide ESD). On operation, it closes all the pneumatically operated valves by venting the instrument air.

Since the tank is fendolite coated, a firewater deluge system will not be installed on the tank. Fixed firewater monitors will be provided to cover the tanker loading/unloading area.

- Pneumatic line between tanker and loading bay. In the case of emergency exit of tanker from loading bay, the pneumatic line would break, causing an automatic emergency shutdown of all air-actuated valves and the loading pump.
- A pilot solenoid sends a signal of the truck air connection to the PLC which opens the tank valves for loading/ unloading. In the event of ESD, the pilot solenoid vents the truck air connection, thus closing the truck ISC valve. At the same time, PLC shuts down the tank valves.

- Excess flow valves in the loading lines at the bay to protect against an unlikely failure of the hose.
- A 3-minute "dead-man" switch that will shut down the loading/unloading process if the operator does not acknowledge the alarm within each 3-minute interval. The dead-man alarm begins to sound after 3 minutes, then 30 seconds later the alarm frequency escalates until the 3-minute time interval is reached and it then shuts down the entire system, liquid and vapour control valves, the pump and the compressor.

  When a 3-minute alarm is raised, a message is also automatically sent to certain Elgas personnel via their mobile phone. Once the driver reactivates the button, another message is sent to inform these Elgas staff of the status.
- Fusible link operated automatic shutdown in the event of fire.

4.4 Cylinder Filling Area

Cylinders brought in for refilling are first sorted in terms of ownership. Only Elgas cylinders are filled onsite. All cylinders are checked for mechanical integrity by ensuring the following are correct.

- The test date on the cylinder needs to be current.
- The cylinder must not be rusted.
- The cylinder must not be cracked, dented or damaged in anyway.
- The cylinder shell, foot ring and neck ring must be in a satisfactory condition.
- Liquid withdrawal cylinders – 45kg and smaller must have a blue coloured vapour protection ring to indicate presence of an eductor tube.

Cylinders that are found of to be 'out of test' are re-tested. If a cylinder fails the test, it is destroyed on site by hydraulic hole punching and placed in a separate dedicated yard for disposal. Prior to retest, the LPG is recovered into the recovery manifold and the cylinder valve is removed. Valves that are removed during testing are replaced by new valves.

The cylinder filling operations take place to the southeast of the LPG storage tank at the cylinder filling shed. This is a manual process. A dedicated 50 mm line runs from the storage tank and then reduces to a 40 mm line on to the cylinder filling station. At the filling station, the line is again reduced to 32 mm and divided into two streams, feeding the cylinders on two parallel weigh scales.

A liquid bypass line returns LPG back to the storage vessel. The bypass line is used when the cylinder fill line is shut for changing cylinders, while the pump would continuously run. Cylinder filling station uses a RC40 Ebsray pump, operating flowrate of 100 L/min, for Bobtail loading and cylinder filling. Cylinder filling operation is also controlled by a PLC to open valves.

The weigh scales are calibrated to fill 8.5, 15, 18 and 45 kg cylinders. The electronic weigh scale would automatically shut off the fill line valve once the set weight is reached. Even if the shutdown mechanism were to fail, the LPG is returned to the vessel by the bypass line and hence cylinder overfilling is prevented. The average filling time for a cylinder is about 45 seconds for 15 kg, 60 seconds for 18 kg and 85 seconds for 45 kg cylinders.

The throughput is approximately 150 - 300 cylinders per day (mixed sizes) - as per seasonal demand.

The following protection systems are provided:

- Excess flow valve in the LPG fill line to shut off flow in the event of a piping failure.
- Field ESD stations that will shut down all the actuated valves in the site and the transfer pump/ compressor.
    - At the tanker loading bay
    - At the cylinder filling shed

LPG can be recovered from returned cylinders at dedicated recovery points. Up to two 45 kg cylinder(s) are connected to a manifold and the LPG is allowed to flow in to a recovery manifold. Liquid collected in the recovery manifold is pumped back to the storage tank by a Haskell air-driven pump immediately and there is no recovery tank.

4.5 LPG Cylinder Storage

The cylinder storage areas are shown in Figure 3.

The proposed cylinder storage maximum inventory can be up to 94 tonnes.

The cylinders come in the following sizes:

- 45 kg cylinders – Stored pallets of 9 cylinders per cage (1 high)
- 15-18 kg cylinders – Stored pallets of 16 cylinders per cage (2 high)
- 8.5kg cylinders – Stored pallets of 40 cylinders per cage. Stored in double decker cages (stacked 2 high)
- 90, 190 and 210 kg cylinders – stored individually on the ground.

4.6 PLC Room

The PLC room is located within the office building. There is no dedicated control room with displays. Personnel will need to go to the PLC room to check status.

The PLC mainly monitors the level in the storage tank, and the status of ESD valves. It does not directly control loading and unloading. The PLC is maintained by technical services reporting the service data in the Technical Maintenance System (TMS), which is maintenance database software.

4.7 Utilities

The main utilities and services in the depot are:

- Nitrogen system which provides instrument gas for pneumatically actuated valves. Nitrogen bottle is provided at the cylinder loading dock.
- The site power is supplied from the grid at 415 V. There is no high voltage required at site.
- Utilities water is supplied from Hunter Water Corporation supply main.
- A workshop is provided for minor maintenance work.
- Uninterruptible power supply (UPS) to provide backup up to the PLC.
- The site fire water is supplied by Hunter Water main in the area, to the firewater hydrants and monitors.

- Compressed dry nitrogen is used for purging LPG lines for maintenance and for pressure testing. Nitrogen is supplied in G type cylinders. The capacity of the cylinders is $7m^3$. There are 2 cylinders in the workshop and others are ordered as required. The nitrogen is supplied by BOC.

4.8 Communications

Day to day communication on the depot is achieved primarily by face to face contact.

Telephone communication within site and to outside is through an internal call transfer system, and direct outside lines.

Mobile phones are not allowed on site, except within the maintenance workshop building (non-hazardous area). Intrinsically safe 2-way radios are used in the operations area.

4.9 Fire Detection and Protection Systems

4.9.1 Fire and Gas Detection

No gas detectors are installed. Gas detection at the tanker loading area and cylinder filling area is by visual detection and smell (gas is odourised).

Smoke detectors are installed in the office building and PLC room.

4.9.2 Fire Protection Equipment

The site is equipped with the following fire protection equipment.

- A system of firewater hydrants and firewater spray monitors located on the firewater ring main.
- Fire extinguishers located around the operations area and the office building.
- Fire protection system will be designed to the requirements of AS-1596, AS-2419 and API 2510A.

For the PHA, details of fire protection system design are unavailable. A fire safety study will be undertaken in accordance with HIPAPNo.2 (13) to provide input to the final design of the fire protection system, and incorporated in the Final Hazard Analysis (FHA).

4.10 Site Security

The entry and exit points for the depot are on Egret Street.

The gates are normally kept closed at all times and access is through the site control process. There will be no tanker or truck movements (delivery/ dispatch) afterhours.

A personnel access gate is located at the office building and can only be opened by Elgas personnel issued with identity password cards. Visitors to the site must report to the reception and will be met by Elgas personnel who will guide them into the work area via this access point (if such access is required).

The site will be enclosed by a mesh wire fence on Egret Street and colour bond walls on the south, north and west, approximately 2m high.

During normal operation, trespassers would typically be detected by site personnel or tanker/truck drivers through their routine operation. The site is unmanned and locked after hours. The site will be well lit.

4.11 Staffing

The Elgas Kooragang Depot will conduct various activities at different operating times;

- Tanker unloading will normally operate during daylight hours. The frequency of tanker unloading and loading activities vary during the summer and winter season. Tanker unloading is performed by the tanker driver (Contractor to Elgas). Bobtail loading is carried out by Elgas drivers.
- There will be a total of 8 drivers to drive the Bobtails as well as the cylinder flat top trucks.
- Cylinder filling will be carried out by Elgas employees. There are two people involved in cylinder filling operation.
- Maintenance contractors are not permanently present, but available on call, and for pre-arranged preventive maintenance.
- The office building is staffed during day time Monday to Friday. The maximum number of staff in the main office can be up 9. A small number of staff may work on Saturdays during the day hours on a need basis.

4.12 Overnight Parking of Laden Tankers / Trucks

The storage of laden LPG 6 and 9 tonnes "Bobtail" tankers may occur overnight. Tankers may be filled at the end of the day and left in a designated laden tanker parking bay overnight ready for dispatch first thing the following morning. There is also the potential for laden tankers to be parked on the site over the weekend. The parked tanker area will be located in the south-east corner of the site.

Cylinders may be loaded onto trucks in the afternoon and the full trucks parked at the site overnight for dispatch first thing the next morning. The cylinder trucks will also be parked in the dedicated parking in the south-east corner of the site.

The maximum number of laden tankers/trucks envisaged to be parked at the site at any time is:

- Up to two bobtails/tankers (1 x 6 tonne and 1 x 9 tonne); and
- Up to two cylinder trucks (1x 8.5 kg truck and 1x18 kg truck assumed) (10 tonnes)

The total overnight storage comes to 25 tonnes. This quantity is included in the total site storage in accordance with the requirements of the NSW WHS Regulation, as listed below.

4.13 NSW WHS Regulations

1. Chapter 9 Part 9.1, Division 1

   Clause 532 Meaning of hazardous chemicals that are "present or likely to be present"

   (f) the maximum quantity of hazardous chemicals loaded into or onto, or unloaded from, vehicles, trailers, rolling stock and ships that are from time to time present at the facility in the course of the facility's operations.

2. Schedule 15, Clause 4

(b) Total quantity of hazardous chemicals present or likely to be present, other than:

(ii) hazardous chemicals that are solely the subject of intermediate temporary storage, while in transit by road or rail (unless it is reasonably foreseeable that, despite the transitory nature of the storage, hazardous chemicals are or are likely to be present frequently or in significant quantities)

The overnight parking of Bobtails and filled cylinders on flat top trucks has been interpreted as "frequent" and in "significant quantities", for the purposes of Preliminary Hazard Analysis.

4.14 Storage Capacity of LPG on site

The distribution of various LPG storage onsite is summarised in

Table 2. The tonnage is reported on water capacity, and not actual inventory as there are maximum fill limits for tanks and tankers as specified in AS 1596-2014.

Table 2: Proposed LPG storage Capacity

Inventory No.	Storage arrangement	Water capacity, kL	LPG capacity, tonnes
1	Storage tank*	100	51
2	Recovery manifold (pipe operating 5% of the time and filled with vapour the rest of the time)	0.05	0.02 max
3	Filed Cylinders on loading dock 300 x45kg, 200 x 15/18 kg	40.6	21
4	Cylinder storage area A: 8.5 kg cylinders, 22-23 cages per row (44-45 cylinders per cage), 2 rows, 2 high	20.8 L per cylinder	76
5	Cylinder storage area B: 45,90,190,210 kg cylinders	19.93	10
6	Bobtail tanker parking** - 6 tonnes	14	7
7	Bobtail tanker parking** - 9 tonnes	23	12
	Total		**177**

* Maximum inventory will be 88% fill level of tank

* Maximum inventory will be 85% of fill levels of Bobtails

4.15 Product Movements

The product movements in and out of the Depot are listed in Table 3.

Table 3: Product Movements

Truck Type	Function	No. of movements

B-Double Tanker	Bulk Delivery	5 per week
Bobtails (6 and 9 tonnes)	Bulk Distribution	3 per day (Mon-Fri)
Cylinder trucks (flat top)	Cylinder Distribution	5 per day
B-double line haul	S'n'G Cylinder Distribution	5 per week

5 HAZARD ANALYSIS

5.1 Level of Assessment

The multi-level risk assessment guideline (14) indicates that for Class 2.1 materials storage exceeding 50 tonnes, a minimum of Level 2 assessment is required. However, the guidelines also state that if the risk from all events that may have on offsite impact is likely to exceed $1x10^{-7}$ per annum, a level 3 assessment is required.

Accordingly, a Level 3 assessment has been adopted, i.e. full quantitative risk analysis (QRA), in accordance with HIPAP No.6.

5.2 Methodology

The methodology applied in the study is summarised in Figure 4.

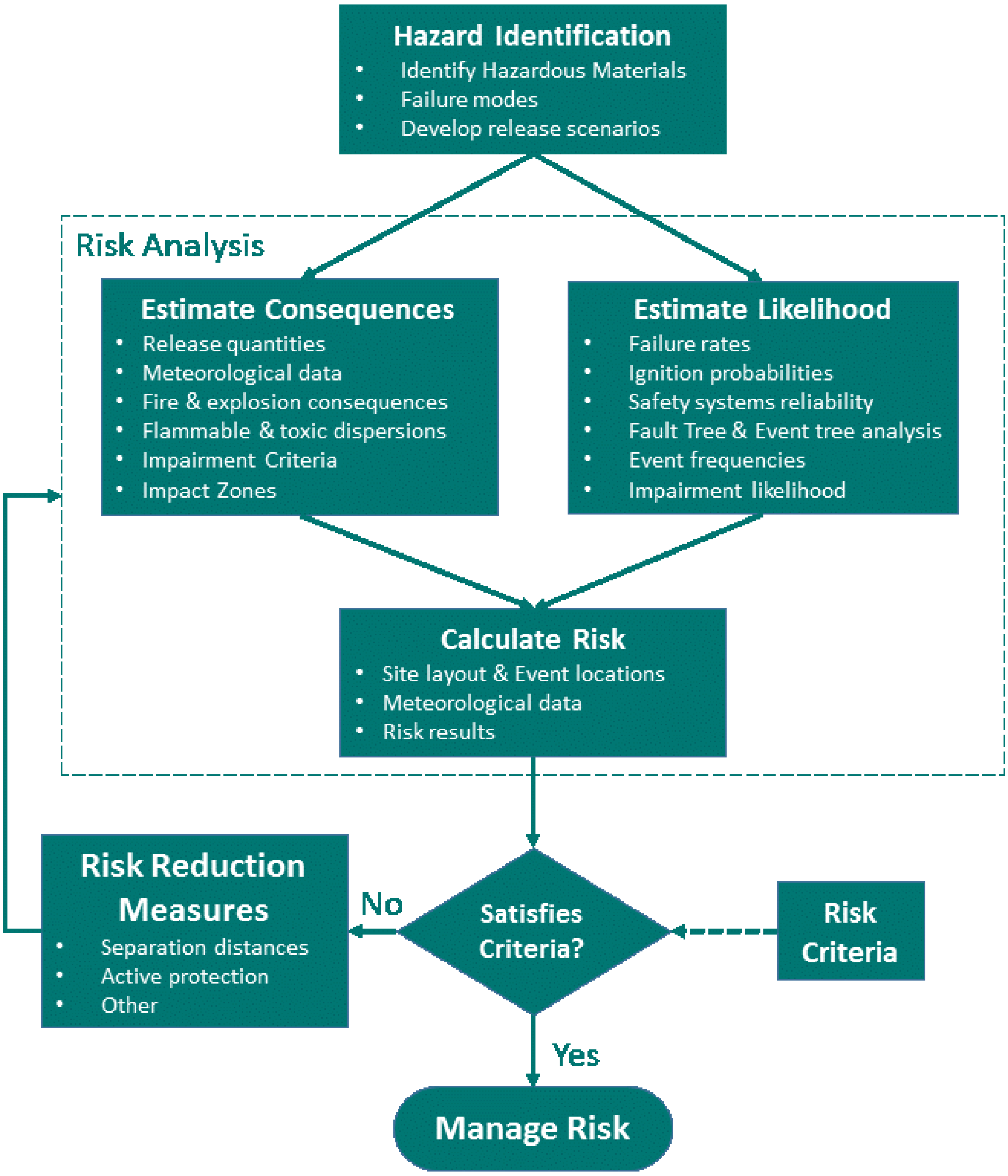

Figure 4: Risk Assessment Methodology Schematic

6 HAZARD IDENTIFICATION

6.1 Hazard Identification

The first step of the PHA and risk assessment is hazard identification. The activities involved in hazard identification included:

- A desktop review of process and storage information (e.g. PFDs, P&IDs, etc.) to identify the locations of dangerous goods across the Depot.
- A qualitative Hazard Identification (HAZID) and evaluation of safeguards, based on similar studies conducted by Elgas.

The hazard identification and safeguards table is provided in Appendix A.

6.2 Hazard Identification and Safeguards

A table of identified hazards and safeguards in place were compiled from the HAZID report prepared for the MHF Safety Report (Ref. (15)). A summary is provided in Appendix A

6.3 Failure Modes for LPG Releases

6.3.1 Fabric Failures

In order to model releases from fabric failures, it is first necessary to divide the equipment into isolatable sections. This enables the grouping of different equipment (e.g. vessels, pipework, fittings, etc.) where similar dangerous goods and conditions are present, and ultimately simplifies the modelling of potential consequences.

After the isolatable sections were identified, representative hole sizes were defined to model fabric failure releases.

The selected representative hole sizes are presented in Table 4.

Table 4: Representative Hole Sizes for Fabric Failures

Hole Size	Hole Diameter (range)	Representative Hole Size Selected	Description
Small	3 ≤ d ≤ 10 mm	3 mm	Covers gaskets and pump / seals. Spiral wound gaskets.
		9 mm	Valve gland leaks
Medium	10mm < d ≤ 25 mm	13 mm	Leak from pipework
		25 mm	Covers small bore pipe work (instrument nozzles and 1” OD pipe work).
Large	25mm < d ≤ 50mm	50 mm	Covers piping (2” full bore, up to 2” from localised ruptures, impact).

Hole Size	Hole Diameter (range)	Representative Hole Size Selected	Description
Catastrophic	d > 50 mm	FBR (Full Bore Release)	Covers the largest hole size from pipe and vessels to a maximum of nozzle size.

6.3.2 Corrosion

LPG is a clean liquid and is non-corrosive. Therefore, the chance of internal corrosion is negligible. All pipe work is painted with a corrosion resistant paint, and inspected externally on a regular basis.

The chance of a major failure of LPG vessels and pipe work due to corrosion is considered very low.

6.3.3 Stress Corrosion Cracking

It is known that stress corrosion cracking is not a consideration with regard to vessels dedicated to LPG storage (non-stress relieved vessels). The bulk of the tankers used will be ELGAS Gas tankers, and the contractor vehicles used for LPG distribution would be dedicated to LPG duty only.

The tanker vessels are externally inspected annually, and are subject to a mag-particle test of critical welds at three-yearly intervals. Any stress corrosion cracking, would be detected during these tests, and if found, the tanker would be taken out of service.

Stress corrosion cracking is not considered to be a significant contributor to failure of the LPG storage tanks or tanker.

6.3.4 Mechanical Damage

The site is protected by security gates, and normally there is no vehicular access to LPG storage. The only vehicle access is forklifts used for cylinder pallets transport within the site.

The LPG vessels do not require frequent maintenance, and any crane access to the site is rare. Even then no heavy objects are moved over the vessels or pipe work, and hence the chance of a mechanical damage due to impact is low.

The pipework has minimum flanged connections, and is mostly welded. No instruments are provided on the piping. The hydrostatic relief valve has an orifice diameter of 1.6 mm, and hence, even if accidentally damaged, the leak would be minimal.

6.3.5 Cold Catastrophic Failure of LPG Vessel

There have been no failures of this type reported in the LPG industry worldwide. It has been generally recognised that the potential for such failure exists in vessels not stress relieved (16), as a failure starting as a small leak can propagate into a rupture. The LPG vessels are not stress relieved and hence the potential for a cold catastrophic failure exists, albeit small.

Statistical failure rates have been predicted for such a failure, based on the number of vessel-years of no failure operation. These values have been used in the study.

6.3.6 Failures of Gaskets/ Flanges

A gasket failure would vary from a weeping leak to a small section of gasket being blown away (typically the section between two adjacent bolts). Only spiral wound gaskets are used for LPG duty and hence the maximum possible hole size for such failures was postulated as 3 mm.

For all failures except those on the first flange on vessel nozzles, the leak could be minimised by activating the ESD buttons.

6.3.7 External Leaks from Valves

The type of failures that could be encountered include a gland leak to atmosphere (weep), a body/ bonnet gasket leak to atmosphere (weep), and a significant body/bonnet gasket leak to atmosphere (16).

Most of the leaks would be small. The maximum possible hole size for a significant leak was taken as 9 mm.

6.3.8 LPG Hose Failure

The likelihood of this incident is low due to the following reasons:

The hoses are hydrostatically tested before first use, and thereafter visually inspected including the weep holes on a half-yearly basis. Any suspect hose is replaced. Spare hoses are carried on site.

The construction of the transfer hose incorporates a double walled hose, with the outer hose provided with pinholes at regular intervals along its full length. Should a failure of the inner hose occur, then atmospheric moisture would condense on the outer wall of the hose, providing an immediate detection method of a failure. The hose would then be decommissioned.

There have been inner hose failures in the past, but these were identified due to ice formation on the outer wall, and the hose was discarded. No loss of containment has been reported.

There have been no reported cases in Australia, of hose failure or failure of the joint between the rubber hose and the metal casing in the last 20-25 years, as the integrity of the hose testing in the LPG industry has significantly improved over the years.

Since the failure of the hose is a credible scenario (based on industry experience), it has been included in the analysis.

6.4 Operational Failures

The following Operational failures have been identified:

- Tanker drive-away
- Bob-tail tanker overpressure
- Overfill of tankers (Bobtails) and tanks (storage tank)
- Cylinder Overfill

6.4.1 Tanker Drive-away While Connected

A release of propane liquid at the tanker loading bay due to tanker drive-away is a credible, however, an unlikely event. The worst-case consequence of a tanker driver away would be a full-bore rupture of the tanker loading hose/pipework.

The following safeguards are in place to minimise the likelihood of a tanker/bobtail drive-away while still being connected:

1. The scully system must be connected in order to commence transfer of product. Once this is connected, the prime-mover battery on the road tanker will be isolated, thus the tanker may not be moved.
2. Mechanical interlock system on all road tanker brakes that prevent the movement of the road tanker should any transfer hoses still be connected.
3. The truck air-lines are connected to plant air to provide pneumatics to enable the SDV to be opened. If the tanker/bobtail drives away the SDV will close and stop the loading pump.
4. The LPG liquid and vapour lines on both loading bays are fitted with breakaway couplings. Thus, in the event the tanker moves from its load-out position with the loading pipes/hoses still connected, limited product release would occur.
5. Excess flow valves are installed in the loading lines at the bays, and in trucks, to protect against an unlikely failure of the hose. This will reduce the consequences in the event of a drive-away.
6. Activation of one of the ESD pushbuttons in the loading bay area (or in the surrounding area) will initiate site-wide ESD, which will close all actuated valves and stop the transfer operation.

There are several independent preventive and mitigation safeguards protecting against this event. The protection level is regarded as high.

6.4.2 Overfilling of Bobtail

Once the Bobtail is connected and it is safe to commence filling, the driver will start the transfer and observe the filling operation. The following safeguards are in place to minimise the likelihood of an overfill of the Bobtail:

1. Tanker loading procedure.
2. The Bobtails are equipped with a digital level gauge. Once the set level is reached (about 85%), this level switch will shut off the air supply from the truck and consequently close the SDV. This will also trip the transfer pump and stop the transfer.
3. Before commencing transfer operation, the driver will open the fixed liquid ullage valve on the Bobtail. If the level has not been stopped manually or automatically as stated above, a small amount of liquid will leak out of this valve. The driver is required to observe this throughout the filling operation and manually stop the transfer if required.
4. If the above measures do not stop the transfer, excess LPG will flow back to the storage tank via the 32 mm vapour return line. There would be no release to atmosphere.

6.4.3 Bobtail Overpressure

The most likely cause for tanker overpressure is an overfill of the tanker (see above), and the bobtail being left in the sun before departure the next working day. An overpressure of the vessel due to thermal expansion would not rupture the tanker, but rather result in a release of LPG through a flange/ or valve gland. The following safeguards exist.

1. Bobtails are generally not filled before late afternoon and generally not left laden over the weekend.
2. Relief valve installed in all road tankers set at 1750 kPag.

6.4.4 Overfill of Storage Tank

Filling of LPG Tank is undertaken by the tanker driver. A potential overfill of tank is possible if either the level measurement is incorrect. Given the pipework configuration during B-double unloading the LPG would flow out of the tank through the vapour line feeding the compressor that drives the product transfer from the B-Double.

The safeguards in place to minimise the likelihood of such event are:

1. Independent high high level switch on the tank that would shut the fill valve.
2. Level switch high on the compressor suction pot would trip the compressor and stop the transfer.

6.4.5 Cylinder Overfill and Leak due to Thermal Expansion

The cylinder filling pipework operates on a reticulation system. There is a cylinder filling manifold from which branch lines feed the cylinders. Between two fills, when a new cylinder is connected, LPG flows back to tank through the manifold. If the weigh scale fails to shutoff on reaching the pre-set weight, the cylinder will be filled, but not overpressurised as the excess liquid flows back to the tank. The overfilled cylinder is taken to the recovery system.

Once the cylinders are filled, they are secured in the cradle and taken by forklift to the loading/storage area for transfer to truck. Occasionally, cylinders can be left in the sun for some time (in storage or on the truck). If a cylinder has been overfilled, thermal expansion due to the heat may result in a release from the relief valve.

The following safeguards are in place to minimise the likelihood of cylinder overfill, resulting in thermal expansion and leak:

1. The scales used for cylinder filling are calibrated and regularly tested for accuracy.
2. The scales will automatically cut off supply when the set weight is reached.
3. The fixed ullage valve is left open during filling to indicate if the cylinder is overfilled (not used on all types of cylinders).
4. All cylinders are equipped with a PSV.
5. Any cylinder detected of being overfilled will be sent to the recovery unit.

6.5 LPG Release Consequences

6.5.1 LPG Fires

Two types of fires are possible with pressurised propane.

1. A jet fire. This could occur if a gas leak or a 2-phase leak from a pipe/ vessel/ equipment is ignited.
2. A flash fire. A flash fire is the result of ignition of a well-mixed air-LPG cloud. A liquid/two-phase leak of LPG would evaporate and disperse into atmosphere forming a flammable air-vapour mixture on ignition, depending on the degree of congestion and confinement in the flame front, and the delay in ignition, a vapour cloud explosion may result. In its absence, a flash fire would be the result.

A pool fire is extremely unlikely with pressurised propane because of the low boiling point of propane (-42ºC) and very high evaporation rates.

6.5.2 Boiling Liquid Expanding Vapour Explosion (BLEVE)

BLEVE is a phenomenon experienced only with liquefied flammable gases such as LPG, stored under pressure above their atmospheric boiling points. A fire impinging on a pressurised tank can weaken the tank wall, and allow the boiling LPG at high pressure to expand into the atmosphere generating high explosive energy, and resulting in a fireball. Even though the BLEVE is, by definition an explosion, the thermal radiation effect of the fireball would have an impact at longer distances than the flying fragments from the explosion effects.

Since the storage tank cannot receive direct flame impingement (passive fire protected tank), the possibility of a BLEVE of this tank has been greatly minimised. However the potential for a BLEVE of a road tanker is possible and included in the analysis.

For the tanker loading bay, the following sources of LPG releases that could impinge on the vapour space were identified:

- Relief valve flange gasket leak at top of the tanker vessel.
- Flange gasket leak at the liquid fill and vapour return lines on the loading bay.
- Screwed fitting leak at liquid and vapour connections at the bottom of the tanker vessel during LPG loading. The leak would be small, and in the unlikely event of ignition, the potential for direct impingement on the vapour space is low.

The tanker driver is always present at the tanker loading bay during transfer operations. In the event of a leak, the leak would be detected by tanker driver by odour, who will initiate the ESD. This action would limit the leak duration.

6.5.3 Vapour Cloud Explosion (VCE)

If a liquefied flammable gas is released to atmosphere, there is a possibility that the ignition of the flammable cloud may result in an explosion, and it is referred to as a Vapour Cloud Explosion (VCE). For a VCE to occur the cloud must have sufficient mass and confinement.

The partial confinement for LPG dispersion are located throughout the facility at the Tanker loading/unloading bay, stacked cylinder storage pallets, and the colour bond fencing providing a vapour barrier, restricting the dispersion rate.

6.6 LPG Release Scenarios

In order to model releases from fabric failures, it is first necessary to divide the equipment into isolatable sections. This enables the grouping of different equipment (e.g. vessels, pipework, fittings, etc.) and simplifies the modelling of potential consequences.

The following steps have been involved in defining isolatable sections:

- Identification of actuated shutdown valves that are used in the ESD function in the event of a loss of containment; and,
- Separation of the process into distinct representative process streams based on the isolatable inventories and the stream operating conditions (e.g. liquid, vapour, temperature and pressure).

After the isolatable sections were identified, representative hole sizes were defined to model fabric failure releases.

The identified release scenarios based on isolatable inventories are listed in Table 5.

Table 5: Release Sources based on Isolatable Inventory

Source No.	Description	Maximum Inventory, kg
MH-1	Tank (Liquid Side)	75,000
MH-2	Tank (Vapour Side)	550
MH-3	Recovery Manifold Pipe (Liquid Side) – Assumed 10% returns in two 45kg cylinders connected – worst case	9
MH-4	Recovery Manifold Pipe (Vapour). This inventory is negligible.	<1
MH-5	Liquid pipework (50 mm) between Road Tanker and Tank, including hose (50mm)	10
MH-6	Vapour pipework (50 mm) at Tanker Unloading Area including hose (50mm)	1
MH-7	Supply Tanker (Liquid Side) at Tanker Unloading Area	18000
MH-8	Supply Tanker (Vapour Side) at Tanker Unloading Area	220
MH-9	"Bobtail" Tanker (Liquid Side) at Tanker Loading Area (Larger tanker selected for analysis)	9000
MH-10	"Bobtail" Tanker (Vapour Side) at Tanker Loading Area	80
MH-11	LPG pump and liquid pipework (50 mm) for cylinder filling	50
MH-12	Liquid pipework (32mm) to cylinder weigh scale	<10
MH-13	Liquid pipework (25 mm) from Product Recovery manifold to storage Tank	<10

Source No.	Description	Maximum Inventory, kg
MH-14	LPG cylinders at storage area A	15-45
MH-15	LPG cylinders at storage area B	8.5
MH-16	Tanker loading/unloading hose (Liquid)	<10
MH-17	Vapour return hose (Vapour)	<1
MH-18	Cylinder filling hose (Liquid)	<5
MH-19	Overnight parking of laden Bobtail (Liquid phase)	7200
MH-20	Overnight parking of laden Bobtail (Vapour phase)	120

Note: While the pipework inventory can be very low, 1-10 kg, the release quantity would be higher than the inventory when we account for the release during time for ESD/ EFV activation. The release quantity could be up to the full source inventory if ESD fails to activate.

7 HAZARD CONSEQUENCE ANALYSIS

7.1 Jet Fires

Jet fires of releases were modelled in PhastRisk 6.7 as frustum of a cone, using the Shell Thornton Research Centre model (Chamberlain model) in PhastRisk 6.7.

Based on the jet flame dimensions, the following observations may be made on potential consequences of jet fires:

- The jet flame dimensions are small and have only localised effects. Apart from the potential to cause flame impingement on the tanker trucks, and a BLEVE, jet fires do not contribute directly to offsite risk.
- For all cases of jet fires at the tanker loading bay an impingement on the tanker vessel is unlikely to occur if the flame were oriented parallel to the vessel axis. For the orientation transverse to the axis, an impingement is possible. It was assumed that there was equal chance of orientation parallel to or transverse to the vessel axis.

The potential for both vessels involved in a BLEVE at the same time in the case of a B-Double was not considered possible for larger releases, as the orientation required for flame impingement of the front vessel of the B-Double is different for that of the rear vessel, and the flame would not impinge on both tanker vessels simultaneously.

For the case of a flange leak at the loading bay, the flame length including lift off was not sufficient to cause impingement on the tanker vessel, if oriented in a direction parallel to the vessel axis, but could cause an impingement if oriented transverse to the vessel axis.

The jet fire results are tabulated in Appendix F.

7.2 Flammable Cloud Size

The dispersion of LPG releases were modelled using the heavy gas dispersion model in PhastRisk 6.7. For release from mounded tanks, it was assumed that complete vaporisation of the LPG would occur as it percolates through the mound and hence the gas density would be 100% vapour at ambient conditions. The source area was taken as one-half the vertical mounded area to allow for vapour percolation effects through the mound.

Distances to Lower Flammability Limit (LFL) and the dimensions of LFL isopleths were calculated for various representative wind speed/ weather stability classes. The gas dispersion package also calculated the mass of flammable gas above LFL, in the gas cloud. Dispersion results are provided in Appendix F.

For the above case, the downwind distance to LFL varied from 92m for D9, to 190m for low wind speeds.

7.3 Vapour Cloud Explosion

Explosion overpressures from VCEs were calculated using the 3D congestion model in PhastRisk. The blast strength curve number for each explosion scenario was calculated by the OREM model in PhastRisk using relationships developed for the UK Health and Safety Executive by TNO (17). The level of congestion on all the four directions from the centre of explosion was specified in the QRA model, using the site layout.

Details of explosion overpressure distances for the various release rates are listed in Appendix F.

7.4 BLEVE

In the event of a flame impingement, the road tanker would heat and the relief valve would discharge the vapour, resulting in a torch fire at the discharge point of the relief valve. The tanker inventory at the time of BLEVE would be lower than the maximum capacity of the tanker as some material is lost through the relief valve while the tanker wall is being heated. However, the BLEVE scenario was modelled conservatively at 16 tonnes of propane (80%) for the large tanker and 5 tonnes of propane for the smaller tanker.

The duration of the road tanker BLEVE was calculated as 11 seconds, with the diameter of the fireball of 140 m. For a 5te BLEVE the duration would be 8 seconds and the diameter of the fireball 101m. The distances to various levels of fatality was calculated using the thermal dose approach in the probit equation by PhastRisk (see Appendix F).

8 FREQUENCY ANALYSIS

Failure rates were based upon UK HSE Data where possible (Failure Rate and Event Data for use within Risk Assessments (28/06/2012)) (18). Additional data from the Oil and Gas Producers Association (OGP) (19) was used for instrument connections and portable pressure vessel (cylinder) failures.

Tables depicting the failure frequencies of various components are presented in Appendix E.

8.1 Isolation Probability

Where manual detection and isolation is required, the time to detect then isolate was assumed to be 10 minutes, with a 90% probability of achieving the isolation. The isolation time includes the time to detect, decide upon appropriate action, and then effect the isolation. It deviates from the Netherlands BEVI (20) risk assessment guidelines.

In areas where gas detection performs an automatic shutdown, the time to isolate was assumed as 2 minutes, with a 99% probability of achieving the isolation. This is consistent with Netherlands BEVI guidelines (20) and is also justified given the other controls in place, including:

- Isolation by excess flow valves for very large leaks
- The closure of tanker loading by the deadman system after five minutes if the system is not acknowledged.

8.2 Tank Overfill Frequency

There is no reported data on tank overfill and hence a value was derived from fault tree logic.

Overfill can occur if (a) level indicator failure or driver not stopping unload using he fixed ullage gauge and (b) Independent high high level trip failure.

Tank overfill frequency = Tank fill frequency (260 per year) x [probability of level indicator failure (0.0042) + driver error (too late in checking fixed ullage gauge, 0.003)] x Independent high high level switch failure (0.01).

= 260 x (0.0042 + 0.003) x 0.01 = 1.87E-03 per year

Overfill will result in LPG flowing back to the compressor suction via the vapour return line. The high level switch in the suction catch pot of the compressor would trip the compressor and stop the transfer. This would cause operational upset, but not result in loss of containment.

8.3 Probability of Ignition

The probability of ignition was based upon the OGP document “OGP Risk Assessment Data Directory – Ignition Probabilities”, March 2010 (21). Scenario 15 - Tank Gas LPG Storage Industrial, was used as the basis for ignition probability. Full details of the relationship between release rate and ignition probability is presented in Appendix G.

Using the OGP methodology, an immediate ignition probability of 0.1% was used for all release rates.

The table of probabilities of ignition is given in Appendix G.

8.4 Estimating BLEVE Frequency

Since a BLEVE incident could only occur as a result of thermal failure of a vessel, the frequency of a BLEVE cannot be directly obtained from a generic data base. Instead, the tanker loading bay configuration and layout and the safety systems in place have to be specially taken into account.

A BLEVE in the proposed fendolite protected storage is not considered possible, and has not been considered. The potential for impingement on a road tanker vessel was modelled as follows.

Flame impingement frequency = Leak frequency x Shutdown failure probability x Probability ignition x probability of flame impingement

For leaks from static system pipe work, the shutdown failure probability was obtained using Event Trees (see Appendix E).

Probability of flame impingement =0.5 (orientation transverse to vessel axis)

The analysis was carried out for each of the postulated leak scenarios, and the overall frequency was summed to obtain the BLEVE frequency.

The overall BLEVE frequency at the tanker loading bay was calculated as 1.77 $x10^{-6}$ p.a for a supply tanker and $2.43x10^{-6}$ p.a. for a Bobtail.

8.5 Probability of Explosion Given Ignition

The probability of explosion given ignition is based upon the following:

1. The likelihood of an explosion based upon the cloud size in the congested area and the flame speed generated in the congested area
2. The overpressures created by the combustion of the cloud in the congested area.

The conditional explosion probabilities are summarised in Table 6.

Table 6: Conditional Explosion Probability

Conditional Explosion Probabilities (fraction)			
Obstructed cloud volume (m^3)	**Flame speed < 0.45 m/s**	**0.45 m/s ≤ flame speed < 0.75 m/s**	**Flame speed ≥ 0.75 m/s**
200	0	0.3	0.6
3000	0.3	0.6	0.9
6000	0.6	0.9	1

9 RISK CRITERIA

9.1 Individual Fatality Risk

The individual fatality risk imposed by a proposed industrial activity should be low relative to the background risk. This forms the basis for the following individual fatality risk criteria adopted by HIPAP No.4 (9) for New South Wales in Table 7 below.

Table 7: Individual Fatality Risk Criteria

Land Use	Risk Criteria* [per million per year]
Hospitals, schools, child care facilities and old age housing developments	0.5
Residential developments and places of continuous occupancy, such as hotels and tourist resorts	1
Commercial developments, including offices, retail centres, warehouses with showrooms, restaurants and entertainment centres	5
Sporting complexes and active open space areas	10
Industrial sites	50

* HIPAP 4 does allow for distinction between an existing site and a new development.

9.2 Risk Criteria for Injury/ Incident Escalation

HIPAP 4 also specifies risk criteria for specified thermal radiation intensities at residential areas, as listed in Table 8.

Table 8: Injury/ Escalation Risk Criteria

Impact	Risk Criteria* [per million per year]
4.7 kW/m^2 thermal radiation intensity at residential and sensitive areas (Injury)	50
23 kW/m^2 thermal radiation intensity at adjoining potentially hazardous industries or public buildings (Property damage and accident propagation)	50
7 kPa explosion overpressure at residential and sensitive areas (Injury)	50
14 kPa explosion overpressure at adjoining potentially hazardous industries public buildings (Property damage and accident propagation)	50

10 Risk Assessment

Risks from major incidents at the Elgas Kooragang Depot were analysed using the PhastRisk 6.7 software package. The software performs a risk summation for a large number of individual points on a grid pattern around the site. Individual risk contours are then drawn connecting all locations of equal risk. This contour is superimposed on a layout diagram of the site and surrounds.

10.1 Individual Risk of Fatality

The contours for individual risk of fatality for risk levels of 0.5, 1, 5 and 10 chances in a million per year for the site are presented in Figure 5. A contour for 50×10^{-6} p.a. did not result.

The contours represent the risk of fatality from fires and explosions.

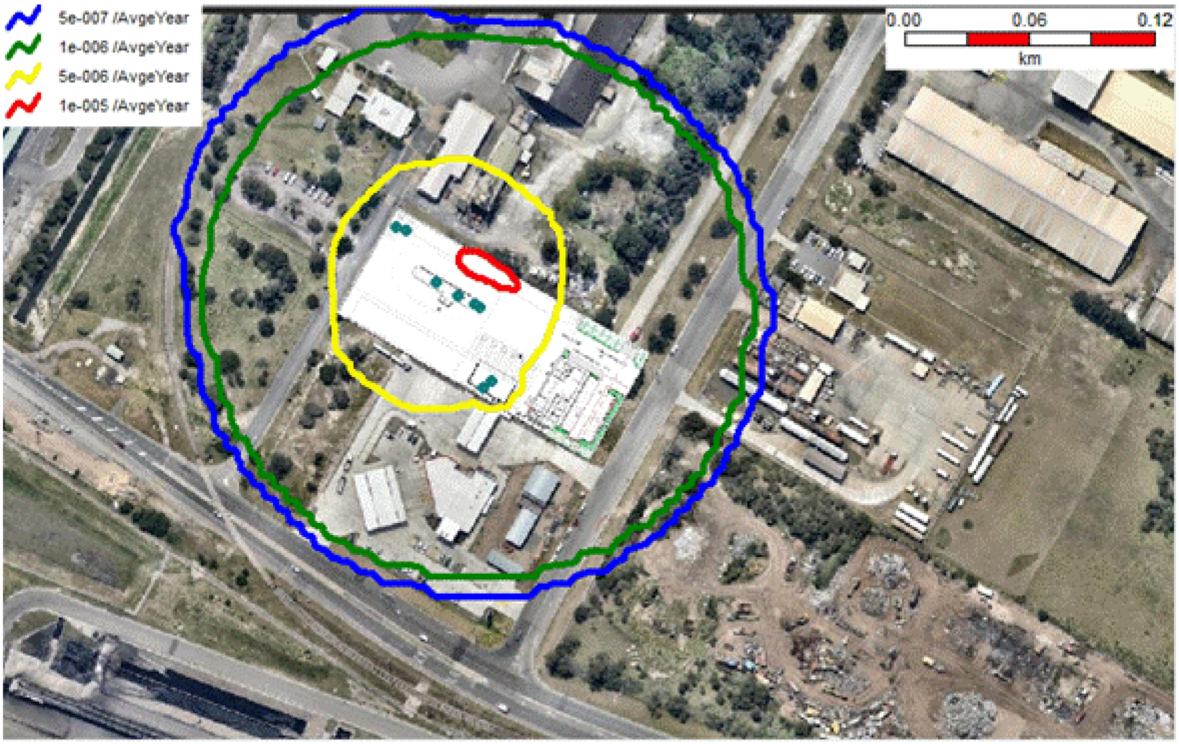

Figure 5: Fatality Risk Contours

The risk contours in Figure 5 were compared with HIPAP 4 criteria. This assessment is summarised in Table 9.

Table 9: Summary of Individual Risk Results by HIPAP No.4 Criteria

Category	Risk Levels (p.a.)	Notes	Criteria Met?
Industrial Sites	50×10^{-6}	Individual fatality risk levels for industrial sites at levels of 50 in a million per year (50 x 10^{-6} per year) should, as a target, be contained within the boundaries of the site.	Yes. The 50 x 10^{-6} per year contour is not generated indicating that the maximum risk from the facility is less than 50×10^{-6} p.a.
Commercial developments - offices, retail centres, warehouses with showrooms, restaurants and entertainment centres	$<5 \times 10^{-6}$	Should not be exposed to individual fatality risk levels in excess of five in a million per year (5 x 10^{-6} per year).	The risk contour lies entirely within the land zoned SP1. The 5×10^{-6} p.a. risk contour marginally encroaches on the service station on the south. Although a service station is commercial in nature, it is ancillary to port related uses in the Zone SP1 and therefore the industrial risk criterion is more applicable in this case. It is however, recommended that the site emergency response plan also address the service station evacuation.
Residential developments and places of continuous occupancy, such as hotels and tourist resorts	$<1 \times 10^{-6}$	Should not be exposed to individual fatality risk levels in excess of one in a million per year (1 x 10^{-6} per year). This criterion assumes that residents will be at their place of residence and exposed to the risk 100% of the time throughout the year.	Yes. No residences are impacted by this contour. The risk contour lies entirely within the SP1 zoned area, and no residential developments are permitted in this Zone.
Hospitals, schools, child-care facilities and old age housing development.	$<0.5 \times 10^{-6}$	Should not be exposed to individual fatality risk levels in excess of half in a million per year (0.5 x 10^{-6} per year)	Yes. The risk contour lies entirely within the SP1 zoned area and no sensitive uses (schools, hospitals or child-care facilities etc.) are permitted in this zone

The risk contours satisfy the risk criteria specified in HIPAP No.4. (Ref. (9).

10.2 Injury Risk and Risk of Property Damage / Accident Propagation

10.2.1 Heat Radiation

The risk contour for injury risk from thermal radiation (4.7 kW/m^2 thermal radiation intensity) at 50×10^{-6} p.a. was not generated.

Similarly, a risk contour for 50 x 10^{-6} p.a. was not generated for incident heat flux of 23 kW/m^2.

10.2.2 Explosion Overpressure

The risk contour for injury risk from explosion overpressure (7 kPa overpressure) and property damage overpressure of 14 kPa at 50 x 10^{-6} p.a. was not generated, indicating that the maximum risks for 7 kPa and 14 kPa were less than 50×10^{-6} p.a.

10.3 Societal Risk

An estimate of societal risk has been made assuming a population in the neighbouring developments. The population density assumed for the facilities are summarised in Assumption 16 of Appendix B.

Hazardous facilities such as Orica, Incitec Pivot and Park Fuel Terminal to the south east are further away from the subject site to be affected by an incident at the proposed development.

Societal risk is normally expressed as a log-log plot of the cumulative frequency (F) at which a given number of fatalities (N) may be exceeded. The plot is known as the F-N curve.

The F-N curve for the proposed Elgas facility is shown in Figure 6.

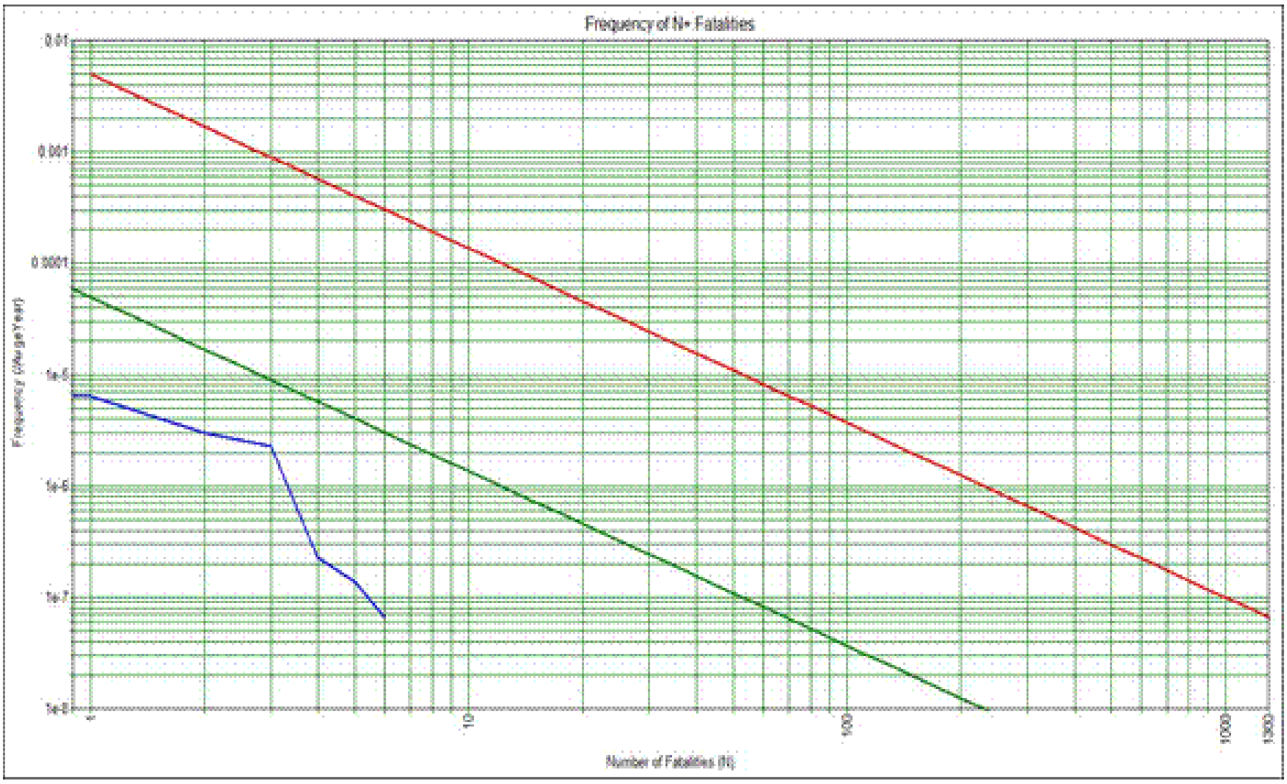

Figure 6: F-N curve for the proposed development

There is no established risk criteria for societal risk, and the risk is assessed on the basis of where the curve falls in a 'risk band'.

There are 3 regions within which the F-N curve may fall.

- An 'intolerable risk' region where the risk is not tolerable and additional risk reduction measures must be implemented.
- A 'tolerable' risk region where the risk is tolerable and shall be maintained by appropriate safety management system.
- An intermediate region where the risk is tolerable only if it is demonstrated that further risk reduction measures are not reasonably practicable. It is also referred to as the ALARP region, where the risk is kept As Low As Reasonably Practicable'.

From Figure 6, it is seen that the F-N curve falls in the 'tolerable region' and the societal risk is very low.

11 Cumulative Risk Impact from Proposed Development

The SEARs requirements for the Environmental Impact Statement (EIS) and the PHA has required the following:

> *"Estimate the cumulative impacts from the site and surrounding potentially hazardous developments in the area and demonstrate that the proposed development does not increase the cumulative risk of the area to unacceptable levels".*

This section addresses the above requirement.

11.1 Surrounding Developments

The developments surrounding the proposed development are listed in Table 10 (1).

Table 10: Developments Surrounding the Proposed Development

No.	Development Description	Location	Potentially hazardous?	Distance from proposed development, m
1	Port Waratah Coal Terminal	South Channel, Hunter River, Kooragang Precinct	No	-
2	Jemena Networks Gas Pipeline	Various	Underground	-
3	Cargill Australia Ltd	Raven Street, Walsh Point Precinct	No	-
4	BOC Ltd	Egret Street, Walsh Point Precinct	Yes	270
5	Orica Ltd - ammonia, ammonium nitrate, nitric acid	Greenleaf Road, Walsh Point Precinct	Yes	2070
6	Incitec Pivot Ltd - ammonia, ammonium nitrate, sulphuric acid	Heron Road/ Greenleaf Road, Walsh Point Precinct	Yes	1670
7	Impact Fertilisers	Greenleaf Road, Walsh Point Precinct	No	-
8	Boral Concrete	Greenleaf Road, Walsh Point Precinct	No	-
9	Origin Energy LPG distribution depot	Egret Street, Walsh Point Precinct	Yes	500
10	Parks Fuels Storage terminal	Greenleaf Road, Walsh Point Precinct	Yes	2230
11	Various storage, manufacturing industries	Walsh Point Precinct	No	-

Note: Distances recorded only for existing risk generators in the area.

11.2 Cumulative Risk

It is not possible to calculate the cumulative risk contour for the area in the absence of the existing risk grid values. This is not a regional risk assessment study.

In this report, qualitative comments have been made, based on the risk contours generated and the separation distances to existing hazardous facilities.

- Except for BOC and Origin Energy that are located in Egret Street, all other hazardous facilities are located at least 1.6 km to 2.2 km from the proposed development. Due to the separation distance, the proposed development will not cause a change in the existing risk contours of these facilities.
- The risk at Origin Energy facility is not increased by the proposed development as the individual risk of fatality is less than 0.5×10^{-6} per year.
- The only facility that might contribute to cumulative risk is the BOC facility on Egret Street. Even then the individual risk of fatality at BOC facility lies between 5×10^{-6} and 1×10^{-6} per year contours of the proposed development.

The societal risk contribution from the proposed development is very low, and hence the cumulative risk of fatality from the proposed development would not result in an acceptable risk level.

12 CONCLUSIONS AND RECOMMENDATIONS

12.1 Conclusions

The following conclusions were reached from the PHA.

- Contours for risk levels of 0.5×10^{-6} p.a. and 1.0×10^{-6} p.a. extend beyond the site boundary, but are confined within the industrial area, and do not impact upon any sensitive or residential land uses.
- Contour for risk level of 5×10^{-6} p.a., marginally encroaches the vacant area on the adjoining service station to the south of the facility, but still within land zoned SP1.
- Contour for risk level of 10×10^{-6} p.a., applicable for sporting complex or active open space, is also contained within the industrial area.
- Contour for risk levels of 50×10^{-6} p.a., applicable for neighbouring potentially hazardous facilities or public buildings was not generated.
- Risk levels at 50×10^{-6} p.a. for incident heat flux of 4.7 kW/m^2 and for explosion overpressure greater than 7 kPa, were not generated.
- Risk levels of 50×10^{-6} p.a. for incident heat flux of 23 kW/m^2 and for explosion overpressure greater than 14 kPa, were not generated.
- The societal risk from the proposed development lies in the 'tolerable' region of the F-N risk band, and considered acceptable.
- The risk levels from the Elgas Kooragang Depot from the proposed development comply with all of the risk criteria of HIPAP No.4.

12.2 Recommendations

The following recommendations are made to Elgas, arising out of the Preliminary Hazard Analysis.

1. Ensure that the night time surveillance patrol of the site includes the parked Bobtail area to detect possible presence of LP Gas (can be detected by odour). This activity is to be included in the procedures.
2. The cylinder storage and stacking arrangements on the site layout must comply with **Error! Reference source not found.** and Table 2 of this report, to ensure compliance with target risk levels.
3. The stacking of cylinder cages must not exceed 2 high for 8.5 and 15-18 kg cylinder cages.
4. A hazardous area classification diagram must be prepared for the site during detailed design.
5. Tanker loading/ unloading liquid and vapour hoses and cylinder filling hoses must be pressure tested annually.
6. Adequate lighting to be provided for after-hours access by taker driver.
7. A traffic management system must be developed on site to prevent vehicle collisions.
8. All cylinder storage areas, tanker loading/unloading area and Bobtails parking areas must be clearly marked on the floor.

9. Appropriate workplace safety signs and Hazmat signs to be installed on the site as required by the codes.
10. The emergency response plan for the facility should also address the response at the service station facility.

The additional safety studies such as a hazard and operability study, fire safety study, emergency plan as described in HIPAP No.3 (Ref. (22), Section 2.3.2) are expected to be conditions of development consent and hence not repeated in this list of recommendations.

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Appendices

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Notation

Abbreviation	Description
AS	Australian Standard
BLEVE	Boiling Liquid Expanding Vapour Explosion
DG	Dangerous Good
EFV	Excess Flow Valve
ESD	Emergency Shutdown
GL	Ground Level
IR	Infra Red
kg/s	Kilograms per second
km/h	Kilometres per hour
kPa	Kilo-Pascals
kPag	Kilo-Pascals gauge
kW/m^2	Kilo-Watts per square metre
L/min	Litres per minute
LFL	Lower Flammability Limit
LOC	Loss of Containment
LPG	Liquefied Petroleum Gas
m	Metres
MCC	Motor Control Centre
MHF	Major Hazards Facility
MI	Major Incident
mm	Millimetres
NR	Not Reached
OPG	Oil & Gas Producers Association
PFD	Probability of Failure on demand
pmpy	Per Million Per Year
PPE	Personal Protection Equipment
PRV	Pressure Relief Valve
PTW	Permit To Work
QRA	Quantitative Risk Assessment
S ‘n’ G	Swap ‘n’ Go facility
t	Tonnes

Abbreviation	Description
UK HSE	United Kingdom Health & Safety Executive
VCE	Vapour Cloud Explosion

Appendix A Hazard Identification and Safeguards

Event Scenario	Causes	Consequences	Safeguards
I. LPG Road Tanker Unloading			
1. LPG liquid leak during tanker unloading	1. Liquid Hose rupture 2. Leakage at connection 3. Valve gland leak 4. Hydrostatic valve leak	1. Exposure to cold spray and cold burns	1. Annual pressure testing of hoses to 2400kPa
		2. Spray fire if ignited	2. Visual inspection of hose by driver before connection
		3. Flash fire/Vapour Cloud Explosion (VCE) for delayed ignition	3. Double walled hose with small holes on the outer wall to indicate inner wall failure
		4. Potential for flame impingement on adjacent tanker (B-double) and BLEVE	4. Excess flow valve shuts flow for large leaks
			5. Ignition control through Hazardous Area Classification), permit to work, earthing to prevent static buildup
			6. E-stops at the tanker loading bay and on the tanker to shut both the tanker ISC valve and the tank valves, trip compressor.
2. LPG vapour leak during tanker unloading	1. Vapour return Hose rupture 2. Leakage at connection 3. Valve gland leak 4. Hydrostatic valve leak 5. Compressor leak	1. Exposure to stored energy and injury	1. Annual pressure testing of hoses to 2400kPa
		2. Jetfire if ignited	2. Visual inspection of hose by driver before connection
		3. Flashfire on delayed ignition	3. Double walled hose with small holes on the outer wall to indicate inner wall failure

Event Scenario	Causes	Consequences	Safeguards
			Excess flow valve to shut off flow for large leaks
		4. Potential for flame impingement on adjacent equipment or tanker and escalation	4. Ignition control through Hazardous Area Classification), permit to work, earthing to prevent static buildup
			5. E-stops at the tanker loading bay and on the tanker to shut both the tanker ISC valve and the tank valves
			6. Excess flow valve at the tank in vapour line would shut for large leaks
3. LPG Supply tanker collides with bobtail/flat top truck/ structure	1. Speeding	1. Potential for LPG release	1. Site speed limit is 10km/h and sign posted
		2. Fire/explosion	2. Driver induction
		3. Injury/ potential fatality	3. Traffic management scheme will be developed for site.
	2. Poor visibility	1. Same as above	1. Adequate lighting will be provided on site
	3. Turning circle obstructed by other parked vehicles	1. Same as above	1. Dedicated marked areas for different activities and for vehicle parking
	4. Mechanical failure	1. Same as above	1. Truck maintenance by contractor
	5. Human error	1. Same as above	1. Driver Training
			2. Fatigue management

Event Scenario	Causes	Consequences	Safeguards
4. Forklift collides with LPG Supply Vehicle/ Bobtail	1. Forklift speed 2. Blind spots 3. Human error 4. Mechanical failure	1. Potential for LPG release	1. Site speed limit is 10km/h and sign posted
		2. Fire/explosion	2. Forklift driver/yard operations training 3. All forklift drivers are ticketed 4. Forklift maintenance by leasing company
		3. Injury/ potential fatality	
5. Tank overfill	1. Contents Level gauge faulty and reads low 2. Human error	1. Potential for liquid LPG release from top of the tank via the PSV's if filling is done through tanker pump	1. Provide an independent float switch (LSH) on storage tank interlocked with ESD
		2. Flashfire/VCE if ignited	
		3. Potential for liquid carryover into the compressor suction and compressor damage and LPG release	
		4. Fire/explosion	
6. Tanker drive away while still connected	1. Human error	1. Potential for LPG release	1. Tanker park brake interlock
		2. Fire/explosion	2. Severed Air Interlock
II. LPG Road Tanker Unloading			
7. LPG liquid leak during Bobtail tanker loading	1. Liquid Hose rupture 2. Leakage at connection 3. Valve gland leak 4. Hydrostatic valve leak	1. Exposure to cold spray and cold burns	1. Annual pressure testing of hoses to 2400kPa
		2. Spray fire if ignited	2. Visual inspection of hose by driver before connection

Event Scenario	Causes	Consequences	Safeguards
		3. Flashfire/Vapour Cloud Explosion (VCE) for delayed ignition	3. Double walled hose with small holes on the outer wall to indicate inner wall failure
		4. Potential for flame impingement on adjacent tanker and BLEVE	4. Ignition control through Hazardous Area Classification, PTW and earthing.
		5.Potential for asphyxiation within gas cloud	5. E-stops at the tanker loading bay and on the tanker to shut both the tanker ISC valve and the tank valve
	5. Pump seal leak	1. As Above	1. Small throttle bush clearance for pump seal
8. LPG vapour leak during tanker loading	1. Vapour return hose rupture 2 Leakage at connection 3. Valve gland leak	1. Exposure to stored energy and injury 2. Jet fire if ignited 3 Flashfire on delayed ignition	1. Annual pressure testing of hoses to 2400kPa 2. Visual inspection of hose by driver before connection 3. External mechanical protection on hoses to minimise hose damage
		4. Potential for flame impingement on adjacent equipment or tanker and escalation	4. Double walled hose with small holes on the outer wall to indicate inner wall failure
			5. Ignition control through hazardous area classification, PTW and earthing.
			6. E-stops at the tanker loading bay and on the tanker to shut both the tanker and the tank valve

Event Scenario	Causes	Consequences	Safeguards
9. LPG Delivery tanker collides with bobtail/flat top truck/ structure	1. Speeding 2. Poor visibility 3. Turning circle obstructed by other parked vehicles	1.Potential for LPG release	1. Site speed limit is 10km/h and sign posted
		2.Fire/explosion	2. Driver induction
		3.Injury/ potential fatality	3. Both supply tankers and Delivery tankers/bobtails follow the same access/egress paths 4. Adequate lighting to be provided onsite 5. Dedicated marked areas for different activities and for vehicle parking 6. Dedicated marked areas for different activities and for vehicle parking
	4. Mechanical failure	1.Same as above	1. Truck maintenance by Elgas/contractor to Elgas standards
	5. Human error	1.Same as above	1. Driver Training
			2 Fatigue management
10.Tanker overfill (Bobtail)	1. Contents Level gauge faulty and reads low 2. Human Error	1.Potential for liquid LPG release from top of the tanker via the PSV	1. Fixed ullage gauge on all tankers, and driver present all the time during loading 2. Rotagauge on tanker 3. Automatic closure of tanker valve by level switch when set level is reached on tanker.
		2.Flashfire/VCE if ignited	

Event Scenario	Causes	Consequences	Safeguards
III. LPG Main Storage Vessel			
11. LPG leak from main storage tank	1. External corrosion	1. Uncontrolled release of the tank inventory with exposure to propane spray and cold burns	1. Cracks in fendolite coating monitored and repaired as necessary.
		2. Flashfire/Vapour Cloud Explosion (VCE) for delayed ignition with potential for fatality	2. 10-yearly internal inspections
	2.Internal corrosion	1. Uncontrolled release of the tank inventory with exposure to propane spray and cold burns	3. Non-corrosive product in tank
	3. Overpressuring due to tank overfilling	1. Exceeds the design pressure of tank and LPG release through flanges and fittings	4. PSV on tanks relieving to atmosphere 5. Liquid flows back via vapour line to compressor which trips on high level in suction catch pot.
	4. Flange gasket failure/ Valve gland leak	1.LPG spray leak	1. Spiral wound gaskets
		2. Spray fire if ignited	2. New gasket installed every time a flange is broken
	5. Small bore pipework fails	1. LPG spray leak	1. Very few release sources
		2. Spray fire if ignited	2. No major rotating equipment to cause vibration
		3. Flashfire/Vapour Cloud Explosion (VCE) for delayed ignition	3. Small bore nozzles are protected from impact

Event Scenario	Causes	Consequences	Safeguards
	6. Embrittlement failures	1. Uncontrolled release of the tank inventory with exposure to propane spray and cold burns 2. Flashfire/Vapour Cloud Explosion (VCE) for delayed ignition with potential for fatality	1. SOP for tank recommissioning after internal inspection o ensure tank is not overpressured when cold.
12. Inadequate purging of vessel during preparation for internal inspection	1. Human error	1. Potential for exposure to flammable vapour during confined space entry 2. Asphyxiation due to inadequate oxygen	1. Generic confined space entry procedure including gas testing and atmosphere testing for oxygen level
	2. N_2 supply runs out	1. Potential to commence air purging before all flammable material is cleared	1. Estimate of N_2 supply required and provision of adequate supply prior to preparation for internal inspection
	3. Dead pockets in the vessel where propane accumulates	1.Potential for exposure to flammable vapour during confined space entry	1. Generic confined space entry procedure including gas testing and atmosphere testing for oxygen level
13. Excessive heat radiation from temporary flare during degassing of tank for preparation for	1.Incorrect location of flare	1. Potential for injury from exposure from thermal radiation	1. Separate study to be undertaken for selecting the temporary flare location and height. This is not due for 10 years since commissioning.
	2.High venting rates	1. Potential for injury from exposure from thermal radiation	

Event Scenario	Causes	Consequences	Safeguards
internal inspectios	3. Inadequate height of flare	1. Potential for injury from exposure from thermal radiation	
IV. Cylinder Filling			
14. LPG Release in the cylinder filling area	1. Flange/fitting failure 2. Piping rupture 3. Valve gland leak 4. Incorrect connection of filling gun to cylinder 5. Hose rupture	1. LPG spray leak and cold burns on exposure	1. Spiral wound gaskets
		3. Spray fire if ignited	3. Ventilated open area
		4. Flashfire on delayed ignition 5. Impingement of flame on a cylinder and cylinder BLEVE	4. Ignition control through Hazardous Area Classification (Zone 1 for cylinder filling) and PTW
			5. Annual pressure testing of hoses
	6. Cylinder filling fails to cut off on reaching set weight	1. Cylinder is 100% and continues to be pressurised to pump closed head pressure. Potential for cylinder failure. 2. Gasket/fitting failure on the filling line	1. PRV on cylinder 2. Cylinder line reticulated back to tank and cannot overpressurise cylinder 3. Overfilled cylinder sent to recovery unit to remove the LPG (treated as a returned cylinder)
	5. PRV opens prematurely	1. LPG spray leak and cold burns on exposure	1. PPE worn by operator
			2. Operator present during filling, visually observed and shutdown initiated

Event Scenario	Causes	Consequences	Safeguards
		2. Spray fire if ignited	3. 10 yearly replacement of PRV as part of cylinder refurbishment
			4. Ignition control through Hazardous Area Classification (Zone 1 for cylinder filling) and PTW
	6. Seal leak/O-ring failure on the filling gun	1. LPG spray leak and cold burns on exposure	1. PPE worn by operator
		2. Spray fire if ignited	2. Operator present during filling, visually observed and shutdown initiated
			3. Visual inspection of O-rings
			4. Ignition control through Hazardous Area Classification (Zone 1 for cylinder filling) and PTW
	9. Overpressuring (bypass valve fails to open and pump dead heading)	1. Pipework pressure rating is higher than the maximum closed head pressure of the pump	1. Inherently safer design
15. Forklift impact on pipework	1. Mechanical failure 2. Forklift speed high 3. Blind spots	1. LPG spray leak and cold burns on exposure	1. Forklift maintenance by leasing company 2. Forklift driver/yard operations training
		2. Asphyxiation due to inadequate oxygen	
		3. Spray fire if ignited	

Event Scenario	Causes	Consequences	Safeguards
	4. Human error	4.Flashfire/Vapour Cloud Explosion (VCE) for delayed ignition	
16. Cylinder rupture/loss of containment from cylinder	1. Defective cylinder being filled	1.Cylinder contents emptied and forms a vapour cloud with cold burns on exposure	1. Operator present during filling, visually observed and shutdown initiated
		2. Asphyxiation due to inadequate oxygen	
		3. Flashfire/Vapour Cloud Explosion (VCE) for delayed ignition	
	2. Overfilled cylinder in yard exposed to sun	1. Overpressurisation of cylinder and potential for weld failure	1. PRV on cylinder
			2. Calibration of weigh scales
	3. Forklift impact on cylinder	1. Cylinder contents emptied and forms a vapour cloud with cold burns on exposure	1. Site speed limit is 10km/h and sign posted
		2. Flashfire for delayed ignition	2. Cylinders transported in stillages
	4. Cylinder dropped during handling	1. Potential for cylinder valve failure and release of contents to atmosphere	1. Neck ring protects cylinder valve
17. Pump seal failure	1. Wear and tear 2. Cavitation	1. LPG release and cold burns on exposure 2. Spray fire if ignited	1. Gas detector in pump area with ESD 2. Weekly inspections

Event Scenario	Causes	Consequences	Safeguards
	3. Pump runs against closed head Misalignment		3. High pressure switch on pump discharge and pump trip 4. Bypass valve in manifold returns LPG back to tank
V. Cylinder Loadout			
18. Stillage fails	1. Corroded/ damaged stillage 2 Ratchet and strap failure	1. Potential for cylinder to drop and roll and LPG leak	1. Visual inspection of stillage and ratchets
		2. Spray fire if ignited	2. Neck ring on cylinder protects cylinder valve
19. Forklift collides with cylinder on Stillage	1. Mechanical failure	1. LPG spray leak and cold burns on exposure 2. Spray fire if ignited 3. Flashfire for delayed ignition	1. Forklift maintenance by leasing company
	2. Forklift speed 3. Human error	1. LPG spray leak and cold burns on exposure	1. Site speed limit is 10km/h and sign posted
		2. Spray fire if ignited 3. Flashfire/Vapour Cloud Explosion (VCE) for delayed ignition 4. Flame impingement on adjacent cylinder and potential BLEVE	2. Forklift driver/yard operations training 3. All forklift drivers are ticketed
20. Dropped load from truck/dock	1. Damaged cylinder foot ring	1. Valve damage and LPG release	1. Inspection of foot ring prior to filling
		2. Jet fire if ignited	2. Neck ring on cylinder protects cylinder valve

Event Scenario	Causes	Consequences	Safeguards
			3. Securing the load after loading the truck 4. Side bars on the flat top truck 5. Control of ignition sources on site 6. After hours emergency numbers and sequence of calling available to cylinder truck driver
21. Overloading of truck	1. Human error	1. Truck control problem during transport and potential for truck accident 2. Potential for LPG release 2.Fire/explosion 3. Injury/ potential fatality	1. Maximum number of cylinders to be loaded available to the driver based on the tare weight of the truck 2. Driver induction
	2. Poor visibility	1. Potential for LPG release 2. Fire/explosion 3. Injury/ potential fatality	1. Adequate lighting to be provided on site 2. Site speed limit is 10km/h and sign posted 3. Driver induction
	3. Turning circle obstructed by other parked vehicles	1. Potential for LPG release 2.Fire/explosion 3.Injury/ potential fatality	1. Dedicated marked areas for different activities and for vehicle parking 2. Adequate lighting to be provided on site 3. Site speed limit is 10km/h and sign posted 4. Driver induction

Event Scenario	Causes	Consequences	Safeguards
	4. Mechanical failure	1. Potential for LPG release 2.Fire/explosion 3. Injury/ potential fatality	1. Truck maintenance by contractor
	5. Human error	1. Potential for LPG release 2.Fire/explosion 3. Injury/ potential fatality	1. Driver Training 2. Fatigue management
22. Unsecured load	1. Ratchet and strap failure	1. Potential for load to drop off the truck during transport and LPG leak	1. Driver daily inspection of equipment 2. Elgas annual audit of cylinder truck contractor fleet
	2. Human error	1. Potential for load to drop off the truck during transport and LPG leak	1. Driver Induction
23. Cylinder PRV passing	1. Damaged PRV	1. Continuous LPG release until pressure drops close to ambient	1. Visual inspection of secured load before leaving site 2. Leak checks on every valve on cylinders during filling
24. Overfilled cylinder leak from thermal expansion	1. Automatic Weighing and shut off system failure	1.Cylinder Overfill	1. PRV on cylinder 2. Calibration of weigh scales 3. Overfilled cylinder sent to recovery unit.

Event Scenario	Causes	Consequences	Safeguards
	2. Cylinder exposed to sun during the day	1.Damage to cylinder, potential LPG release and associated consequences	1. Fill level allows for thermal expansion from exposure to sun.
	3. Human error	1. Damage to cylinder, potential LPG release and associated consequences	1. Filling procedures 2. Operator training 3. Driver induction
25. Bleeder valve not closed fully	1. Human error	1.Leak continues while cylinder is at the dock. Potential to load leaking cylinder onto truck	1. Filling procedures
		2. Problems during transport	2. Operator training
		2. Asphyxiation due to inadequate oxygen	
		3. Flashfire/Vapour Cloud Explosion (VCE) for delayed ignition	
VI. Overnight Parking of Laden BobTail Tankers			
30. Leak from parked tanker	1. Inadequate isolation after filling. Leaking isolation valve.	1. Potential for fire if ignited and incident escalation	1. Internal self-closing valve within the tanker, in addition to manual isolation valve. 2. Separation distance between tankers to the requirements of AS 1596.

Appendix B Assumptions Register

When developing the models for the QRA, it is necessary to make a number of technical assumptions. These typically relate to specific data inputs (e.g. material properties, equipment failure rates, etc.) and modelling assumptions (e.g. release orientations, impairment criteria, etc.).

It is important that the assumptions be supported by:

- experimental data in the literature, where available;
- actual plant experience, where available;
- similar assumptions made by professionals in the field and a general consensus among process safety experts; and
- engineering judgement.

The main objectives are to minimise uncertainty in the risk estimate as far as is possible, and to ensure that the assumptions result in a 'cautious best estimate' of the risk.

The key assumptions adopted for the QRA are listed in this Appendix. Each assumption is numbered and detailed separately. The basis for each assumption is explained together with its potential impact on the results of the QRA and the Release Events potentially affected. Key references are also listed for each assumption, where relevant.

B.1 Isolatable Sections

Assumption No. 1: Defining Isolatable Sections
Subject: Isolatable Sections
Assumption: • An isolatable section was defined as a section of the facility with equipment that is connected and contains LPG. • The boundaries of an isolatable section were defined by valves that are actuated automatically by ESD activation, either manually or by gas detection. Other valves, such as manually operated valves and non-return valves have not been considered. • The total mass potentially released in a LOC equals the inventory of the isolatable section plus the incoming flows from other isolatable sections in normal process conditions, until isolation is achieved. Failure to isolate increases the total mass potentially released in a LOC. • During an LOC from an isolatable section, the process conditions are assumed to remain constant (e.g. pressure, temperature, etc.).
Justification and Impact of Assumption: • Remotely actuated valves are adequate boundaries for defining isolatable sections because they close automatically on ESD activation. • Assuming constant process conditions is a reasonable assumption as a conservative estimate of release rate and mass released is obtained (i.e. the effect of decreasing pressure and subsequent reduction in release rate is ignored).
Release Events Affected: All Fabric Failures
References: • Purple Book [Guidelines for Quantitative Risk Assessment - Purple Book CPR 18E - Committee for the Prevention of Disasters, CPR 18E, First Edition, The Hague, 1999].

B.2 Operating Temperatures, Pressures and process flows

Assumption No. 2: Operating Temperatures, Pressures and process flows
Subject: Process Conditions
Assumption: • Storage conditions were taken as that for saturated propane at an ambient temperature of 20^{O}C. • Cylinder filling line pressures were based on the pump discharge pressure (higher than the saturated vapour pressure). • Tanker loading/unloading rates were based on the LPG vapour compressor performance curve (provided by Elgas). Corken FD 491 model. • Cylinder filling rate was taken as the pump discharge rate (from pump curve). Ebsray RC40 pump 100 L/min • Vapour release rates were based on compressor capacity. Corken Model FD 491 compressor
Justification and Impact of Assumption: • The release rate for a given scenario increases with pressure.
Release Events Affected: All Fabric Failures
References: • Elgas Ltd, RC 40 Ebsray Pump data from manufacturer's catalogue. • Elgas Ltd, Corken FD 491 compressor data from manufacturer's catalogue.

B.3 Vessel Volumes

Assumption No. 3: Vessel Volumes
Subject: Process Conditions
Assumption: • Actual volumes of vessels have been considered for the modelling. • Internal fittings and packing in vessels have not been considered. • Liquid level in Tank taken as 75% (vapour 25%) • Average liquid level in tanker was taken as 75% (vapour 25%)
Justification and Impact of Assumption: • Ignoring internal fittings and packing in vessels results in greater inventories being calculated for the isolatable sections and therefore it is considered to lead to conservative results.
Release Events Affected: All Fabric Failures
References: • Prelimary P&ID Drawing E201202, Revision C (for Elgas Rocklea site). The Kooragang site will be similar.

B.4 Pipe Lengths

Assumption No. 4: Pipe Lengths

Subject: Process Conditions

Assumption:

- Pipe lengths were estimated from a scaled plot plan, and proposed locations of equipment.
- In calculating pipe lengths, the changes in elevation were considered by factoring the length estimated from the plot plan. A factor of 1.2 was applied to the pipe length to account for routing of pipeline and vertical runs.

Justification and Impact of Assumption:

- The pipe length influences the:
  - Release frequency - The failure frequency for pipelines is given per unit of pipe length, i.e. the longer pipe the pipe, the higher the frequency associated with a LOC.
  - Hold-up mass - The hold-up mass increases proportionately with pipe length. This is particularly relevant for liquid pipelines. For gas pipelines, this effect is negligible.

Release Events Affected:

All Fabric Failures

References:

- Scaled facility plot plan.

B.5 Representative Hole Sizes

Assumption No. 5: Representative Hole Sizes
Subject: Representative Hole Sizes
Assumption: • Several representative hole sizes were assumed for each isolatable section (Refer to Appendix E.4). To accurately represent the failure frequency data shown in Assumption No. 9, each selected hole size represents a range of hole sizes. • Vessel ruptures were modelled as a catastrophic failure of the vessel.
Justification and Impact of Assumption: • Representative hole sizes were selected to coincide with the failure frequency data used within the study. The selection of hole sizes has therefore been made in conjunction with the selection of the failure frequencies (See Assumption No. 9). • The representative hole size may impact the calculated release rate, and corresponding consequence distance.
Release Events Affected: All Fabric Failures
References: • UK HSE, 2012, *Failure Rate and Event Data for use within Risk Assessments*. • International Association of Oil & Gas Producers (OGP), March 2010, *Process release frequencies*, OGP, Report No. 434 – 1.

B.6 Release Rates

Assumption No. 6 : Release Rates
Subject: Release Characteristics
Assumption: • Release rates were calculated based on the process conditions in Assumption 2. • Releases were modelled at a constant initial (maximum) rate. • If the calculated release rate was higher than the process flow rate, then the process flow rate was used.
Justification and Impact of Assumption: • The release rate used will affect the magnitude of the consequence distances, particularly for LOCs of flammable gases and liquefied gases as the maximum distance to the LFL depends on the release rate rather than the inventory. Therefore, using the initial release rate as the representative release rate for the entire release duration will result in conservative results. • In cases where the inventory within an isolatable section is negligible compared to the process flow rate into that isolatable section, the equilibrium release rate will be dictated by the process flow rate. • While it would be conservative to assume the higher initial release rates for all cases, the consideration of the process flow rate as a determining factor ensures a more realistic result by maintaining the overall process mass balance.
Release Events Affected: All
References: • TNO, 1999, *Guidelines for Quantitative Risk Assessment*, Committee for the Prevention of Disasters, CPR 18E, First Edition, The Hague.

B.7 Release Duration

Assumption No. 7: Release Duration
Subject: Release Characteristics
Assumption: • The release duration also depends on whether detection and subsequent isolation occurs (Refer to Assumption No. 8). • The time to deplete the inventory was calculated by dividing the total mass potentially available for release in a LOC event by the calculated release rate for the isolatable section, for the case where ESD is either not activated or fails. • For excess flow valve actuation, the inventory would be isolated in 1 minute. • For ESD activation, the release duration was taken as time manually operate the ESD push button (3 minutes), plus the time taken for the depletion of isolated inventory. • For ESD failure or delayed activation, the maximum release duration was taken as 60 minutes (i.e. manual isolation in the field with protective clothing), unless full tank inventory depletes earlier.
Justification and Impact of Assumption: • The duration of the release will affect the amount of material released. However, the approach taken for the calculation of the release duration ensures the results are realistic by applying the laws of conservation of mass.
Release Events Affected: All
References: • TNO, 1999, *Guidelines for Quantitative Risk Assessment*, Committee for the Prevention of Disasters, CPR 18E, First Edition, The Hague.

B.8 Isolation Time

Assumption No. 8: Isolation Time
Subject: Release Characteristics

Assumption:
• The total time taken to isolate following a LOC includes the time to detect and the time to complete the isolation once detected.
  ◦ For automatic isolation triggered by gas detection system (cylinder fill area), the time to isolate the release was assumed to be 2 minutes [Purple Book].
  ◦ For excess valve successful closure situations, the isolation time was taken as 1 minute maximum.
• For manually activated isolation:
  ◦ The time to detect and isolate a leak in the cylinder filling area (operator present) was taken as 3 minutes.
  ◦ The time to detect and isolate a leak during tanker loading/ unloading was taken as 3 minutes (driver present all the time).
  ◦ The time to detect a release at the tank (when an operator is present on site) was assumed to be 20 minutes for medium leaks and 60 minutes for small leaks (no gas detection).

Justification and Impact of Assumption: • Overall, the isolation time (the time to detect and isolate) affects the duration of the release or fire event. For a flammable release, the increased duration potentially increases the size of both the resulting vapour cloud and the subsequent explosion event. For ignited releases, the potential for escalation events, such as BLEVE, can increase the longer a jet fire event continues. • Detection method is entirely manual. • The time to isolate a release (once detected) does not vary with release size because the decision to isolate and the action of isolation itself is generally the same for all release sizes.
Release Events Affected: All Release Events where isolation is possible (Note: Some releases direct from tanks will not be isolatable).
References: • TNO, 1999, *Guidelines for Quantitative Risk Assessment*, Committee for the Prevention of Disasters, CPR 18E, First Edition, The Hague. • Onsite discussions with Elgas operations personnel.

B.9 Failure Frequencies

Assumption No. 9: Failure Rate Data
Subject: Frequency Analysis
Assumption: • Generic industry data for equipment failures was selected for the QRA, as presented in Appendix E.1.

Justification and Impact of Assumption:
• Generic industry data for equipment failures was selected as there is no specific failure data at the facility. The use of generic industry data facilitates a comparison of the results of the risk assessment with other sites (i.e. benchmarking).
• A review of several sources of failure data was made prior to selecting the failure frequencies for the parts count QRA (i.e. base line frequencies for the fabric failures).
• The principal sources of the data used in the QRA were:
  • UK HSE, 2012, *Failure Rate and Event Data for use within Risk Assessments*.
  • International Association of Oil & Gas Producers (OGP), March 2010, *Process release frequencies*, OGP, Report No. 434 – 1.
• When different failure data for a specific component was referenced, a conservative selection was made.

Release Events Affected: All Fabric Failures
References: • UK HSE, 2012, *Failure Rate and Event Data for use within Risk Assessments*. • International Association of Oil & Gas Producers (OGP), March 2010, *Process release frequencies*, OGP, Report No. 434 – 1.

B.10 Low Frequency Cut-off

Assumption No. 10: Low Frequency Cut Off
Subject: Frequency Analysis
Assumption: • Release scenarios with fire frequencies of less than 1.0 x 10^{-8} per year were excluded from the study.
Justification and Impact of Assumption: • This assumption simplifies the assessment by discarding scenarios which have negligible impact on the calculated cumulative risk. This is qualified on the basis that 1.0 x 10^{-8} per year is significantly lower than the relevant risk criteria.
MIs Affected: All
References: • None.

B.11 Release Orientations

Assumption No. 11: Orientation of Releases
Subject: Consequence Analysis
Assumption: • Releases from pipe work were directed horizontally with the wind. • Releases from vessels were directed either horizontally or vertically downward.
Justification and Impact of Assumption: • Releases from process equipment can occur in a number of different possible orientations. • Modelling releases horizontally with the wind generally results in the most conservative consequence distances for all potentially hazardous outcomes (e.g. jet fires, flash fires) • Downward impinging liquid jets resulted in pool fires (horizontal releases did not) and pool fire radiation would be significant. • Conservatism was maintained in the assessment.
Release Events Affected: All
References: • TNO, 1999, *Guidelines for Quantitative Risk Assessment*, Committee for the Prevention of Disasters, CPR 18E, First Edition, The Hague. The reference suggests horizontal releases if specific information was unavailable.

B.12 Flash Fires

Assumption No. 12: Flash Fires
Subject: Consequence Analysis
Assumption: • The footprint of the flammable gas/ vapour cloud was assumed to be the consequence area from a flash fire event. • The footprint of a flammable gas/ vapour cloud was defined by the downwind and crosswind distances from the release location to a ground level concentration equal to the lower flammability limit (LFL) concentration, and 50% LFL.
Justification and Impact of Assumption: • The selection of the concentration to LFL used in determining the footprint of flammable clouds is critical to determine the impact zones for flash fires. • Using a concentration equal to 50% of the LFL to determine the footprint of flammable clouds provides consequence distances for identification of known ignition sources in risk modelling.
Release Events Affected: All Release Events with flash fire as a potential outcome
References: • PhastRisk v.6.7 software documentation.

B.13 Vapour Cloud Explosions

Assumption No. 13: Vapour Cloud Explosions
Subject: Consequence Analysis

Assumption:
• The key parameters for modelling VCEs are the explosive mass and the strength of the VCE. The approach taken for modelling the effects of VCEs can be summarised in the following paragraphs:
  • The maximum explosive mass in a flammable/vapour cloud is the maximum mass between the LFL and UFL concentration for that section of the cloud that overlaps a congested area. However, all mass above LFL was used for the assessment.
  • The peak side-on overpressures resulting from vapour cloud explosions (VCEs) were assessed using the Extended Explosion Modelling option in the PhastRisk software. Congested areas were identified on site layout and specified in the risk model
  • The blast strength was estimated in the PhastRisk software based on the obstructed volume (%) and size of the obstructions in each congested area.
  • The following congested areas were considered: LPG Tank, cylinder storage areas, cylinder filling shed. For the scenarios in these areas, the % blockage in each direction was specified in the PhastRisk 3D congestion model for explosion.

Justification and Impact of Assumption: • The Extended Explosion Modelling option considers the interactions between the flammable cloud and obstructed regions that have been defined for the study area. This is more valid than simple models (e.g. TNT equivalence) which do not consider these interactions.
Release Events Affected: All Release Events with VCE as a potential outcome
References: • PhastRisk v.6.7 software documentation.

B.14 Height for Calculation of Consequence and Risk Results

Assumption No. 14: Height for Calculation of Consequence and Risk Results
Subject: Consequence and Risk Analysis
Assumption: • The effects of each potentially hazardous outcome were calculated at ground level. • The cumulative risk was calculated at ground level.
Justification and Impact of Assumption: • There are no elevated, normally populated, areas surrounding the facility.
Release Events Affected: All
References: • None

B.15 Representative Release Locations

Assumption No. 15: Representative Release Locations
Subject: Consequence Analysis
Assumption: • Each representative potentially hazardous scenario was located on a scale plot plan within the PhastRisk software. • Vessels, pumps, short sections of piping, etc. were located as 'point sources' at the centre of the relevant location. • Cylinder storage area covering a large rectangular area was modelled using the “linear source” model in PhastRisk. Rows of cylinders to cover the cage depths were considered. Stacked cages were modelled as elevated linear sources.
Justification and Impact of Assumption: • It is standard practice in QRAs to use representative release locations for each scenario. • The cylinder locations modelling captures the benefits from the “linear source” model in the PhastRisk software.
Release Events Affected: All
References: • None

B.16 Population density in surrounding potentially hazardous industries

Assumption No. 16: Population density in surrounding industries

Subject: Societal Risk Assessment

Assumption:

- The following population density has been assumed in the facilities surrounding the proposed development, to assess the societal risk.

Location	Number of persons	Fraction of Time Exposed	Notes
Car Wash	3	0.116	24hr operation, 10 minutes to wash, 50washers/day (3 simultaneous washes)
Shell - Diesel Bowser	2	0.174	24hr operation, 10-minute fill, 50 fills per day (2 simultaneous fills)
Shell - Petrol Bowser	4	0.2	24hr operation, 5-minute fill, 100 fills per day (4 simultaneous fills)
Shell - Shop/Café	5	0.1458	No exposure indoors -30minutes outdoor exposure assumed 7days/week
Boral Buildings	6	0.1042	No exposure indoors -30minutes outdoor exposure assumed (Mon-Fri)
Boral Admin	10	0.1042	No exposure indoors -30minutes outdoor exposure assumed (Mon-Fri)
Boral Yard	6	0.3571	Assumed daytime (6am-6pm), Mon-Fri
BOC Admin	10	0.1042	No exposure indoors -30minutes outdoor exposure assumed (Mon-Fri)
BOC Yard	2	0.3571	Assumed daytime (6am-6pm), Mon-Fri
Simsmetal	3	0.3571	Assumed daytime (6am-6pm), Mon-Fri
Coal Loader – Port Waratah Wharf	3	0.4762	Personnel on dock during load. 10hrs/shift, 2 shifts/d, 4 days/week
Cargill	6	0.3571	Assumed daytime (6am-6pm), Mon-Fri
Port Hunter Commodities	6	0.3571	Assumed daytime (6am-6pm), Mon-Fri
Cleanaway	6	0.3571	Assumed daytime (6am-6pm), Mon-Fri
Origin	6	0.3571	Assumed daytime (6am-6pm), Mon-Fri

Justification and Impact of Assumption:

- Details of other facilities were not available. Assumptions were based on the type of industry, and hence should be considered approximate.
- Some of the basis for the assumptions are listed in the comments column of the Table above.

Release Events Affected:

All

References:

- None

Appendix C Meteorological Data

Wind weather data relevant to the estimation of the effects of an LPG release was used in the site QRA study. The data (mean cloud cover, temperature, wind speeds) was collected by the Bureau of Meteorology at Williamtown RAAF base weather station. This raw data was rationalised in a form appropriate for vapour dispersion calculations. Williamtown weather station was selected as being closest to the Elgas Kooragang site, compared to the next weather station at Nobby's Head.

Dispersion of gas releases is strongly dependent upon the prevailing wind speed and atmospheric stability. Information regarding wind weather for input into the dispersion model was extracted from the meteorological data.

Wind speed data and wind rose data were combined to obtain annual averages. Pasquil stability classes of A, B, C, D, E and F have been evaluated using an estimation of lapse rates, from mean cloud cover and maximum/ minimum temperatures. The wind rose was divided into each stability class.

The data has been processed into a rationalised form consisting of six wind speed/stability group classes arranged into sixteen wind direction groups. The arrangement into wind speed/stability group classes followed the criteria set out below in the table below and the rationalised wind weather data is shown in the following table.

The average temperature and the average humidity varied for different wind speeds and weather stability conditions.

A total of 16 wind directions and 6 stability classes were used in the analysis, as listed below.

Table 1: Williamtown Weather Station Processed Meteorological Data Wind Direction (from) - % Probability

Class	Wind speed m/s	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
B	1.86	0.70	0.45	0.44	0.29	0.34	0.37	0.57	0.39	0.24	0.12	0.10	0.16	0.42	0.70	0.82	0.75	6.85
DH	8.13	0.04	0.12	0.76	1.40	1.40	1.36	1.76	2.31	3.45	1.09	0.60	0.45	1.96	5.99	1.15	0.13	23.97
DL	0.83	1.68	1.11	1.18	1.01	1.04	0.52	0.52	0.55	0.71	0.37	0.37	0.53	1.27	1.97	1.57	0.89	15.30
DM	4.03	1.30	1.57	3.22	2.24	2.49	2.02	2.17	1.98	2.59	1.16	0.95	1.37	3.26	5.79	3.46	1.11	36.66
E	3.10	0.22	0.29	0.44	0.32	0.20	0.08	0.08	0.06	0.12	0.05	0.06	0.10	0.36	0.87	0.62	0.16	4.03
F	0.58	1.37	1.09	1.11	0.96	0.87	0.34	0.35	0.34	0.42	0.21	0.24	0.43	1.19	1.88	1.64	0.76	13.21
Total		**5.32**	**5.32**	**5.32**	**5.32**	**5.32**	**5.32**	**5.32**	**5.32**	**5.32**	**5.32**	**5.32**	**5.32**	**5.32**	**5.32**	**5.32**	**5.32**	**100.00**

Note 1: DH – Neutral stability High wind speed; DL – Neutral stability Low wind speed; DM – Neutral stability Medium wind speed

Note 2: Where the wind speed is less than 1m/s, it was reset to 1m/s for dispersion calculations as PhastRisk results are validated only up to a minimum wind speed of 1 m/s.

Table 2: Average Atmospheric Conditions

Stability Class	Average Temp °C	Average Speed m/s	Average of Solar Radiation W/m²	Average Moisture g/kg	Average Pressure kPa
B	22.34	1.86	625.50	10.33	101.63
DH	19.52	8.13	345.00	8.46	101.39
DL	15.56	0.83	47.93	9.77	101.69
DM	17.82	4.03	174.48	9.42	101.65
E	14.29	3.10	0.00	8.34	101.70
F	13.91	0.58	0.00	8.80	101.76

Appendix D Isolatable Sections and Representative Failure Cases

D.1 Isolatable Sections

The isolatable sections, including relevant process conditions, are listed in Table 3.

Table 3 Isolatable Sections and Process Conditions

Isolatable Section No.	Description	Phase	T (°C)	P (kPag)	Inventory, kg	Utilisation (%)
1	Tank (Liquid Side)	L	20	733	37500	100
2	Tank (Vapour Side)	V	20	733	550	100
3	Recovery Manifold (Liquid Side)	L	20	733	<10	100
4	Recovery Manifold (Vapour Side) - Negligible	V	20	733	<1	100
5	Liquid pipework (50 mm) between Road Tanker and Tank including hose	L	20	733	10	10.0
6	Vapour pipework (50 mm) at Tanker Unloading Area including hose	V	20	1620	< 1	10.0
7	Supply Tanker (Liquid Side) at Tanker Unloading Area	L	20	733	18000**	5.9
8	Supply Tanker (Vapour Side) at Tanker Unloading Area	V	20	733	220	5.9
9	"Bobtail" Tanker (Liquid Side) at Tanker Loading Area	L	20	733	9000	4.5
10	"Bobtail" Tanker (Vapour Side) at Tanker Loading Area	V	20	1620	120	4.5
11	LPG pump and liquid pipework (50 mm) for cylinder filling	V	20	1520	20	30.0
12	Liquid pipework to Electronic scale, including hose (20 mm)	V	20	1520	20	30.0
13	Liquid pipework (25 mm) for Product Recovery manifold to storage	V	20	1520	< 10	20.0

Isolatable Section No.	Description	Phase	T (°C)	P (kPag)	Inventory, kg	Utilisation (%)
14	LPG cylinders at storage area A (8.5 kg)	L	20	733	76000	100
15*	LPG cylinders at storage area B (i) (45 kg)	L	20	733	7900	100
16*	LPG cylinders at storage area B (ii) (210 kg)	L	20	733	2100	100
17	Bobtail parked overnight (liquid)	L	20	733	9000	58.3
18	Bobtail parked overnight (vapour)	V	20	733	120	58.3

*The cylinders may consist of 45, 90,190 or 210kg in size with a total weight of 10 tonnes. Table indicates the values used for analysis.

**Based on the larger of the two tankers in the B-double tanker.

D.2 Representative Failure Cases

The representative failure cases selected for each isolatable section are listed in Table 3. The following representative locations were considered in the QRA:

The representative failure cases were selected to align with the relevant leak frequency data (Refer to Appendix D). For example, four cases were selected for a liquid leak from a bulk storage tank:

- Rapid release of the entire contents of the tank (catastrophic failure)
- A 50 mm leak (liquid) from the tank (including pipework & fittings)
- 25 mm leak (liquid) from tank (including pipework & fittings)
- 13 mm leak (liquid) from tank (including pipework & fittings)
- For stored cylinders, the hole sizes used were 2mm, 5mm and rupture

Each representative failure case was assigned a unique identification number. This number is used to identify each case, particularly for the tabulated data and results in Table 3 and Appendix E.

Table 4: Representative Failure Cases

Item Description	Isolatable Section	Failure Case Description	Failure Case ID No.	Hole Size Range [mm]	Max. Inventory [kg]	Release quantity with isolation [kg]	Release Height [m]
Tank (Liquid Side)	1	Rapid release of entire contents (catastrophic failure)	1-TA-L--RUP	Rupture	37500	37500	1
		50 mm leak (liquid) from tank (including pipework & fittings)	1-TA-L-50mm	50			
		25 mm leak (liquid) from tank (including pipework & fittings)	1-TA-L-25mm	25			
		13 mm leak (liquid) from tank (including pipework & fittings)	1-TA-L-13mm	13			
Tank (Vapour Side)	2	Rapid release of entire contents (catastrophic failure)	2-TA-V--RUP	Rupture	550	550	1
		50 mm leak (liquid) from tank (including pipework & fittings)	2-TA-V-50mm	50			
		25 mm leak (liquid) from tank (including pipework & fittings)	2-TA-V-25mm	25			
		13 mm leak (liquid) from tank (including pipework & fittings)	2-TA-V-13mm	13			
Recovery Manifold (Liquid Side)	3	50 mm leak (liquid) from manifold (including pipework & fittings)	3-LI-L-50mm	50	9	9	0.5
		25 mm leak (liquid) from manifold (including pipework & fittings)	3-LI-L-25mm	25			
Liquid pipework (50 mm) between Road Tanker and Tank including hose	5	50 mm leak (liquid) from pipe	5-LI-L-50mm	50	< 10	<10	1
		25 mm leak (liquid) from pipe	5-LI-L-25mm	25			
		3 mm leak (liquid) from flanges	5-LI-L-3mm	3			
		9 mm leak (liquid) from valve glands	5-LI-L-9mm	9			
		50 mm leak (liquid) from hose failure	5-LI-L-50mm-Hose	50			
Vapour pipework (50 mm) at Tanker Unloading Area including hose	6	50 mm leak (vapour) from pipe	6-LI-V-32mm	32	<1	240	1
		25 mm leak (vapour) from pipe	6-LI-V-25mm	25			
		9 mm leak (vapour) from valve glands	6-LI-V-9mm	9			
		50 mm leak (vapour) from hose failure	6-LI-V-32mm-Hose	32			
Supply Tanker Liquid Side) at Tanker Unloading Area	7	Rapid release of entire contents (catastrophic failure)	7-Tanker-L-RUP	Rupture	18000	18000	2
		50 mm leak (liquid) from tanker (including pipework & fittings)	7-Tanker-L-50mm	50			
		25 mm leak (liquid) from tanker (including pipework & fittings)	7-Tanker-L-25mm	25			
		13 mm leak (liquid) from tanker (including pipework & fittings)	7-Tanker-L-13mm	13			
Supply Tanker (Vapour Side) at	8	Rapid release of entire contents (catastrophic failure)	8-Tanker-V--RUP	Rupture	120	120	2

Item Description	Isolatable Section	Failure Case Description	Failure Case ID No.	Hole Size Range [mm]	Max. Inventory [kg]	Release quantity with isolation [kg]	Release Height [m]
Tanker Unloading Area		50 mm leak (vap) from tank (including pipework & fittings)	8-Tanker-V-50mm	50			
		25 mm leak (vap) from tank (including pipework & fittings)	8-Tanker-V-25mm	25			
		13 mm leak (vap) from tank (including pipework & fittings)	8-Tanker-V-13mm	13			
"Bobtail" Tanker (Liquid Side) at Tanker Loading Area	9	Rapid release of entire contents (catastrophic failure)	9-Tanker-L-RUP	Rupture	9000	9000	2
		50 mm leak (liquid) from tanker (including pipework & fittings)	9-Tanker-L-50mm	50			
		25 mm leak (liquid) from tanker (including pipework & fittings)	9-Tanker-L-25mm	25			
		13 mm leak (liquid) from tanker (including pipework & fittings)	9-Tanker-L-13mm	13			
"Bobtail" Tanker (Vapour Side) at Tanker Loading Area	10	Rapid release of entire contents (catastrophic failure)	10-Tanker-V-RUP	Rupture	120	120	2
		50 mm leak (liquid) from tanker (including pipework & fittings)	10-Tanker-V-50mm	50			
		25 mm leak (liquid) from tanker (including pipework & fittings)	10-Tanker-V-25mm	25			
		13 mm leak (liquid) from tanker (including pipework & fittings)	10-Tanker-V-13mm	13			
LPG pump liquid pipework (50 mm) for cylinder filling	11	50 mm leak (liquid) from pipe	11-LI-L-50mm	50	< 10	675	1
		25 mm leak (liquid) from pipe	11-LI-L-25mm	25		675	
		3 mm leak (liquid) from flanges	11-LI-L-3mm	3		305	
		9 mm leak (liquid) from valve glands	11-LI-L-9mm	9		2025	
		50mm pump casing failure (largest nozzle)	11-P-L-50mm	50		37500	0.5
		9mm leak (liquid) from pump seal	11-P-L-9mm	9		2025	0.5
Liquid pipework (32mm) to Electronic scale, including hose (20 mm)	12	32 mm leak (liquid) from pipe	12-LI-L-32mm	32	<10	3438	1
		3 mm leak (liquid) from flanges	12-LI-L-3mm	3		31	
		9 mm leak (liquid) from valve glands	12-LI-L-9mm	9		275	
		20 mm leak (liquid) from hose failure	12-LI-L-20mm-Hose	20		1345	
Liquid pipework (25 mm) from Cylinder Recovery manifold to storage	13	25 mm leak (liquid) from pipe	13-LI-L-25mm	25	9	9	1
		3 mm leak (liquid) from flanges	13-LI-L-3mm	3		9	
		9 mm leak (liquid) from valve glands	13-LI-L-9mm	9		9	
LPG cylinders at storage area A (8.5 kg)	14	Rapid release of entire contents (catastrophic failure)	L14-CYL-RUPTURE	Rupture	76000	8.5 (single cylinder failure)	1 to 3m
		5 mm leak (liquid) from LPG cylinder	L14-CYL-5mm-L	5			

Item Description	Isolatable Section	Failure Case Description	Failure Case ID No.	Hole Size Range [mm]	Max. Inventory [kg]	Release quantity with isolation [kg]	Release Height [m]
		2 mm leak (liquid) from LPG cylinder	L14-CYL-2mm-L	2			
LPG cylinders at storage area B (i) (45 kg)	15	Rapid release of entire contents (catastrophic failure)	L15-CYL-RUPTURE	Rupture	7900	45 (single cylinder failure)	1
		5 mm leak (liquid) from LPG cylinder	L15-CYL-5mm-L	5			
		2 mm leak (liquid) from LPG cylinder	L15-CYL-2mm-L	2			
LPG cylinders at storage area B (ii) (210 kg)	16	Rapid release of entire contents (catastrophic failure)	L16-CYL-RUPTURE	Rupture	2100	210 (single cylinder failure)	1
		5 mm leak (liquid) from LPG cylinder	L16-CYL-5mm-L	5			
		2 mm leak (liquid) from LPG cylinder	L16-CYL-2mm-L	2			
Bobtail parked overnight (liquid)	17	Rapid release of entire contents (catastrophic failure)	17-Tanker-L-RUP	Rupture	9000	9000	1
		50 mm leak (liquid) from tank (including pipework & fittings)	17-Tanker-L-50mm	50			
		25 mm leak (liquid) from tank (including pipework & fittings)	17-Tanker-L-25mm	25			
		13 mm leak (liquid) from tank (including pipework & fittings)	17-Tanker-L-13mm	13			
Bobtail parked overnight (vapour)	18	Rapid release of entire contents (catastrophic failure)	18-Tanker-V-RUP	Rupture	120	120	1
		50 mm leak (liquid) from tanker (including pipework & fittings)	18-Tanker-V-50mm	50			
		25 mm leak (liquid) from tanker (including pipework & fittings)	18-Tanker-V-25mm	25			
		13 mm leak (liquid) from tanker (including pipework & fittings)	18-Tanker-V-13mm	13			

Note: Scenario 13 has a small inventory and a release will have only localised impact, but still modelled for completeness.

Appendix E Frequency Analysis

E.1 Frequency Data

A hazard analysis requires quantification of the frequencies and consequences of all hazardous events to combine and produce an overall quantitative risk assessment.

The common approach is direct use of statistical data on failure of equipment such as vessels, pipe work, valves, fittings etc. This is sometimes called the "historical approach" and the resulting data is referred to as “generic” or “historical” data.

Equipment failure rate data is available from a number of sources. The equipment failures rates used in this study are presented below.

Table 5: Failure Rate Data for LPG Pressure Vessels (Ref: HSE (2012), Item FR 1.1.3.2)

Type of release	Frequency (per vessel year)	Notes
Catastrophic	2.00E-06	Cold vessel failures
BLEVE	1.00E-05-1.00E-07	Tank not mounded. Needs to be assessed by sources of flame impingement and orientation.
BLEVE	0.00E+00	Mounded tank
50 mm diameter hole	5.00E-06	
25 mm diameter hole	5.00E-06	
13 mm diameter hole	1.00E-05	

Table 6: Failure Rate Data for Excess Flow Valves (Ref: HSE (2012), Item FR 1.2.1)

Type of event	Failure rate (per demand)	Notes
Failure to operate	1.30E-01	Excess flow valves (XSFV) if tested every 10 years.

Table 7: Failure Rate Data for Hoses and Couplings (Ref: HSE (2012), Item FR 1.2.3)

	Failure rate (per operation)				
Facility	Guillotine failure	15 mm diameter hole	5 mm diameter hole	Total	Notes
Basic facilities	4.00E-05	1.00E-06	1.30E-05	5.40E-05	These have one pullaway prevention system such as wheel chocks, carry out inspection and pressure/leak tests to prevent transfer system leaks and bursts, but have no pullaway mitigation.
Average facilities	4.00E-06	4.00E-07	6.00E-06	1.04E-05	Two pullaway prevention systems (one of which should be wheel chocks) as well as inspection and pressure/leak tests to prevent transfer system leaks and bursts but no effective pullaway mitigation.

Table 8: Failure Rate Data for Flanges and Gaskets (Ref: HSE (2012), Item FR 1.2.4)

			Equivalent Hole Diameter for Pipe Diameter (1/8" or 3.2 mm thick gasket)				
Type of event	Frequency (per year per joint)	Notes	25 mm	50 mm	100 mm	150 mm	600 mm
Failure of Spiral Wound Gasket	1.00E-07	Hole size calculated as gasket thickness multiplied by pipe circumference.	17.9	25.3	35.8	43.8	87.6

Table 9: Failure Rate Data for Pipework (Ref: HSE (2012), Item FR 1.3)

	Frequency (per m per y) for pipework diameter (mm)	
Hole size	0 - 49	50 - 149
3 mm diameter	1.00E-05	2.00E-06
4 mm diameter	-	-
25 mm diameter	5.00E-06	1.00E-06
1/3 pipework diameter	-	-
Guillotine	1.00E-06	5.00E-07

Table 10: Failure Rate Data for Flexible hoses in Process (Ref: HSE (2012), Item FR 1.2.3)

Hole size	Frequency per operation
Hose diameter (spray release)	1.20E-07

Table 11: Failure Rate Data for Instrument Connections (Ref: OGP (2010), Report No. 434 – 1)

Hole size	Frequency (per instrument year)
1 to 3 mm diameter	3.50E-04
3 to 10 mm diameter	1.50E-04
10 to 50 mm diameter	6.50E-05

Table 12: Failure Rate Data for Tankers (Ref: HSE (2012), Item FR 3.2.1)

Type of event	Frequency (per vessel year)	Notes
Catastrophic failure	3.00E-06	With a pressure relief system
50 mm diameter hole	3.00E-05	This includes releases due to the valve being left open by the operator.
25 mm diameter hole	3.00E-05	
13 mm diameter hole	6.00E-05	
4 mm diameter hole	3.00E-04	

Table 13: Failure Rate Data for Gas Cylinders (Ref: OGP (2010), Report No. 434 – 3)

Type of event	Frequency (per cylinder year)
Catastrophic failure	1.00E-07
5 mm diameter hole	4.60E-07
2 mm diameter hole	4.40E-07

Table 14: Failure Rate Data for Pumps (Ref: HSE (2012), Item FR 1.2.2)

Type of event	Frequency (per year per pump)	Notes
Pump single seal	5.00E-04	Shaft circumference
Pump double seal	5.00E-05	Shaft circumference
Failure of casing	3.00E-05	Largest connection

E.2 Operations Data

The following operations data was used to estimate the leak frequencies for each representative hazardous incident (Refer to Section D.4). This data is generally one of two types:

(i) Frequency data (e.g. frequency of tanker deliveries) – This data is generally included in the ‘No. of Equipment Items, Operations or Pipe Length (m)’ column of Table 14 (Refer to Section D.4); or,

(ii) Probability data – This data was used to factor the leak frequency data (e.g. proportion of time that an area is utilised or the probability that a leak from a tank shell occurs above or below the liquid level in the tank). This data is generally included in the ‘Factor’ column of Table 15 (Refer to Section D.4), and may be combined with the utilisation factor for the relevant isolatable section (Refer to Appendix C).

Table 15: Operations Data

Description	Value	Note/s
Hours of operation (per year)	6600	5.5 days/wk, 24 hours/ day, less public holidays
Frequency of LPG B-double tanker unloading (per year)	260	5 per week
Duration of B-double LPG tanker unloading operation (hours)	2.0	Compressor used
Frequency of LPG tanker ("Bobtail" or rigid tanker) loading (per year)	780	3 per day, 5 days/week
Duration of each LPG tanker ("Bobtail" or rigid tanker) loading operation (hours)	0.5	Pump used
Use of Tanks 1, 2 and 3 (proportion of time)	1.0	100% of the time
Use of Cylinder Filling System (proportion of time)	0.57	200,000 cylinders @1.5min/fill on average
Number of full LPG cylinders at storage area	See Table 1 of main report	Maximum
LPG cylinders present at storage area (proportion of time)	1.0	100% of the time
Probability of liquid leak (i.e. failure below liquid level) from Tanks	0.75	Tanks assumed 75% full

Description	Value	Note/s
Probability of vapour leak (i.e. failure above liquid level) from Tanks	0.25	25% vapour space
Probability of liquid leak (i.e. failure below liquid level) from LPG tanker	0.85	
Probability of vapour leak (i.e. failure above liquid level) from LPG tanker	0.15	
Fraction of time of overnight and Sundays Bobtail Parking	0.49	10 hours x 5 days/ week + Sunday
Fraction of time of overnight and Sundays Flat Top Truck Parking	0.49	10 hours x 5 days/ week + Sunday
Fraction of the time cylinder recovery is online	0.05	

E.3 Excess Flow Valves

Excess flow valves (EFVs) are installed at the facility in locations listed in the following table. It is assumed that the EFV would close for full bore failures and 25mm failures in a 50mm pipe.

Table 16: Excess Flow Valves

No	Location
1	Tank liquid inlet line
2	Tank liquid outlet line
3	Road tanker liquid line
4	Road tanker vapour line
5	Filling point – plant side of hose
6	Cylinder filling – manifold to hose connection line (both fill points)*

*No credit given for this as the EFV has no set inspection/ service schedule

The probability of failure on demand (PFD) for an XFV is 0.13 if tested every 10 years (Ref. HSE (2012), Item FR 1.2.1).

If the release rate exceeds the XFV closing flow rate setting, then the leak frequency was reduced by a factor of 0.13 (Refer to Section D.1).

E.4 Event Trees

This section presents the event tree data that has been used in the development of the event trees for the depot.

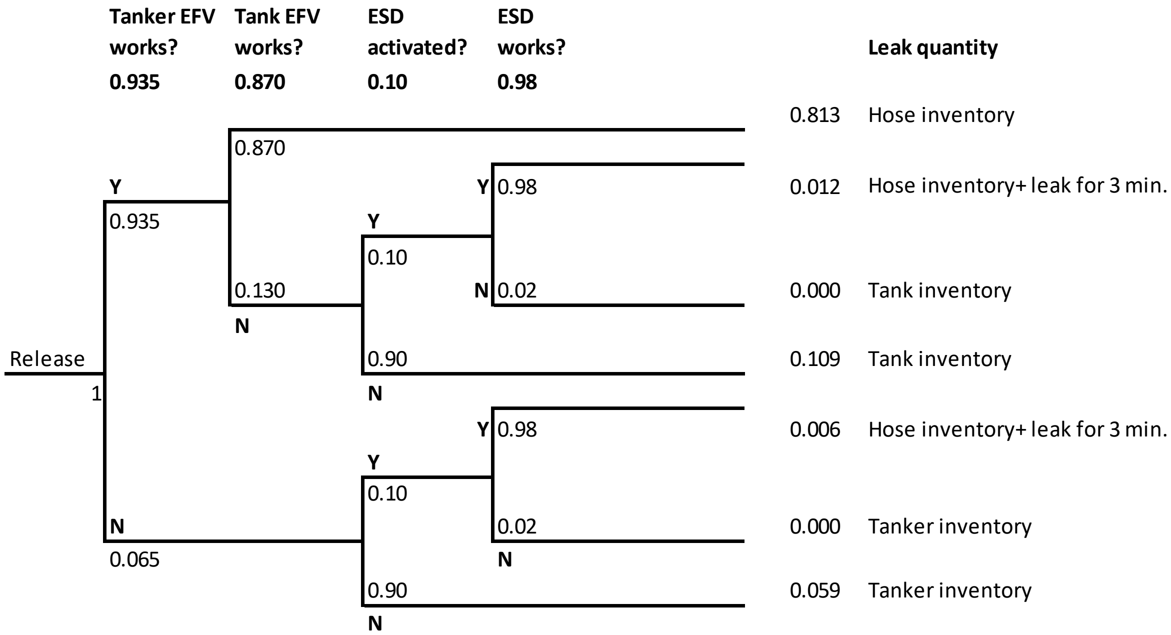
Event Tree Data

General event tree data is presented in Table 17. The general assumptions made for these event trees are listed in Appendix A. While Table 17 contains specific notes that are referred to in the event tree tables notes sections.

Table 17: Event Tree Data

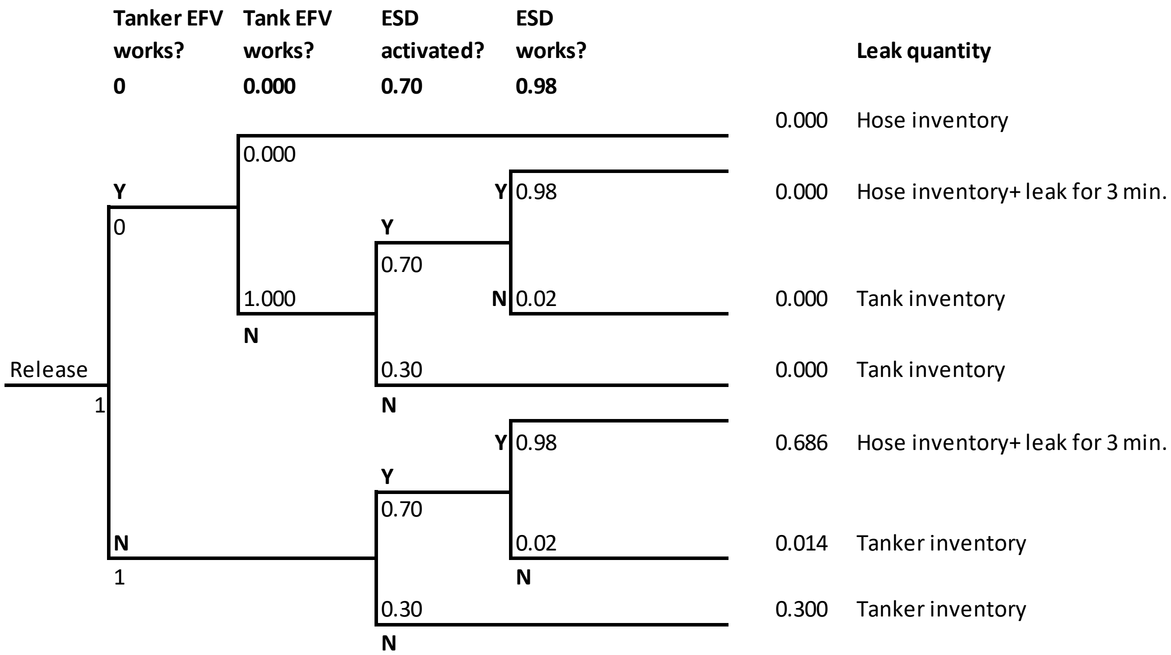
Parameter	Value
Excess flow valve failure on tank (serviced once in 10 years during tank internal inspection)	0.13
Excess flow valve failure on supply tanker and Botail (serviced once in 5 years during statutory inspection)	0.065
Probability of activating ESD by driver during a large leak	0.1
Probability of activating ESD by driver during a small leak (<10mm)	0.7
Probability of ESD valve failing to close on demand	0.02
Large liquid release	Full bore release
Smaller liquid release	Less than full bore release (Excess flow valve would not operate)

The event trees are presented below:



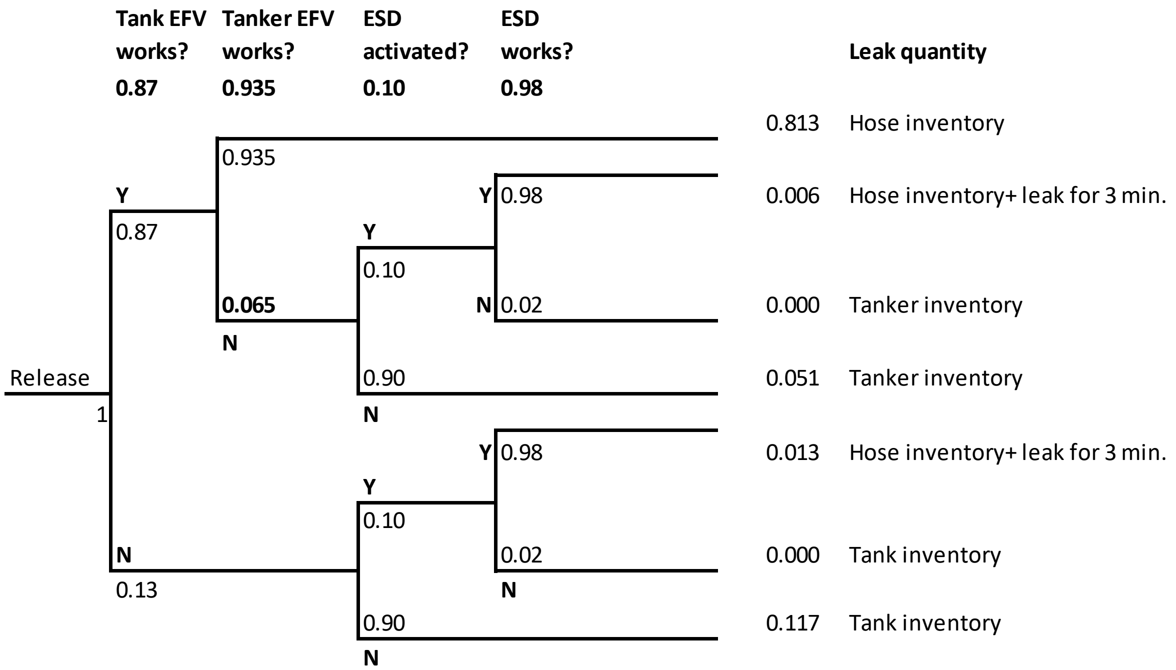
Release	Probabilities
Short duration leak (3 mir	0.832
Tanker inventory	0.059
Tank inventory	0.110

Figure 1: Event Tree for Full Bore Release during Tanker Unloading



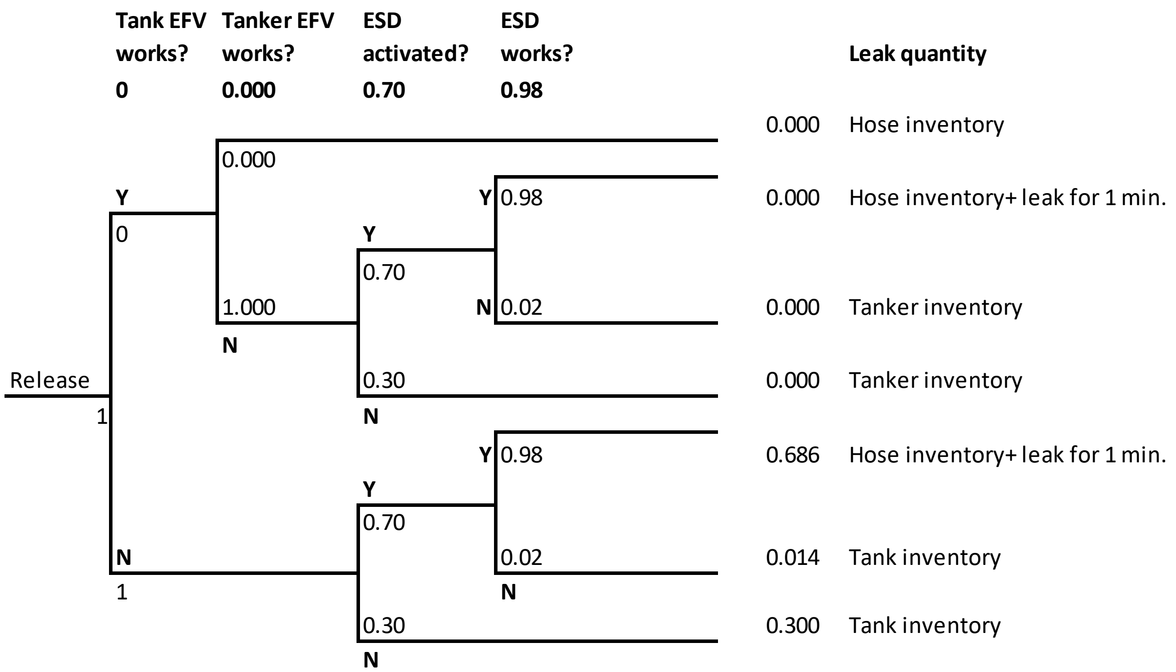
Release	Probabilities
Smaller leak	0.686
Tanker inventory	0.314
Tank inventory	0.000

Figure 2: Event Tree for Smaller Release during Tanker Unloading



Release	Probabilities
Smaller leak	0.832
Tank inventory	0.117
Tanker inventory	0.051

Figure 3: Event Tree for Full Bore Release during Bobtail Tanker Loading



Smaller leak	0.686
Tank inventory	0.314
Tanker inventory	0.000

Figure 4: Event Tree for Smaller Release during Bobtail Tanker Loading

The probabilities are multiplied by the hose/ fittings failure frequency to obtain release frequencies for the various hole size leaks.

E.5 Leak Frequencies

ESD isolation successful

Leak frequencies are calculated and summarised in Table 15 for the case where the ESD operates. Where excess flow valve is provided, the failure of EFV resulting in continuous flow until the ESD operates is taken into account. The result would be the frequency for the case of limited inventory release at the initial release frequency.

The generic component failure frequency is multiplied the number of components (or length of pipework where frequency is given per metre length), and the utilisation factor ("Factor").

The last column of Table 18 provides the frequency for inventory limited releases, due to successful isolation.

Table 18: Leak Frequencies

Item Description	Isolatable Section No.	Failure Case ID	No. of Equipment Items or Pipe Length (m)	Leak Frequency - Leak Isolated by EFV or ESD (per year)	Probability of Isolation failure (Where applicable)	Leak frequency - NOT isolated by EFV or ESD (per year)
Tank (Liquid side)	1	1-T1-L-RUP	1	1.50E-06	1.000	1.50E-06
		1-T1-L-50mm	1	3.75E-06	1.000	3.75E-06
		1-T1-L-25mm	1	3.75E-06	1.000	3.75E-06
		1-T1-L-13mm	1	7.50E-06	1.000	7.50E-06
Tank (Vapour side)	2	2-T1-V--RUP	1	0.00E+00	1.000	5.00E-07
		2-T1-V-50mm	1	0.00E+00	1.000	1.25E-06
		2-T1-V-25mm	1	0.00E+00	1.000	1.25E-06
		2-T1-V-13mm	1	0.00E+00	1.000	2.50E-06
Recovery Manifold (Liquid side)	3	3-T2-L-50mm	1	0.00E+00	1.000	7.50E-08
		3-T2-L-25mm	1	0.00E+00	1.000	1.50E-07
Recovery Manifold (Vapour side)	4	4-T2-V-50mm	1	0.00E+00	1.000	1.43E-06
		4-T2-V-25mm	1	0.00E+00	1.000	2.85E-06
Liquid pipework (50mm) between Tanker and Tank including hose (50mm)	5	5-LI-L-50mm	10m	8.31E-07	0.168	1.68E-07
		5-LI-L-25mm	10m	4.16E-06	0.168	8.39E-07
		5-LI-L-3mm	15	1.32E-07	0.118	1.77E-08
		5-LI-L-9mm	7	1.23E-04	0.118	1.65E-05
		5-LI-L-50mm-Hose	1	2.16E-04	0.168	4.37E-05

Item Description	Isolatable Section No.	Failure Case ID	No. of Equipment Items or Pipe Length (m)	Leak Frequency - Leak Isolated by EFV or ESD (per year)	Probability of Isolation failure (Where applicable)	Leak frequency - NOT isolated by EFV or ESD (per year)
Vapour pipework (32 mm) at Tanker Unloading Area including hose (32 mm)	6	6-LI-V-32mm	10	2.80E-06	0.168	2.68E-08
		6-LI-V-25mm	10	1.31E-05	0.168	1.03E-06
		6-LI-V-9mm	4	1.05E-05	0.168	8.24E-07
		6-LI-V-32mm-Hose	2472	2.16E-04	0.168	4.37E-05
Supply Tanker (Liquid Side) at Tanker Unloading Area	7	7-Tanker-L-RUP	1	0.00E+00	1.000	4.80E-07
		7-Tanker-L-50mm	1	0.00E+00	1.000	1.20E-06
		7-Tanker-L-25mm	1	0.00E+00	1.000	1.20E-06
		7-Tanker-L-13mm	1	0.00E+00	1.000	2.40E-06
Supply Tanker (Vapour Side) at Tanker Unloading Area	8	8-Tanker-V-RUP	1	0.00E+00	1.000	1.70E-06
		8-Tanker-V-50mm	1	0.00E+00	1.000	4.25E-06
		8-Tanker-V-25mm	1	0.00E+00	1.000	4.25E-06
		8-Tanker-V-13mm	1	0.00E+00	1.000	8.50E-06
"Bobtail" Tanker (Liquid Side) at Tanker Loading Area	9	9-Tanker-L-RUP	1	0.00E+00	1.000	7.28E-08
		9-Tanker-L-50mm	1	0.00E+00	1.000	1.82E-07
		9-Tanker-L-25mm	1	0.00E+00	1.000	1.82E-07
		9-Tanker-L-13mm	1	0.00E+00	1.000	3.64E-07
"Bobtail" Tanker (Vapour Side) at Tanker Loading Area	10	10-Tanker-V-RUP	1	0.00E+00	1.000	1.28E-08
		10-Tanker-V-50mm	1	0.00E+00	1.000	3.21E-08
		10-Tanker-V-25mm	1	0.00E+00	1.000	3.21E-08
		10-Tanker-V-13mm	1	0.00E+00	1.000	6.42E-08
LPG pump liquid pipework (50 mm) for cylinder filling reticulation	11	11-LI-L-50mm	50m	1.25E-05	0.168	2.52E-06
		11-LI-L-25mm	50m	6.24E-05	0.168	1.26E-05
		11-LI-L-3mm	14	3.70E-07	0.168	4.96E-08
		11-P-L-50mm	1	2.50E-05	0.168	5.04E-06
		11-P-9mm	8	8.11E-04	0.118	1.09E-04

Item Description	Isolatable Section No.	Failure Case ID	No. of Equipment Items or Pipe Length (m)	Leak Frequency - Leak Isolated by EFV or ESD (per year)	Probability of Isolation failure (Where applicable)	Leak frequency - NOT isolated by EFV or ESD (per year)
Liquid pipework (32mm) to cylinder weigh scale, including hose (20 mm)	12	12-LI-L-32mm	2	1.25E-06	0.168	2.52E-07
		12-LI-L-3mm	2	5.29E-08	0.118	7.08E-09
		12-LI-L-9mm	2	1.06E-04	0.118	1.42E-05
		12-LI-L-20mm-Hose	2	2.01E-05	0.118	2.69E-06
Liquid pipework (25 mm) - Recovery to Storage	13	13-LI-L-25mm	20	0.00E+00	1.000	2.00E-06
		17-LI-L-3mm	14	0.00E+00	1.000	2.00E-07
		17-LI-L-9mm	7	0.00E+00	1.000	5.80E-04
LPG cylinders at storage area A (8.5 kg)	14	L14-CYL-RUPTURE	1787*	0.00E+00	1.000	1.79E-04
		L14-CYL-5mm-L	1787*	0.00E+00	1.000	8.22E-04
		L14-CYL-2mm-L	1787*	0.00E+00	1.000	7.86E-04
LPG cylinders at storage area B (45 kg)	15	L15-CYL-RUPTURE	56	0.00E+00	1.000	5.60E-06
		L15-CYL-5mm-L	56	0.00E+00	1.000	2.58E-05
		L15-CYL-2mm-L	56	0.00E+00	1.000	2.46E-05
LPG cylinders at storage area B (210 kg)	16	L16-CYL-RUPTURE	10	0.00E+00	1.000	1.20E-06
		L16-CYL-5mm-L	10	0.00E+00	1.000	5.52E-06
		L16-CYL-2mm-L	10	0.00E+00	1.000	5.28E-06
Liquid release Overnight parking of laden Bobtail (per tanker)	17	17-Tanker-L-RUP	1**	0.00E+00	1.000	9.92E-07
		17-Tanker-L-50mm	1**	0.00E+00	1.000	2.48E-06
		17-Tanker-L-25mm	1**	0.00E+00	1.000	2.48E-06
		17-Tanker-L-13mm	1**	0.00E+00	1.000	4.96E-06
Overnight parking of laden Bobtail - Vapour release	18	18-Tanker-V-RUP	1**	0.00E+00	1.000	3.50E-07
		18-Tanker-V-50mm	1**	0.00E+00	1.000	8.75E-07
		18-Tanker-V-25mm	1**	0.00E+00	1.000	8.75E-07
		18-Tanker-V-13mm	1**	0.00E+00	1.000	1.75E-06

*Number of cylinders represents per row per level. There are two rows, two levels each.

**There are two Bobtails parked overnight. Frequencies are shown for one tanker.

E.6 BLEVE Frequencies

Table 19: BLEVE Frequencies

Item Description	Isolatable Section No.	Max. Inventory [kg]	Total BLEVE Frequency (per year)	Notes
Storage Tank	1	50,000	0	BLEVE frequency = 0 / yr for (tank fendolite protected)
Supply tanker at unloading area	7	12,000	1.77E-06	50% of total fire frequency for this location (Excluding rupture of tank and isolated releases with leak duration < 5 minutes). Frequency adjusted for total proportion of time that tanker is on site (5.7%). Releases from 1,2,5,6,7,8,11,13
Bobtail at loading area	9	7200	2.43E-06	50% of total fire frequency for this location (Excluding rupture of tank and isolated releases with leak duration < 5 minutes). Frequency adjusted for total proportion of time that a Bobtail is loaded (4.3%). Releases from 1,2,5,6,9,11,13
Parked Bobtail tanker (per tanker)	17	7200	2.61E-07	50% of total fire frequency for this location from adjacent parked Bobtail (Excluding rupture of tanker). Frequency adjusted for total proportion of time that a Bobtail is parked (58.3%). Releases from 16,17

Appendix F Consequence Analysis

F.1 Release Rate

Table 20 summarises the release rates for the various release scenarios. Where the calculated initial release exceeds the process flow rate, the release rate was restricted to the process flow rate.

Table 20: Release Rates

Item Description	Isolatable Section	Failure Case ID No.	Phase (Liquid / Vapour)	Release Rate [kg/sec]
Tank (Liquid side)	1	1-T1-L-RUP	L	RUPTURE
		1-T1-L-50mm		33.5
		1-T1-L-25mm		8.34
		1-T1-L-13mm		2.25
Tank (Vapour side)	2	2-T1-V--RUP	V	RUPTURE
		2-T1-V-50mm		4.1
		2-T1-V-25mm		1.03
		2-T1-V-13mm		0.28
Recovery Manifold (Liquid side)	3	3-T2-L-50mm	L	8
		3-T2-L-25mm		8
Recovery Manifold (Vapour side)	4	4-T2-V-50mm	V	1
		4-T2-V-25mm		1
Liquid pipework (50 mm) between Road Tanker and Tanks including hose	5	5-LI-L-50mm	L	33.5
		5-LI-L-25mm		8.34
		5-LI-L-3mm		0.1
		5-LI-L-9mm		1.13
		5-LI-L-50mm-Hose		33.5
Vapour pipework (50 mm) at Tanker Unloading Area including hose	6	6-LI-V-50mm	V	4.1
		6-LI-V-25mm		1.03
		6-LI-V-9mm		0.13
		6-LI-V-50mm-Hose		4.1
Supply Tanker (Liquid Side) at Tanker Unloading Area	7	7-Tanker-L-RUP	L	RUPTURE
		7-Tanker-L-50mm		40.75
		7-Tanker-L-25mm		10.19

Item Description	Isolatable Section	Failure Case ID No.	Phase (Liquid / Vapour)	Release Rate [kg/sec]
		7-Tanker-L-13mm		2.76
Supply Tanker (Vapour Side) at Tanker Unloading Area	8	8-Tanker-V-RUP	V	RUPTURE
		8-Tanker-V-50mm		4.08
		8-Tanker-V-25mm		1.02
		8-Tanker-V-13mm		0.28
"Bobtail" Tanker (Liquid Side) at Tanker Loading Area	9	9-Tanker-L-RUP	L	RUPTURE
		9-Tanker-L-50mm		40.75
		9-Tanker-L-25mm		10.19
		9-Tanker-L-13mm		2.76
"Bobtail" Tanker (Vapour Side) at Tanker Loading Area	10	10-Tanker-V-RUP	V	RUPTURE
		10-Tanker-V-50mm		4.08
		10-Tanker-V-25mm		1.02
		10-Tanker-V-13mm		0.28
LPG pump & liquid pipework (50 mm) for cylinder filling reticulation	11	11-LI-L-50mm	L	1.13
		11-LI-L-25mm		1.13
		11-LI-L-3mm		0.12
		11-LI-L-9mm		1.08
		11-P-L-50mm		44.5
Liquid pipework (32mm) to cylinder weigh scale, including hose (20 mm)	12	12-LI-L-32mm	L	1.13
		12-LI-L-3mm		0.7
		12-LI-L-9mm		0.7
		12-LI-L-20mm-Hose		0.7
Liquid pipework (25 mm) for Product Recovery to storage tank	13	13-LI-L-25mm	L	0.7
		13-LI-L-3mm		RUPTURE
		13-LI-L-9mm		0.7

Item Description	Isolatable Section	Failure Case ID No.	Phase (Liquid / Vapour)	Release Rate [kg/sec]
LPG cylinders at storage area	14-16	L14-CYL-RUPTURE	L	10.19
		L14-CYL-5mm-L		2.76
		L14-CYL-2mm-L		RUPTURE
Liquid release Overnight parking of laden Bobtail	17	17-Tanker-L-RUP	L	4.08
		17-Tanker-L-50mm		1.02
		17-Tanker-L-25mm		0.28
		17-Tanker-L-13mm		RUPTURE
Overnight parking of laden Bobtail - Vapour release	18	18-Tanker-V-RUP	V	40.75
		18-Tanker-V-50mm		10.19
		18-Tanker-V-25mm		2.76
		18-Tanker-V-13mm		RUPTURE

F.2 Jet Fire

Table 21: Jet Fire Consequences

Inventory No.	Item Description	Failure Case ID No.	Hole Size Range [mm]	Release Rate (kg/s)	Flame length (m)	Downwind Distance (m) to Heat Radiation (kW/m^2) @ Ground Level		
						4.7	12.5	23
1	Tank (Liquid Side)	1-TA-L-50mm	50	31.4	51	74	47	39
		1-TA-L-25mm	25	7.8	28	38	24	20
		1-TA-L-13mm	13	2.1	16	21	13	11
2	Tank (Vapour Side)	2-TA-V-50mm	50	4.1	19	37	29	26
		2-TA-V-25mm	25	1.1	10	19	15	13
		2-TA-V-13mm	13	0.3	6	10	7	5

Inventory No.	Item Description	Failure Case ID No.	Hole Size Range [mm]	Release Rate (kg/s)	Flame length (m)	Downwind Distance (m) to Heat Radiation (kW/m^2) @ Ground Level		
						4.7	12.5	23
3	Recovery Manifold (Liquid Side)	3-TB-L-50mm	50	8	28	38	24	20
		3-TB-L-25mm	25	8	28	38	24	20
5	Liquid pipework (50 mm) between Road Tanker and Tank including hose	5-LI-L-50mm	50	31.4	51	74	47	39
		5-LI-L-25mm	25	7.8	28	38	24	20
		5-LI-L-9mm	9	1.1	12	23	19	17
		5-LI-L-50mm-Hose	50	4.1	19	37	29	26
6	Vapour pipework (50 mm) at Tanker Unloading Area including hose	6-LI-V-50mm	50	4.1	19	37	29	26
		6-LI-V-25mm	25	1.1	10	19	15	13
		6-LI-V-9mm	9	0.3	6	10	7	5
		6-LI-V-50mm-Hose	50	4.1	19	37	29	26
7	Supply Tanker (Liquid Side) at Tanker Unloading Area	7-Tanker-L-50mm	50	31.4	51	74	47	39
		7-Tanker-L-25mm	25	7.8	28	38	24	20
		7-Tanker-L-13mm	13	2.1	16	21	13	11
8	Supply Tanker (Vapour Side) at Tanker Unloading Area	8-Tanker-V-50mm	50	4.1	19	37	29	26
		8-Tanker-V-25mm	25	1.1	10	19	15	13
		8-Tanker-V-13mm	13	0.3	6	10	7	5
9	"Bobtail" Tanker (Liquid Side) at Tanker Loading Area	9-Tanker-L-50mm	50	31.4	51	74	47	39
		9-Tanker-L-25mm	25	7.8	28	38	24	20
		9-Tanker-L-13mm	13	2.1	16	21	13	11

Inventory No.	Item Description	Failure Case ID No.	Hole Size Range [mm]	Release Rate (kg/s)	Flame length (m)	Downwind Distance (m) to Heat Radiation (kW/m^2) @ Ground Level		
						4.7	12.5	23
10	"Bobtail" Tanker (Vapour Side) at Tanker Loading Area	10-Tanker-V-50mm	50	4.1	19	37	29	26
		10-Tanker-V-25mm	25	1.1	10	19	15	13
		10-Tanker-V-13mm	13	0.3	6	10	7	5
11	LPG pump liquid pipework (50 mm) for cylinder filling	11-LI-L-50mm	50	1.8	15	30	24	21
		11-LI-L-25mm	25	1.8	15	30	24	21
		11-LI-L-9mm	9	1.8	15	30	24	21
		11-P-L-9mm	9	1.8	15	30	24	21
12	Liquid pipework to Electronic scale, including hose (20 mm)	12-LI-L-9mm	9	1.8	15	30	24	21
		12-LI-L-20mm-Hose	20	1.8	15	30	24	21
13	Liquid pipework (25 mm) for Product Recovery to storage	13-LI-L-25mm	25	1.8	15	30	24	21
		13-LI-L-9mm	9	1.8	15	30	24	21
14	LPG cylinders at storage area A (8.5 kg)	L14-CYL-5mm-L	5	0.3	7	12	6	N.R.
15	LPG cylinders at storage area B (45 kg)	L15-CYL-5mm-L	5	0.3	7	12	6	N.R.
16	LPG cylinders at storage area B (210 kg)	L16-CYL-5mm-L	5	0.3	7	12	6	N.R.
17	Bobtail parked overnight (liquid)	17-Tanker-L-50mm	50	31.4	51	74	47	39
		17-Tanker-L-25mm	25	7.8	28	38	24	20

Inventory No.	Item Description	Failure Case ID No.	Hole Size Range [mm]	Release Rate (kg/s)	Flame length (m)	Downwind Distance (m) to Heat Radiation (kW/m²) @ Ground Level		
						4.7	12.5	23
		17-Tanker-L-13mm	13	2.1	16	21	13	11
18	Bobtail parked overnight (vapour)	18-Tanker-V-50mm	50	4.1	19	37	29	26
		18-Tanker-V-25mm	25	1.1	10	19	15	13
		18-Tanker-V-13mm	13	0.3	6	10	7	5

F.3 Pool Fire

Table 22: Pool Fire Consequences

Inventory No.	Item Description	Failure Case ID No.	Hole Size Range [mm]	Pool Diameter (m)	Flame length (m)	Downwind Distance (m) to Heat Radiation (kW/m²) @ Ground Level		
						4.7	12.5	23
1	Tank (Liquid Side)	1-TA-L-50mm	50	15.7	35	77	53	41
		1-TA-L-25mm	25	9.1	21	44	30	23
		1-TA-L-13mm	13	4.1	13	23	16	12
5	Liquid pipework (50 mm) between Road Tanker and Tank including hose	5-LI-L-50mm	50	15.7	35	77	53	41
		5-LI-L-25mm	25	9.1	21	44	30	23
		5-LI-L-50mm-Hose	50	9.1	21	44	30	23
7	Supply Tanker (Liquid Side) at Tanker Unloading Area	7-Tanker-L-50mm	50	15.7	35	77	53	41
		7-Tanker-L-25mm	25	9.1	21	44	30	23
		7-Tanker-L-13mm	13	4.1	13	23	16	12

Inventory No.	Item Description	Failure Case ID No.	Hole Size Range [mm]	Pool Diameter (m)	Flame length (m)	Downwind Distance (m) to Heat Radiation (kW/m²) @ Ground Level		
						4.7	12.5	23
9	"Bobtail" Tanker (Liquid Side) at Tanker Loading Area	9-Tanker-L-50mm	50	15.7	35	77	53	41
		9-Tanker-L-25mm	25	9.1	21	44	30	23
		9-Tanker-L-13mm	13	4.1	13	23	16	12
17	Bobtail parked overnight (liquid)	17-Tanker-L-50mm	50	15.7	35	77	53	41
		17-Tanker-L-25mm	25	9.1	21	44	30	23
		17-Tanker-L-13mm	13	4.1	13	23	16	12

F.4 Flash Fire

Table 23: Flash Fire Consequences

Inv. No.	Description	Failure Case ID No.	Release Rate [kg/s]	Wind Stability - Speed: B – 1.86		Wind Stability - Speed: D(L) -1.0		Wind Stability - Speed: D(M) – 4.0		Wind Stability - Speed: D(H) - 8.13		Wind Stability - Speed: E - 3.1		Wind Stability - Speed: F – 1.0	
				Max. Down-wind Distance to LFL (m)	Max. Plume Width to LFL (m)	Max. Down-wind Distance to LFL (m)	Max. Plume Width to LFL (m)	Max. Down-wind Distance to LFL (m)	Max. Plume Width to LFL (m)	Max. Down-wind Distance to LFL (m)	Max. Plume Width to LFL (m)	Max. Down-wind Distance to LFL (m)	Max. Plume Width to LFL (m)	Max. Down-wind Distance to LFL (m)	Max. Plume Width to LFL (m)
1	Tank (Liquid Side)	1-TA-L-50mm	50	128	166	199	260	102	134	91	128	105	124	190	226
		1-TA-L-25mm	25	70	126	101	128	57	70	52	68	57	62	95	116
		1-TA-L-13mm	13	38	52	54	68	33	40	30	40	32	44	48	144
2	Tank (Vapour Side)	2-TA-V-50mm	50	15	1.4	17	1.4	14	1.4	12	1.4	15	1.4	17	1.5
		2-TA-V-25mm	25	8	0.7	9	0.7	7	0.7	7	0.6	8	0.7	9	0.7
		2-TA-V-13mm	13	4	0.4	5	0.4	4	0.4	4	0.3	4	0.4	5	0.4
3	Recovery Manifold (Liquid Side)	3-TB-L-50mm	70	126	101	128	57	70	52	68	57	62	95	116	70
		3-TB-L-25mm	25	70	126	101	128	57	70	52	68	57	62	95	116
5	Liquid pipework (50 mm) between Road Tanker and Tank including hose	5-LI-L-50mm	50	128	166	199	260	102	134	91	128	105	124	190	226
		5-LI-L-25mm	25	70	126	101	128	57	70	52	68	57	62	95	116
		5-LI-L-9mm	9	38	52	54	68	33	40	30	40	32	44	48	144

Inv. No.	Description	Failure Case ID No.	Release Rate [kg/s]	Wind Stability - Speed: B – 1.86		Wind Stability - Speed: D(L) -1.0		Wind Stability - Speed: D(M) – 4.0		Wind Stability - Speed: D(H) - 8.13		Wind Stability - Speed: E - 3.1		Wind Stability - Speed: F – 1.0	
				Max. Down-wind Distance to LFL (m)	Max. Plume Width to LFL (m)	Max. Down-wind Distance to LFL (m)	Max. Plume Width to LFL (m)	Max. Down-wind Distance to LFL (m)	Max. Plume Width to LFL (m)	Max. Down-wind Distance to LFL (m)	Max. Plume Width to LFL (m)	Max. Down-wind Distance to LFL (m)	Max. Plume Width to LFL (m)	Max. Down-wind Distance to LFL (m)	Max. Plume Width to LFL (m)
		5-LI-L-50mm-Hose	50	128	166	199	260	102	134	91	128	105	124	190	226
6	Vapour pipework (50 mm) at Tanker Unloading Area including hose	6-LI-V-50mm	50	11	1.08	13	1.12	10	1.04	7	0.94	10	1.08	14	1.12
		6-LI-V-25mm	25	11	1.08	13	1.12	10	1.04	7	0.94	10	1.08	14	1.12
		6-LI-V-9mm	9	11	1.08	13	1.12	10	1.04	7	0.94	10	1.08	14	1.12
		6-LI-V-50mm-Hose	50	11	1.08	13	1.12	10	1.04	7	0.94	10	1.08	14	1.12
7	Supply Tanker (Liquid Side) at Tanker Unloading Area	7-Tanker-L-50mm	50	128	166	199	260	102	134	91	128	105	124	190	226
		7-Tanker-L-25mm	25	70	126	101	128	57	70	52	68	57	62	95	116
		7-Tanker-L-13mm	13	38	52	54	68	33	40	30	40	32	44	48	144
8	Supply Tanker (Vapour Side) at Tanker Unloading Area	8-Tanker-V-50mm	50	15	1.4	17	1.4	14	1.4	12	1.4	15	1.4	17	1.5
		8-Tanker-V-25mm	25	8	0.7	9	0.7	7	0.7	7	0.6	8	0.7	9	0.7
		8-Tanker-V-13mm	13	4	0.4	5	0.4	4	0.4	4	0.3	4	0.4	5	0.4

Inv. No.	Description	Failure Case ID No.	Release Rate [kg/s]	Wind Stability - Speed: B – 1.86		Wind Stability - Speed: D(L) -1.0		Wind Stability - Speed: D(M) – 4.0		Wind Stability - Speed: D(H) - 8.13		Wind Stability - Speed: E - 3.1		Wind Stability - Speed: F – 1.0	
				Max. Down-wind Distance to LFL (m)	Max. Plume Width to LFL (m)	Max. Down-wind Distance to LFL (m)	Max. Plume Width to LFL (m)	Max. Down-wind Distance to LFL (m)	Max. Plume Width to LFL (m)	Max. Down-wind Distance to LFL (m)	Max. Plume Width to LFL (m)	Max. Down-wind Distance to LFL (m)	Max. Plume Width to LFL (m)	Max. Down-wind Distance to LFL (m)	Max. Plume Width to LFL (m)
9	"Bobtail" Tanker (Liquid Side) at Tanker Loading Area	9-Tanker-L-50mm	50	128	166	199	260	102	134	91	128	105	124	190	226
		9-Tanker-L-25mm	25	70	126	101	128	57	70	52	68	57	62	95	116
		9-Tanker-L-13mm	13	38	52	54	68	33	40	30	40	32	44	48	144
10	"Bobtail" Tanker (Vapour Side) at Tanker Loading Area	10-Tanker-V-50mm	50	15	1.4	17	1.4	14	1.4	12	1.4	15	1.4	17	1.5
		10-Tanker-V-25mm	25	8	0.7	9	0.7	7	0.7	7	0.6	8	0.7	9	0.7
		10-Tanker-V-13mm	13	4	0.4	5	0.4	4	0.4	4	0.3	4	0.4	5	0.4
11	LPG pump liquid pipework (50 mm) for cylinder filling	11-LI-L-50mm	50	15	1.4	17	1.4	13	1.3	9	1.2	14	1.3	18	1.5
		11-LI-L-25mm	25	15	1.4	17	1.4	13	1.3	9	1.2	14	1.3	18	1.5
		11-LI-L-9mm	9	15	1.4	17	1.4	13	1.3	9	1.2	14	1.3	18	1.5
		11-P-L-9mm	9	15	1.4	17	1.4	13	1.3	9	1.2	14	1.3	18	1.5

Inv. No.	Description	Failure Case ID No.	Release Rate [kg/s]	Wind Stability - Speed: B – 1.86		Wind Stability - Speed: D(L) -1.0		Wind Stability - Speed: D(M) – 4.0		Wind Stability - Speed: D(H) - 8.13		Wind Stability - Speed: E - 3.1		Wind Stability - Speed: F – 1.0	
				Max. Down-wind Distance to LFL (m)	Max. Plume Width to LFL (m)	Max. Down-wind Distance to LFL (m)	Max. Plume Width to LFL (m)	Max. Down-wind Distance to LFL (m)	Max. Plume Width to LFL (m)	Max. Down-wind Distance to LFL (m)	Max. Plume Width to LFL (m)	Max. Down-wind Distance to LFL (m)	Max. Plume Width to LFL (m)	Max. Down-wind Distance to LFL (m)	Max. Plume Width to LFL (m)
12	Liquid pipework to Electronic scale, including hose (20 mm)	12-LI-L-9mm	9	15	1.4	17	1.4	13	1.3	9	1.2	14	1.3	18	1.5
		12-LI-L-20mm-Hose	20	15	1.4	17	1.4	13	1.3	9	1.2	14	1.3	18	1.5
13	Liquid pipework (25 mm) for Product Recovery to storage	13-LI-L-25mm	25	15	1.4	17	1.4	13	1.3	9	1.2	14	1.3	18	1.5
		13-LI-L-9mm	9	15	1.4	17	1.4	13	1.3	9	1.2	14	1.3	18	1.5
14	LPG cylinders at storage area A (8.5 kg)	L14-CYL-5mm-L	5	6	0.6	7	0.6	5	0.5	4	0.5	6	0.6	7	0.6
15	LPG cylinders at storage area B (45 kg)	L15-CYL-5mm-L	5	6	0.6	7	0.6	5	0.5	4	0.5	6	0.6	7	0.6

Inv. No.	Description	Failure Case ID No.	Release Rate [kg/s]	Wind Stability - Speed: B – 1.86		Wind Stability - Speed: D(L) -1.0		Wind Stability - Speed: D(M) – 4.0		Wind Stability - Speed: D(H) - 8.13		Wind Stability - Speed: E - 3.1		Wind Stability - Speed: F – 1.0	
				Max. Down-wind Distance to LFL (m)	Max. Plume Width to LFL (m)	Max. Down-wind Distance to LFL (m)	Max. Plume Width to LFL (m)	Max. Down-wind Distance to LFL (m)	Max. Plume Width to LFL (m)	Max. Down-wind Distance to LFL (m)	Max. Plume Width to LFL (m)	Max. Down-wind Distance to LFL (m)	Max. Plume Width to LFL (m)	Max. Down-wind Distance to LFL (m)	Max. Plume Width to LFL (m)
16	LPG cylinders at storage area B (210 kg)	L16-CYL-5mm-L	5	6	0.6	7	0.6	5	0.5	4	0.5	6	0.6	7	0.6
17	Bobtail parked overnight (liquid)	17-Tanker-L-50mm	50	128	166	199	260	102	134	91	128	105	124	190	226
		17-Tanker-L-25mm	25	70	126	101	128	57	70	52	68	57	62	95	116
		17-Tanker-L-13mm	13	38	52	54	68	33	40	30	40	32	44	48	144
18	Bobtail parked overnight (vapour)	18-Tanker-V-50mm	50	15	1.4	17	1.4	14	1.4	12	1.4	15	1.4	17	1.5
		18-Tanker-V-25mm	25	8	0.7	9	0.7	7	0.7	7	0.6	8	0.7	9	0.7
		18-Tanker-V-13mm	13	4	0.4	5	0.4	4	0.4	4	0.3	4	0.4	5	0.4

Note: Wind speeds for D -Low and F stabilities in the weather data are < 1m. These have seen set to 1m for dispersion calculations, as PhastRisk validation is restricted to a minimum wind speed of 1 m/s.

F.5 Vapour Cloud Explosion

Table 24: Vapour Cloud Explosion Consequences (1)

Inventory No.	Description	Failure Case ID No.	Release Rate [kg/s]	Distance to Overpressure (kPa)								
				7 kPa			14 kPa			21 kPa		
				F1	D1	D4.5	F1	D1	D4.5	F1	D1	D4.5
1,5,11, 21	Tank/ Tanker (Liquid Side) (T1, Road Tanker and Bobtail)	1,5,11,13,21-Tank-L-RUP	Rupture	532	497	262	402	389	190	N.R.	N.R.	N.R.
		1,5,11,13,21-Tank-L-50mm	33.5	279	241	141	191	175	103	N.R.	N.R.	N.R.
		1,5,11,13,21-Tank-L-25mm	8.34	109	98	54	74	71	39	N.R.	N.R.	N.R.
		1,5,11,13,21-Tank-L-13mm	2.25	76	70	42	52	51	31	N.R.	N.R.	N.R.
7,9	Liquid pipework (50 mm) between Road Tankers and T1 & hoses	7,9-LI-L-50mm	2.72	76	70	42	52	51	31	N.R.	N.R.	N.R.
		7,9-LI-L-25mm	2.72	76	70	42	52	51	31	N.R.	N.R.	N.R.
		7,9-LI-L-9mm	1.08	42	42	30	29	31	22	N.R.	N.R.	N.R.
		7-LI-L-50mm- Hose	2.72	76	70	42	52	51	31	N.R.	N.R.	N.R.
		9-LI-L-32mm- Hose	3.3	76	70	42	52	51	31	N.R.	N.R.	N.R.
15, 18	LPG pump liquid pipework (50 mm) for cylinder filling	15-LI-L-50mm	3.3	76	70	42	52	51	31	N.R.	N.R.	N.R.
		15-LI-L-25mm	3.3	76	70	42	52	51	31	N.R.	N.R.	N.R.
		15-LI-L-9mm	1.07	42	42	30	29	31	22	N.R.	N.R.	N.R.
16	Liquid pipework (32mm) to Electronic scale, including hose (20 mm)	16-LI-L-32mm	1.1	42	42	30	29	31	22	N.R.	N.R.	N.R.
		16-LI-L-9mm	1.07	42	42	30	29	31	22	N.R.	N.R.	N.R.
		16-LI-L-20mm- Hose	1.10	42	42	30	29	31	22	N.R.	N.R.	N.R.

Table 25: Vapour Cloud Explosion Consequences (2)

Inventory No.	Description	Failure Case ID No.	Release Rate [kg/s]	Distance to Overpressure (kPa)								
				7 kPa			14 kPa			21 kPa		
				D7.5	E2.6	B1.8	D7.5	E2.6	B1.8	D7.5	E2.6	B1.8
1,3,5,11,21	Tank/ Tanker (Liquid Side) (T1, Road Tanker and Bobtail)	1,5,11,13,21-Tank-L-RUP	Rupture	21	34	30	16	25	23	N.R.	N.R.	N.R.
		1,5,11,13,21-Tank-L-50mm	33.5	49	69	66	37	49	48	N.R.	N.R.	N.R.
		1,5,11,13,21-Tank-L-25mm	8.34	116	178	156	85	126	113	N.R.	N.R.	N.R.
		1,5,11,13,21-Tank-L-13mm	2.25	212	332	290	156	235	210	N.R.	N.R.	N.R.
7,9	Liquid pipework (50 mm) between Road Tankers and T1 & hoses	7,9-LI-L-50mm	2.72	35	51	48	26	37	35	N.R.	N.R.	N.R.
		7,9-LI-L-25mm	2.72	35	51	48	26	37	35	N.R.	N.R.	N.R.
		7,9-LI-L-9mm	1.08	21	34	30	16	25	23	N.R.	N.R.	N.R.
		7-LI-L-50mm- Hose	2.72	35	51	48	26	37	35	N.R.	N.R.	N.R.
		9-LI-L-32mm- Hose	3.3	21	34	30	16	25	23	N.R.	N.R.	N.R.
15, 18	LPG pump liquid pipework (50 mm) for cylinder filling	15-LI-L-50mm	3.3	21	34	30	16	25	23	N.R.	N.R.	N.R.
		15-LI-L-25mm	3.3	21	34	30	16	25	23	N.R.	N.R.	N.R.
		15-LI-L-9mm	1.07	21	34	30	16	25	23	N.R.	N.R.	N.R.
16	Liquid pipework (32mm) to Electronic scale, including hose (20 mm)	16-LI-L-32mm	1.1	21	34	30	16	25	23	N.R.	N.R.	N.R.
		16-LI-L-9mm	1.07	21	34	30	16	25	23	N.R.	N.R.	N.R.
		16-LI-L-20mm- Hose	1.10	21	34	30	16	25	23	N.R.	N.R.	N.R.

F.6 BLEVE/Fireball

Due to very low duration of the BLEVE and correspondingly lower exposure times (of the order of seconds), the thermal radiation intensity required to cause harm to exposed persons is higher than the values selected for on-going fires. Due to the varying duration of different fireball scenarios, injury from BLEVE fireballs has been determined using Thermal Dose Units (TDU), which are in units of $(kW/m^2)^{4/3}.s$. These values were calculated from the probit equation in Phast Risk and thermal dose (1) as listed in Table 24.

Table 26: Thermal radiation intensities for harm from BLEVE exposure

(1)	Thermal Dose Units	
	$(kW/m^2)^{4/3}.s$	$(W/m^2)^{4/3}.s$
Onset of 1st degree burns	105	1050000
Onset of 2nd degree burns	290	2900000
Onset of 3rd degree burns and Fatality	1000	10000000

Table 27 BLEVE/ Fireball Consequences

Inventory No.	Description	Fireball radius, m	Duration, s	Distance to TDU			Comment
				105	290	1000	
1	LPG Storage tank	Fendolite protected					
7	Supply road tanker	70.4	10.0	382	246	123	
9,17	Bobtail BLEVE	52.9	8.0	258	168	70	
14	8.5 kg cylinder rupture (S 'n' G)	5.6	1.3	N.R.	N.R.	N.R.	No injuries
15	45 kg cylinder rupture (2 cylinders)	14	2.75	36	15	N.R.	-
16	210 kg cylinder rupture (2 cylinders)	18.3	3.4	52	26	N.R.	-

Appendix G Probability of Ignition

The probability of ignition was based on the data reported by the OGP.

The OGP ignition probability curves represent "total" ignition probability. The method assumes that the immediate ignition probability is 0.001 and is independent of the release rate. As a result, all the curves start at a value of 0.001 relating to a release rate of 0.1 kg/s. The delayed ignition probabilities are obtained by subtracting 0.001 from the total ignition probability, e.g. an ignition probability value of 0.004 obtained from the look-up correlations can be considered as an immediate ignition probability of 0.001 and a delayed ignition probability of 0.003.

Ignition probabilities for LPG storage facilities in an industrial area are reported in Table 28.

Table 28: OGP Ignition Probabilities for LPG Storage in an Industrial Area (Scenario No. 15 of OGP)

Release Rate (kg/s)	Total Ignition Probability	Delayed Ignition Probability
0	0.0000	0.0000
0.1	0.0010	0.0000
0.2	0.0010	0.0000
0.5	0.0011	0.0001
1	0.0012	0.0002
2	0.0026	0.0016
5	0.0073	0.0063
10	0.0162	0.0152
20	0.0359	0.0349
50	0.1026	0.1016
100	0.2270	0.2260
200	0.3555	0.3545
500	0.6434	0.6424
1000	1.0000	0.9990

Ignition probabilities were interpolated from this data for release rates other than specified in Table 22. Delayed ignition probabilities for the vessel or cylinder rupture scenarios were based on a release of the entire inventory in one second.