Riskcon engineering

Preliminary Hazard Analysis

8 Johnston Crescent, Horsley Park

Jalco Australia Pty Limited
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Executive Summary

Background

Jalco Australia Pty Limited (Jalco) has proposed to develop a new warehouse to aggregate their operations from other sites into one site for operation and production efficiency gains. The site manufactures washing liquids which are non-Dangerous Goods (DG) products; however, the raw inputs are classified as DGs. A review of the quantity of goods to be stored indicates the site would exceed the limits listed in the State Environmental Planning Policy No. 33 (SEPP 33, Ref. [1]) which requires the risks associated with a facility storing DGs to be assessed in the form of a Preliminary Hazard Analysis (PHA) to determine whether there is the potential for offsite impacts.

Jalco has commissioned Riskcon Engineering Pty Ltd (Riskcon) to prepare a PHA for the facility. This document represents the PHA study for the warehouse at Horsley Park.

Conclusions

A hazard identification table was developed for warehouse facility to identify potential hazards that may be present at the site as a result of operations or storage of materials. Based on the identified hazards, scenarios were postulated that may result in an incident with a potential for offsite impacts. Postulated scenarios were discussed qualitatively and any scenarios that would not impact offsite were eliminated from further assessment. Scenarios not eliminated were then carried forward for consequence analysis.

Incidents carried forward for consequence analysis were assessed in detail to estimate the impact distances. Impact distances were developed into scenario contours and overlaid onto the site layout diagram to determine if an offsite impact would occur. The consequence analysis showed that several incidents involving the LPG tanks had the potential to impact offsite which were carried forward for frequency analysis and risk assessment.

The frequency analysis and risk assessment showed that the incidents carried forward would have a fatality risk of 0.0012 chances per million per year (pmpy) at the site boundary, with lesser risk at further distances from the boundary. HIPAP No. 4 (Ref. [2]) publishes acceptable risk criteria at the site boundary of 50 pmpy (for industrial sites). Therefore, the probability of a fatality at the site boundary is within the acceptable risk criteria.

In addition, incidents exceeding 23 kW/m^2 were reviewed which indicated that the contours from such incidents would not impact any structures and thus propagation incidents would be not expected to occur based upon the analysis.

Based on the analysis conducted, it is concluded that the risks at the site boundary are not considered to exceed the acceptable risk criteria; hence, the facility would only be classified as potentially hazardous and would be permitted within the current land zoning for the site.

Recommendations

Notwithstanding the conclusions drawn, the following recommendations have been made:

- The warehouse and/or site boundaries shall be capable of containing 702 m3 which may be contained within the warehouse footprint, site stormwater pipework and any recessed docks or other containment areas that may be present as part of the site design.
- The civil engineers designing the site containment shall demonstrate the design is capable of containing at least 702 m3.

- A storm water isolation point (i.e. penstock isolation valve) shall be incorporated into the design. The penstock shall automatically isolate the storm water system upon detection of a fire (smoke or sprinkler activation) to prevent potentially contaminated liquids from entering the water course.

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Abbreviations

Abbreviation	Description
ADG	Australian Dangerous Goods Code
AS	Australian Standard
CBD	Central Business District
CCPS	Centre for Chemical Process Safety
DA	Development Application
DAF	Dissolve Air Floatation
DGs	Dangerous Goods
DGS	Dangerous Goods Store
DPE	Department of Planning and Environment
FHA	Final Hazard Analysis
HIPAP	Hazardous Industry Planning Advisory Paper
HSE	Health and Safety Executive
PFD	Probability of Failure on Demand
PHA	Preliminary Hazard Analysis
Pmpy	Per million per year
SEP	Surface Emissive Power
SEPP	State Environmental Planning Policy

Abbreviation	Description
SMSS	Storage Mode Sprinkler System
SSC	Spread Sheet Calculator
VF	View Factor

1.0 Introduction

1.1 Background

Jalco Australia Pty Limited (Jalco) has proposed to develop a new warehouse to aggregate their operations from other sites into one site for operation and production efficiency gains. The site manufactures washing liquids which are non-Dangerous Goods (DG) products; however, the raw inputs are classified as DGs. A review of the quantity of goods to be stored indicates the site would exceed the limits listed in the State Environmental Planning Policy No. 33 (SEPP 33, Ref. [1]) which requires the risks associated with a facility storing DGs to be assessed in the form of a Preliminary Hazard Analysis (PHA) to determine whether there is the potential for offsite impacts.

Jalco has commissioned Riskcon Engineering Pty Ltd (Riskcon) to prepare a PHA for the facility. This document represents the PHA study for the warehouse at Horsley Park.

1.2 Objectives

The objectives of the PHA project, for the proposed Jalco facility at 327-335 Burley Road, NSW, include:

- Complete the PHA according to the Hazardous Industry Planning Advisory Paper (HIPAP) No. 6 – Hazard Analysis (Ref. [3]);
- Assess the PHA results using the criteria in HIPAP No. 4 – Risk Criteria for Land Use Planning (Ref. [2]); and
- Demonstrate compliance of the site with the relevant codes, standards and regulations (i.e., NSW Planning and Assessment Regulation 1979, WHS Regulation, 2017 Ref. [4]).

1.3 Scope of Services

The scope of work is to complete a PHA study for the Jalco Warehouse located at 8 Johnston Crescent, Horsley Park required by the Planning Regulations for the proposed development. The scope does not include any other assessments at the site nor any other Jalco facilities.

2.0 Methodology

2.1 Multi-Level Risk Assessment

The Multi-Level Risk Assessment approach (Ref. [5]) published by the NSW Department of Planning and Environment, has been used as the basis for the study to determine the level of risk assessment required. The approach considered the development in context of its location, the quantity and type (i.e. hazardous nature) Dangerous Goods stored and used, and the facility's technical and safety management control. The Multi-Level Risk Assessment Guidelines are intended to assist industry, consultants and the consent authorities to carry out and evaluate risk assessments at an appropriate level for the facility being studied.

There are three levels of risk assessment set out in Multi-Level Risk Assessment which may be appropriate for a PHA, as detailed in **Table 2-1**.

Table 2-1: Level of Assessment PHA

Level	Type of Analysis	Appropriate If:
1	Qualitative	No major off-site consequences and societal risk is negligible
2	Partially Quantitative	Off-site consequences but with low frequency of occurrence
3	Quantitative	Where 1 and 2 are exceeded

The Multi-Level Risk Assessment approach is schematically presented in **Figure 2-1**.

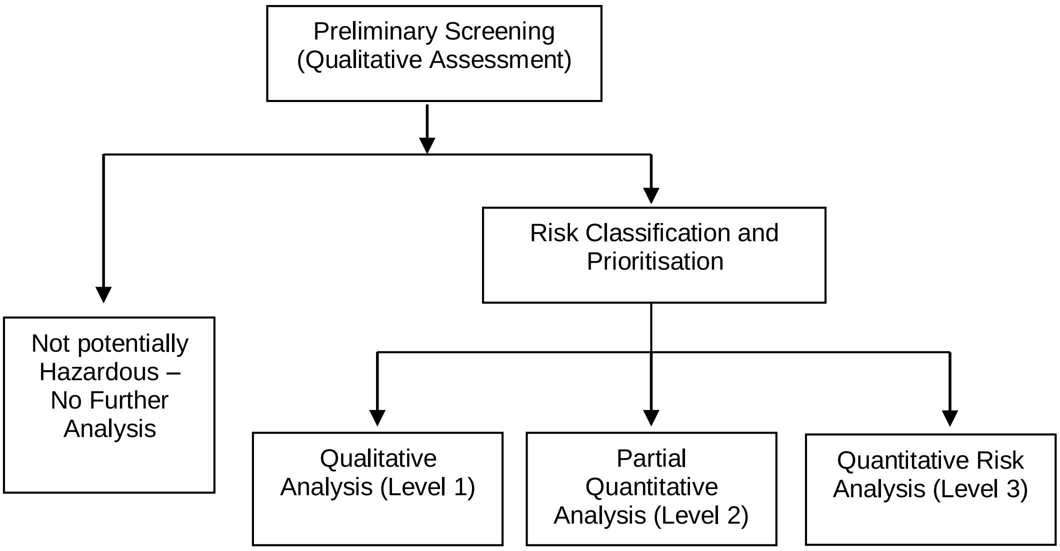

Figure 2-1: The Multi-Level Risk Assessment Approach

Based on the type of DGs to be used and handled at the proposed facility, a **Level 2 Assessment** was selected for the Site. This approach provides a qualitative assessment of those DGs of lesser quantities and hazard, and a quantitative approach for the more hazardous materials to be used on-site. This approach is commensurate with the methodologies recommended in "Applying SEPP 33's" Multi Level Risk Assessment approach (DPIE, 2011).

2.2 Risk Assessment Study Approach

The methodology used for the PHA is as follows;

Hazard Analysis – A detailed hazard identification was conducted for the site facilities and operations. Where an incident was identified to have a potential off-site impact, it was included in the recorded hazard identification word diagram (**Appendix A**). The hazard identification word diagram lists incident type, causes, consequences and safeguards. This was performed using the word diagram format recommended in HIPAP No. 6 (Ref. [3]).

Each postulated hazardous incident was assessed qualitatively in light of proposed safeguards (technical and management controls). Where a potential offsite impact was identified, the incident was carried into the main report for further analysis. Where the qualitative review in the main report determined that the safeguards were adequate to control the hazard, or that the consequence would obviously have no offsite impact, no further analysis was performed. **Section 3.1** of this report provides details of values used to assist in selecting incidents required to be carried forward for further analysis.

Consequence Analysis – For those incidents qualitatively identified in the hazard analysis to have a potential offsite impact, a detailed consequence analysis was conducted. The analysis modelled the various postulated hazardous incidents and determined impact distances from the incident source. The results were compared to the consequence criteria listed in HIPAP No. 4 (Ref. [2]). The criteria selected for screening incidents is discussed in **Section 3.1**.

Where an incident was identified to result in an offsite impact, it was carried forward for frequency analysis. Where an incident was identified to not have an offsite impact, and a simple solution was evident (i.e. move the proposed equipment further away from the boundary), the solution was recommended, and no further analysis was performed.

Frequency Analysis – In the event a simple solution for managing consequence impacts was not evident, each incident identified to have potential offsite impact was subjected to a frequency analysis. The analysis considered the initiating event and probability of failure of the safeguards (both hardware and software). The results of the frequency analysis were then carried forward to the risk assessment and reduction stage for combination with the consequence analysis results.

Risk Assessment and Reduction – Where incidents were identified to impact offsite and where a consequence and frequency analysis was conducted, the consequence and frequency analysis for each incident were combined to determine the risk and then compared to the risk criteria published in HIPAP No. 4 (Ref. [2]). Where the criteria were exceeded, a review of the major risk contributors was performed, and the risks reassessed incorporating the recommended risk reduction measures. Recommendations were then made regarding risk reduction measures.

Reporting – on completion of the study, a draft report was developed for review and comment by Jalco. A final report was then developed, incorporating the comments received by Jalco, for submission to the regulatory authority.

3.0 Site Description

3.1 Site Location

The Jalco warehouse is to be located at 8 Johnston Crescent, Horsley Park, approximately 36 km west of the Sydney Central Business District (CBD). **Figure 3-1** shows the regional location of the site in relation to the Sydney CBD. Provided in **Figure 3-2** is the proposed layout of the warehouse within the site, with the DG storage areas marked on the image.

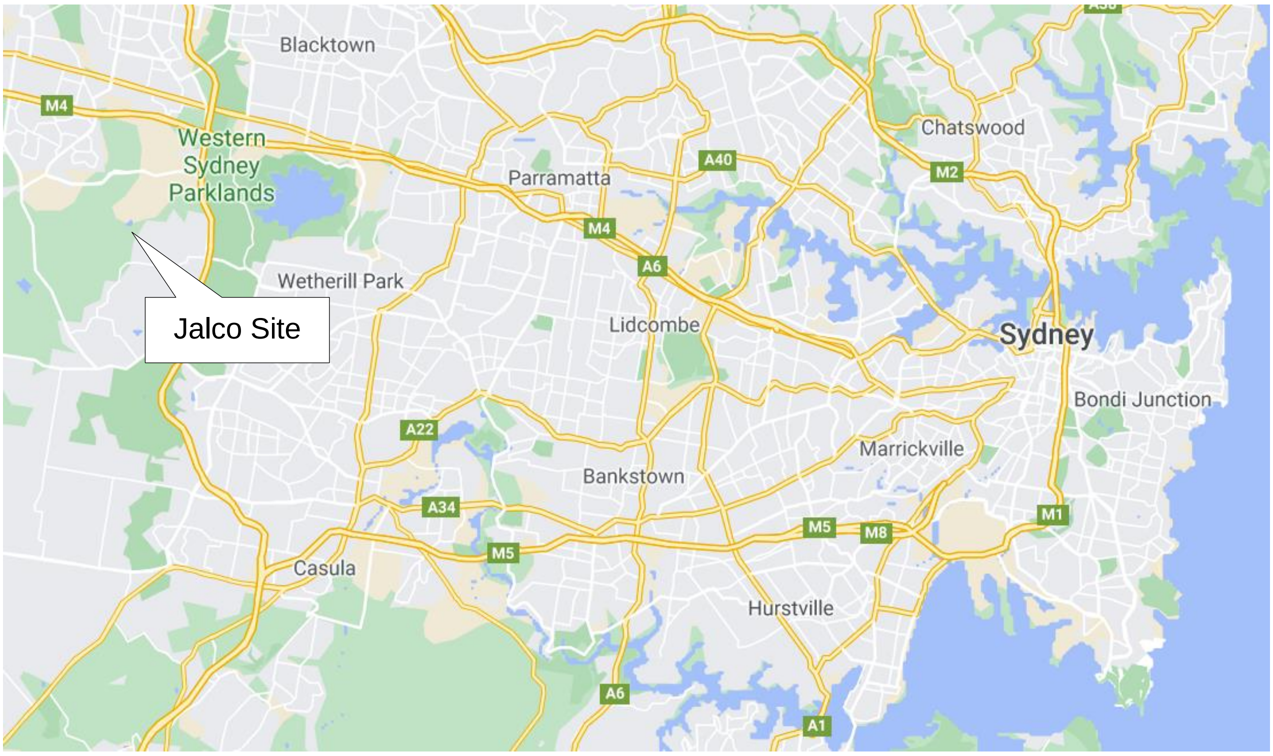

Figure 3-1: Site Location

3.2 General Building Description

The site operations are housed within a warehouse covering an area of 20,390 m^2. The building consists of an office (800 m^2), the automated warehouse and dispatch (7,500 m^2), the bottle storage area (5400 m^2), liquid packaging area (5,000 m^2), a workshop (285 m^2), flammable liquid dispensary (approximately 300 m^2) and the product manufacture and packaging area (approximately 1,400 m^2).

Outside of the warehouse there is a car park with a 109-car capacity, a loading dock, an LPG storage area (375 m^2), liquid storage shed (375 m^2), three liquid truck filling bays, and a Dissolved Air Flotation (DAF) facility.

The details of each area have been outlined in the following sections.

3.2.1 Tank Storage

The raw materials used for the manufacture of the liquid detergent products are stored in 15 tanks ranging from 30 kL to 70 kL along the east wall of the warehouse. The storage tanks are connected to the blending tanks, where the products are manufactured. Most of these substances are DGs and will be separately bunded based upon DG Class and compatibility. Adequate separation distances between incompatible substances will be ensured.

3.2.2 Liquid Storage Shed

The liquid shed will contain Class 5.1, 6.1, 8, 9 DGs. These substances will be stored for use in the liquid products manufacturing process. The DGs will be contained in drums and stored in racking, with a total storage capacity of 288,000 L.

3.2.3 Flammable Liquid Dispensary

Class 3 substances will be stored in a flammable liquid dispensary which will contain a range of Class 3.1, 4.1 and C1/C2 products stored in drums and IBCs. The store will be bunded and constructed of walls with an FLR of 240/240/240.

3.2.4 Blending

The blending process is the first stage of the manufacturing operations. A series of storage tanks containing raw materials are connected to nineteen (19) separate stirred tanks. In each of these tanks raw materials, some of which are considered DGs, are mixed and diluted with water to form the final products. The majority of final products are no longer regarded as DGs because of the significant dilution which occurs. These products are then sent down the process line to be packaged and stored.

3.2.5 Blow Moulder

The plastic packages (bottles) for the final products are produced at the warehouse using a blow moulder. 16 blow moulders are located adjacent to the dispatch receiving office and the loading docks. The manufactured bottles are manually loaded onto pallets, which are then transferred to the bottle storage area.

3.2.6 Package Filling

The empty bottles are filled with the final products at the 3 high-speed and 7 normal-speed filling lines. The empty bottles are manually loaded onto the lines, which are then automatically filled and conveyed to storage. The high-speed filling lines are capable of filling 90 bottles per minute. The normal-speed filling lines are capable of filling 12-40 bottles per minute.

3.2.7 Conveyor to Storage

The filled packages are manually loaded onto a conveyor belt to be sent to the automated warehouse storage.

3.2.8 Automated Storage System

The storage system uses a Swisslog Vectura pallet stacker crane to efficiently store the packaged final products prior to dispatch. This crane uses robotic technology to lift pallets onto multi-storey racking, allowing increased storage capacity. The system is fully automated ensuring personnel are not required to access the automated warehouse. The system has been designed to efficiently move product within the warehouse and includes brake to energy efficiency measures (i.e. when slowing brake energy is used to raise the load or lowering a package is used to drive the crane forward).

All product stored within the warehouse is given a unique identifying code and location within the warehouse which is tracked by the system. Product is stored and extracted in a manner to minimise storage time within the warehouse to ensure oldest product is despatched first (i.e. first in, first out).

3.2.9 Dissolved Air Flotation

Dissolved Air Flotation (DAF) tanks are used for wastewater treatment. The DAF facility is located immediately outside the warehouse, adjacent to the LPG tanks and the pump room. The DAF includes a balance tank, a sludge tank and an overflow tank. The tanks will be dosed with Class 8 DGs, which will be stored in IBCs.

3.2.10 LPG Tanks

The LPG tank will be used for filling forklifts which will be used within the warehouse. The LPG tank will be stored outside the warehouse next to the loading docks and DAF facility. The tank will have a volume of 3,920 L water capacity and will be separated from other DGs and protected places.

3.2.11 Workshop

The workshop is located adjacent to the bottle storage area. The workshop will be used for general repairs of equipment. Minor quantities of acetylene, argon and oxygen will be stored in the workshop.

3.3 Quantities of Dangerous Goods Stored and Handled

A combination of different classes and packing groups of DGs are proposed to be stored at the site. A breakdown of these DGs is provided in **Table 3-1.** A full breakdown of the product list has been provided in **Appendix A**.

Table 3-1: Quantities of DGs Stored and Handled

Class	PG	Description	Quantity (L)	Storage
2.1	n/a	Flammable gases – LPG	3,920	Bulk Tank
3	II	Flammable Liquids	10,000	Flammable dispensary
	III		60,000	
4.1	II	Flammable Solid	1,000	
	III		1,000	
5.1	II	Oxidising Agents	44,000	Liquid Storage Shed
	II		1,000	DAF
6.1	II	Toxic Substances	5,000	Liquid Storage Shed
8	II	Corrosive Substances – Acids and Bases	60,000	Tank Farm
	III		100,000	
8	II	Corrosive Substances	25,000	Liquid Storage Shed
	III		30,000	
8	II	Corrosive Substance	1,000	DAF
9	III	Environmentally Hazardous Substances	150,000	Liquid Storage Shed

Class	PG	Description	Quantity (L)	Storage
9	III	Miscellaneous DG	30,000	Tank Farm
C1	n/a	Combustible Liquid	50,000	Flammable dispensary
C2	n/a		30,000	Flammable dispensary

3.4 Aggregate Quantity Ratio

Where more than one class of DGs are stored and handled at the site, and aggregate quantity ratio (AQR) exists. This ratio is calculated using **Equation 3-1**.

$$AQR = \frac{q_x}{Q_x} + \frac{q_y}{Q_y} + [\dots] + \frac{q_n}{Q_n}$$ **Equation 3-1**

Where:

x,y […] and n are the dangerous goods present

q_x, q_y, […] and q_n is the total quantity of dangerous goods x, y, […] and n present.

Q_x, Q_y, […] and Q_n is the individual threshold quantity for each dangerous good of x, y, […] and n

Where the ratio AQR exceeds a value of 1, the site would be considered a Major Hazard Facility (MHF). The threshold quantities for each class are taken from the NSW Work Health and Safety Regulation (Ref. [4]). These are summarised in **Table 3-2**, noting that Class 4.1(III), 8 and 9 are not subject to MHF legislation.

Table 3-2: Major Hazard Facility Thresholds

Class	Packing Group	Description	Threshold (tonnes)	Storage (tonnes)
2.1	n/a	LPG	200	2
3	II & III	Flammable liquids	50,000	70
5.1	II	Oxidizing materials	200	45
6.1	II	Toxic substances	200	5

A review of the thresholds, commodities and packing groups listed in **Table 3-2** indicates that only Class 2.1, Class 3, Class 5.1 and Class 6.1 are assessable against the MHF thresholds. Therefore, substituting the storage masses into **Equation 3-1**, the AQR is calculated as follows:

$$AQR = \frac{2}{200} + \frac{70}{50000} + \frac{45}{200} + \frac{5}{200} = 0.262$$

The AQR is less than 1; hence, the facility would not be classified as an MHF.

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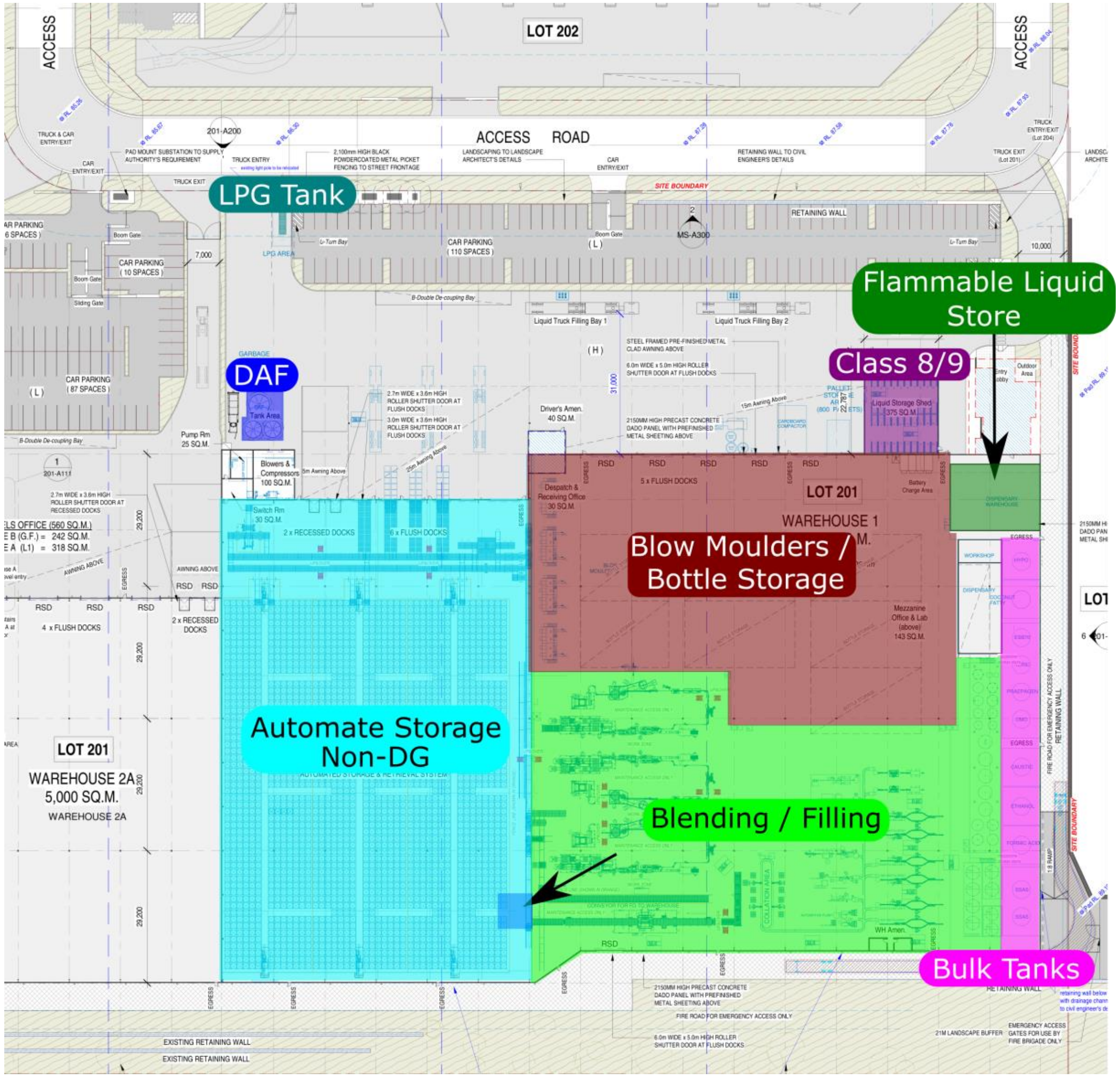

Figure 3-2: Site Layout

4.0 Hazard Identification

4.1 Introduction

A hazard identification table has been developed and is presented at **Appendix A**. This table has been developed following the recommended approach in Hazardous Industry Planning Advisory Paper No .6, Hazard Analysis Guidelines (Ref. [3]). The Hazard Identification Table provides a summary of the potential hazards, consequences and safeguards at the site. The table has been used to identify the hazards for further assessment in this section of the study. Each hazard is identified in detail and no hazards have been eliminated from assessment by qualitative risk assessment prior to detailed hazard assessment in this section of the study.

In order to determine acceptable impact criteria for incidents that would not be considered for further analysis, due to limited impact offsite, the following approach has been applied:

- *Fire Impacts* - It is noted in Hazardous Industry Planning Advisory Paper (HIPAP) No. 4 (Ref. [2]) that a criterion is provided for the maximum permissible heat radiation at the site boundary (4.7 kW/m^2) above which the risk of injury may occur and therefore the risk must be assessed. Hence, to assist in screening those incidents that do not pose a significant risk, for this study, incidents that result in a heat radiation less that at 4.7 kW/m^2, at the site boundary, are screened from further assessment.

  Those incidents exceeding 4.7 kW/m^2 at the site boundary are carried forward for further assessment (i.e. frequency and risk). This is a conservative approach, as HIPAP No. 4 (Ref. [2]) indicates that values of heat radiation of 4.7 kW/m^2 should not exceed 50 chances per million per year at sensitive land uses (e.g. residential). It is noted that the closest residential area is approximately 200 m from the site, hence, by selecting 4.7 kW/m^2 as the consequence impact criteria (at the adjacent industrial site boundary) the assessment is considered conservative.

- *Explosion* - It is noted in HIPAP No. 4 (Ref. [2]) that a criterion is provided for the maximum permissible explosion over pressure at the site boundary (7 kPa) above which the risk of injury may occur and therefore the risk must be assessed. Hence, to assist in screening those incidents that do not pose a significant risk, for this study, incidents that result in an explosion overpressure less than 7 kPa, at the site boundary, are screened from further assessment. Those incidents exceeding 7 kPa, at the site boundary, are carried forward for further assessment (i.e. frequency and risk). Similarly, to the heat radiation impact discussed above, this is conservative as the 7 kPa value listed in HIPAP No. 4 relates to residential areas, which are approximately 200 m from the site.

- *Toxicity* – Toxic substances have been proposed to be stored at the site; hence, toxicity has been assessed.

- *Property Damage and Accident Propagation* - It is noted in HIPAP No. 4 (Ref. [2]) that a criterion is provided for the maximum permissible heat radiation/explosion overpressure at the site boundary (23 kW/m^2/14 kPa) above which the risk of property damage and accident propagation to neighbouring sites must be assessed. Hence, to assist in screening those incidents that do not pose a significant risk to incident propagation, for this study, incidents that result in a heat radiation heat radiation less than 23 kW/m^2 and explosion over pressure less than 14 kPa, at the site boundary, are screened from further assessment. Those incidents exceeding 23 kW/m^2 at the site boundary are carried forward for further assessment with respect to incident propagation (i.e. frequency and risk).

- *Societal Risk* – HIPAP No. 4 (Ref. [2]) discusses the application of societal risk to populations surrounding the proposed potentially hazardous facility. It is noted that HIPAP No. 4 indicates that where a development proposal involves a significant intensification of population, in the vicinity of such a facility, the change in societal risk needs to be taken into account. In the case of the facility, there is currently no significant intensification of population around the proposed site; however, the adjacent land has been rezoned residential; hence, there will be housing located approximately 200 m from the site. Therefore, societal risk has been considered in the assessment.

4.2 Properties of Dangerous Goods

The type of DGs and quantities stored and used at the site has been described in **Section 3**. **Table 4-1** provides a description of the DGs stored and handled at the site, including the Class and the hazardous material properties of the DG Class.

Table 4-1: Properties* of the Dangerous Goods and Materials Stored at the Site

Class	Hazardous Properties
2.1 – Flammable Gas	Class 2.1 includes flammable gases which are ignitable when in a mixture of 13 per cent or less by volume with air or have a flammable range with air of at least 12 percentage points regardless of the lower flammable limit. Ignited gas may result in explosion or flash fire.
2.2 – Non-Flammable, Non-Toxic Gas	Class 2.2 includes non-flammable and non-toxic gases which are asphyxiant (dilute or replace the oxygen normally in the atmosphere).
3 – Flammable Liquids	Class 3 includes flammable liquids which are liquids, or mixtures of liquids, or liquids containing solids in solution or suspension (for example, paints, varnishes, lacquers, etc.) which give off a flammable vapour at temperatures of not more than 60°C closed-cup test or not more than 65.6°C open-cup test. Vapours released may mix with air and if ignited, at the right, concentration will burn resulting in pool fires at the liquid surface.
4.1 – Flammable Solids	Flammable solid materials are materials that may burn when exposed to an ignition source, examples of flammable solids include matches and some waxes.
5.1 – Oxidising Agent	Class 5.1 materials will not combust but these materials include substances which can in a fire event, liberate oxygen and could accelerate the burning of other combustible or flammable materials. Releases to the environment may cause damage to sensitive receptors within the environment.
8 – Corrosive Substances	Class 8 substances (corrosive substances) are substances which, by chemical action, could cause damage when in contact with living tissue (i.e. necrosis), or, in case of leakage, may materially damage, or even destroy, other goods which come into contact with the leaked corrosive material. Releases to the environment may cause damage to sensitive receptors within the environment.
9 – Miscellaneous DGs	Class 9 substances and articles (miscellaneous dangerous substances and articles) are substances and articles which, during transport present a danger not covered by other classes. Releases to the environment may cause damage to sensitive receptors within the environment.

Class	Hazardous Properties
C1/C2	C1/C2 products are not classified as a DGs; however, they are combustible liquids. Therefore, it may sustain combustion although initial ignition is difficult due to the high flash point of the material. Combustible liquids do not generate flammable vapours which eliminates the potential for flash fire or explosions to occur when confined.

* The Australian Code for the Transport of Dangerous Goods by Road and Rail (Ref. [6]

4.3 Hazard Identification

Based on the hazard identification table presented in **Appendix A**, the following hazardous scenarios have been developed:

- Package store (Class 5.1, 6.1, 8 & 9), release and environmental incident.
- Package store (Class 8), incompatible mixing, and exothermic reaction.
- Flammable liquid store, release, delayed ignition and flash fire or explosion.
- Flammable liquid store, release, ignition and fire.
- Tank release (acids) and environmental incident.
- Tank release (bases) and environmental incident.
- Tank release (acids and bases), incompatible mixing, and exothermic reaction.
- DAF release, and environmental incident.
- DAF release, incompatible mixing, and exothermic reaction.
- Fire escalation and full warehouse fire and radiant heat.
- Fire escalation and full warehouse fire and toxic smoke emission.
- Warehouse fire, sprinkler activation and potentially contaminated water release.
- LPG release, ignition and pool fire.
- LPG unloading incident, hose rupture, LPG release, ignition and jet fire.
- LPG release and ignition causing flash fire or explosion.
- LPG unloading incident, hose rupture, LPG release, ignition and jet fire and impact on LPG delivery tanker and Boiling Liquid Expanding Vapour Explosion (BLEVE).
- LPG unloading incident, hose rupture, LPG release, ignition and jet fire and impact on LPG tank and BLEVE.

Each identified scenario is discussed in further detail in the following sections.

4.4 Package Store (Class 5.1, 6.1, 8 & 9), Release and Environmental Incident

The package store contains class 5.1, 6.1, 8 and class 9 DGs in packages and IBCs with a maximum package volume within the store of 1,000 L. There is the potential for a spill to occur if the packages or IBCs were dropped, dislodged from the racking or punctured by forklift tynes, which could result in a release of DGs and an environmental spill. An environmental release of class 8 and class 9 DGs into local waterways could have serious impacts on local flora and fauna.

In order for the spill to have an off-site impact, a loss of containment is required within the store which is able to flow into the stormwater system. The potential for a loss of containment has been minimised by ensuring that the store is bunded in accordance with AS 3780-2008 (Ref. [7]). In the event that the bunding is not able to contain the release (e.g., a fire triggering the sprinkler system), the contaminated water will be contained on site via an isolation valve (stormwater containment). The contaminated water would be tested and only released to the environment if compliant with regulatory limits. As any potential releases will not have offsite impacts, this scenario has not been carried forward for further analysis.

4.5 Package Store (Class 8), Incompatible Mixing, and Exothermic Reaction

Class 8 and Class 9 DGs are stored within one package storage area as a mixed store. Both acids and bases are stored which if a spill were to occur and acids and bases mixed, they would react exothermically which could result in an incident (i.e. ignition of combustible material and fire).

The materials in the package store which are considered incompatible are acids and bases (both Class 8 substances). The maximum package size of these substances stored in the area is approximately 1,000 L. The mixing of these two substances is only possible in the event that two separate packages had a simultaneous spill, which would most likely occur as a result of packages falling off the racking, or if a forklift punctures multiple packages. The small volume of liquid which could be involved in a mixed spillage means that only a small amount of heat could be generated.

There are a number of safety measures in place to minimise the risk of incompatible substances mixing. Firstly, incompatible substances are stored in separate spillage containment compounds in accordance with AS 3780-2008 (Ref. [8]). Hence, in the event that both an acid and a base spill, the contents are separated, and no mixing can occur. The packages are all stored on purpose-built racking so the chance of a spill resulting from fallen packages is minimised.

There are no combustible or flammable materials within the package storage area, so incident escalation (i.e. fire resulting from heat generation) is avoided. In the event a fire did occur, the area is protected by sprinklers complying with AS 2118.1-2017 (Ref. [9]) which would activate to suppress and control the fire whilst also diluting any spills. Additionally, the store will be constructed of walls having an FRL of 60/60/60 and have first attack firefighting equipment readily accessible. As the potential for incompatible mixing and incident escalation is not considered a credible scenario due to the protection measures installed, it is considered there would be no offsite impacts; hence, this incident has not been carried forward for further analysis.

4.6 Flammable Liquid Store, Release, Delayed Ignition and Flash Fire or Explosion

There is the potential for flammable liquids to be released in the store if packages or containers are dropped, dislodged from the racking or damaged by forklift tynes. The maximum package sized stored is an Intermediate Bulk Container (IBC) which has a volume of 1,000 L. In the event that a liquid pool forms and it is not identified and cleaned quickly, there is a potential for a vapour cloud to accumulate in the store, which may ignite resulting in a flash fire or explosion.

In order for a vapour cloud to explode it must be confined, it must accumulate within the explosive limits, and an ignition source must be present. The flammable liquids contained in the store have explosive limits ranging from 0.6%-7% (eucalyptus compound & oil) to 3.1%-19% (ethanol), so it possible for a vapour cloud to accumulate within the explosive limits. The risk of explosion has been mitigated by ensuring that the store is adequately ventilated in accordance with AS/NZS

1940-2017 (Ref. [10]). Ventilation limits the potential for the accumulation of the vapour to occur by extracting vapours and discharging them externally to the store. confinement and the accumulation of vapour.

In the event that the ventilation system fails and a vapour cloud accumulates within the store, it will not be able to explode as ignition sources have been eliminated via compliance with AS/NZS 60079 series of standards. The store has been zoned as a hazardous area in accordance with AS/NSZ 60079.10.1:2009 (Ref. [11]), and all electrical equipment within the store is compliant with AS/NZS 600079.14:2017 (Ref. [12]). Ignition sources have also been controlled by a no smoking policy onsite, and by placarding the store in accordance with AS/NZS 1940-2017 (Ref. [10]). As vapour cloud will not be able to accumulate and ignition sources will be minimised, an explosion is unlikely to occur. Therefore, this scenario will not been carried forward for further analysis.

There is also a potential for a vapour cloud to ignite resulting in a flash fire. As previously discussed, the ventilation system and HAC reduce the likelihood of the conditions for a flash fire to be present.. Furthermore, the flash fire will not propagate beyond the store itself which has been constructed with firewalls having an FRL of 240/240/240, hence it will not impact offsite. As no off site impact will occur, this scenario has not been carried forward for further analysis.

4.7 Flammable Liquid Store, Release, Ignition and Fire

There is the potential for flammable liquids to be released in the store if packages are dropped, dislodged from the racking or punctured by forklift tynes. In the event that a liquid pool forms and ignites, a fire would occur within the store. In order for the fire to have an offsite impact, it would need to propagate beyond the store and into the warehouse.

As previously discussed in **Section 4.6**, the risk of a fire has been mitigated by minimising ignition sources in and around the flammable liquids store and providing ventilation which reduces the accumulation of vapours within the area. These controls include a hazardous area classification in accordance with AS/NSZ 60079.10.1:2009 (Ref. [11]), compliant electrical equipment in accordance with AS/NZS 600079.14:2017 (Ref. [12]), a no smoking policy and placarding in accordance with AS/NZS 1940-2017 (Ref. [10]).

If these controls were to fail and a pool fire occurred, it would be suppressed and controlled by the sprinkler system and contained by firewalls which have an FRL of 240/240/240, limiting the potential for radiant heat to impact over the site boundary...

In addition to the fire walls, the store is located away from the site boundary, in accordance with AS 1940-2017 (Ref. [10]) providing additional distance for attenuation of the radiant heat. Notwithstanding this, the separation distances in AS 1940-2017 are based upon generic flammable liquids; hence, it is possible that the distances are insufficient given the properties of the various flammable liquids in the store. Therefore, for conservatism, this incident has been carried forward for further analysis.

4.8 Tank Release (Acids) and Environmental Incident

The acids will be stored in bulk tanks within the main warehouse area in bunded areas. There is the potential for a release to occur from the tank predominantly from valves, pipework, minor holes in tank shell. The tanks are designed to be corrosion resistant to be able to contain the product in a safe manner. Therefore, large releases are not expected to occur during the lifetime of the plant as tanks will be tested for integrity ensuring catastrophic failure of the tank cannot occur.

Notwithstanding this, there is the potential for a release from the tanks to occur which if not contained may result in a release offsite which could contaminate the environment or result in flora and fauna death within the local environment. As noted above, the tanks are stored in bunded areas which have been designed to comply with AS 3780-2008 (Ref. [8]). In addition, the warehouse area has containment acting as a secondary barrier to release. Finally, there is tertiary containment at the site preventing discharge of potentially contaminated water from the site into the stormwater system.

A review of the protection measures indicates there are three levels of containment at the site which prevent discharge of corrosive substances (acids) from the site. Therefore, it is considered that an offsite release is not a credible scenario; hence, this incident has not been carried forward for further analysis.

4.9 Tank Release (Bases) and Environmental Incident

Basic corrosive substances will also be stored in a similar manner to the acid corrosive substances (i.e. stored in accordance with AS 3780-2008, Ref. [8]). However, these are stored in separate compounds to the acids to prevent potential in compatible mixing. As discussed in **Section 4.8** there are 3 levels of containment preventing discharge of corrosive substances from the site; hence, release from the site is not considered a credible scenario. This also applies to the basic solutions; hence, this incident has not been carried forward for further analysis.

4.10 Tank Release (Acids and Bases), Incompatible Mixing, and Exothermic Reaction

As discussed in **Section 4.8** and **Section 4.9**, acids and bases will be stored in tanks within the warehouse which could leak into the storage bunds in the event of failure or damage to valves, pipework or fittings. If simultaneous leak of acid and bases occurred and mixed there is the potential for them to interact resulting in an acid base reaction neutralising of the chemicals with the evolution of heat. If a substantial volume of both acid and base were to interact the reaction would be sustained and may result in sufficient heat to ignite combustible material within the area (i.e. debris, etc.) which may result in a fire.

A review of the design indicates the tank storages have been designed in accordance with AS 3780-2008 (Ref. [8]) which requires the acids and bases to be stored in separate compounds to prevent the interaction of the incompatible chemicals. Therefore, in the event of a release they would be unable to interact and thus an exothermic reaction would not occur.

In addition, the tanks are stored within the warehouse which minimises the potential for combustible material to accumulate within the bunds. The warehouse is also subject to housekeeping to minimise the potential for material to accumulate further reducing the potential for an incident to escalate into a fire. A review of the surrounding area indicates that there isn’t any substantial accumulations of combustible material; hence, if a fire did occur it would be unlikely to propagate to other areas.

It is noted that for this scenario to occur, simultaneous failure of both the acid and base tanks would be required which is an unlikely event. As the probability of the initiating event is incredibly low and the consequence is mitigated by the design such that an exothermic reaction couldn’t occur, it is considered that this scenario is not a credible and no offsite impact would occur. Therefore, this scenario has not been carried forward for further analysis.

4.11 DAF Release, and Environmental Incident

The DAF will house acids, bases and oxidising agents to treat process water at the site prior to discharge. The chemicals are stored in Intermediate Bulk Containers (IBCs) within a bunded area complying with AS 3780-2008 (Ref. [8]). There is the potential for releases to occur from the IBCs via deterioration of the IBC, damaged IBC during transport, etc; however, these releases or leaks would be contained within the bund.

The quantity substances are dosed into the process water; hence, should a release occur it can't escape from the bund into the stormwater system and would be fully contained on site. As the releases would be fully contained, an offsite incident is not expected to occur; hence, this incident has not been carried forward for further analysis.

4.12 DAF Release, Incompatible Mixing, and Exothermic Reaction

The DAF contains both acids and basis which, if they were to interact they would mix in an acid base reaction neutralising of the chemicals with the evolution of heat. If a substantial volume of both acid and base were to interact the reaction would be sustained and may result in sufficient heat to ignite combustible material within the area (i.e. detritus, leaves, debris, etc.) which may result in a fire.

A review of the design indicates the DAF has been designed in accordance with AS 3780-2008 (Ref. [8]) which requires the acids and bases to be stored in separate compounds to prevent the interaction of the incompatible chemicals. Therefore, in the event of a release they would be unable to interact and thus an exothermic reaction would not occur.

It is noted that for this scenario to occur, simultaneous failure of both the acid and base IBCs would be required which is an unlikely event. As the probability of the initiating event is incredibly low and the consequence is mitigated by the design such that an exothermic reaction couldn't occur, it is considered that this scenario is not a credible and no offsite impact would occur. Therefore, this scenario has not been carried forward for further analysis.

4.13 Fire Escalation and Full Warehouse Fire and Radiant Heat

A review of the site indicates that the majority of the warehouse is used for storage of manufactured plastic bottles or the manufacturing process which essentially results in a water based product. While there are storage areas within the warehouse containing flammable liquids, if these were to ignite they would be contained (i.e. within the bund for the ethanol tank or within the fire rated DG store for the flammable liquids). As the potential for the fire is contained and there is substantial space between these storages and combustible material, it is not expected that a fire would propagate further than the storage areas.

In terms of the finished product storage, the product is non-DG and is predominantly water based and would not be expected to be a source of fire, nor would it be expected for fire to propagate uncontrolled through the warehouse. This is because if a fire were to damage the containers resulting in a release of material it would inhibit fire growth, furthermore, the area is sprinkler protected which would add additional control and suppression to a fire within the storage.

Based upon the analysis conducted, it is not considered that a full warehouse fire is a credible scenario based upon the fuel load, separation, isolation and products stored within the warehouse. Therefore, a full warehouse fire has not been carried forward for further analysis.

4.14 Fire Escalation and Full Warehouse Fire and Toxic Smoke Emission

As discussed in **Section 4.13,** the potential for a full warehouse fire to occur is considered to be negligible which eliminates the potential for a substantial smoke plume to form which may carry toxic products of combustion noting that small fires will burn 'cleanly' resulting in minimal formation of toxic bi-products. Therefore, a toxic smoke emission is not considered to be a credible threat from the warehouse; hence, this incident has not been carried forward for further analysis.

4.15 Warehouse Fire, Sprinkler Activation and Potentially Contaminated Water Release

In the event of a fire, the SMSS will activate discharging fire with water to control and suppress the fire. Contact of the fire water with DGs may result in contamination which, if released to the local watercourse, could result in environmental damage. The SMSS system delivers approximately 5 m^3/min of water which, if operated for a long period, may result in overflow of site bunding and potential release. The facility has been designed to be able to contain all DG spills and liquid effluent resulting from the management of an incident (i.e. fire) within the premises.

The site will hold 60 minutes of water storage on site as required by FM Global standards; hence, to allow for additional conservatism, following a risk assessment methodology as outlined by the Department of Planning document "*Best Practice Guidelines for Potentially Contaminated Water Retention and Treatment Systems*" (Ref. [13]), an allowance of 90 minutes of potentially contaminated water has been selected noting this includes all sources of application (i.e. onsite storage and towns mains) thus far exceeding the 60 minute on site storage. In a DG fire scenario, the following protection systems are likely to be discharging:

- SMSS at 6 m^3/min.
- 3 hydrant hoses at 1.8 m^3/min.

The total water discharge would be 7.8 m^3/min. Therefore, operation for 90 minutes would result in a total discharge of 702 m^3. The following recommendation has been made:

- The warehouse and/or site boundaries shall be capable of containing 702 m^3 which may be contained within the warehouse footprint, site stormwater pipework and any recessed docks or other containment areas that may be present as part of the site design.
- The civil engineers designing the site containment shall demonstrate the design is capable of containing at least 702 m^3.
- A storm water isolation point (i.e. penstock isolation valve) shall be incorporated into the design. The penstock shall automatically isolate the storm water system upon detection of a fire (smoke or sprinkler activation) to prevent potentially contaminated liquids from entering the water course.

Based on the design and containment for the premises, there is adequate fire water retention to meet the '*Best Practice Guidelines for Contaminated Water Retention and Treatment Systems*" (Ref. [13]), hence, this incident has not been carried forward for further analysis.

4.16 LPG Release, Ignition and Pool Fire

In the event of a small leak from a vessel or pipework a pool of LPG may form when the rate of evaporation of LPG is less than the flow rate of LPG from the leak. If the pool were to ignite an LPG pool fire would occur which may impact over the site boundary.

A leak sufficient to cause a release that exceeds the evaporation rate to develop a pool large enough to ignite (noting the area is zoned per the requirements of AS/NZS 60079.10.1:2009, Ref. [11]) and the subsequent fire to impact over the site boundary is very low. This is substantiated by numerous similar sized LPG tanks installed throughout Australia with very low incidences of leaks and fires occurring from such installations.

As the potential for a leak and LPG pool and subsequent ignition to occur is incredibly low, this incident has not been carried forward for further analysis.

4.17 LPG Unloading Incident, Hose Rupture, LPG Release, Ignition and Jet Fire

As the site LPG is depleted, it will be refilled by a delivery tanker at the site. During loading of the tank there is the potential for the hose to rupture which may be the result of a puncture of the hosing or deterioration through general wear and tear. It has been assumed the hoses are inspected monthly and pressure tested annually in accordance with the Australian Dangerous Goods Code (ADG, Ref. [14]).

Notwithstanding this, there is the potential for a hose to become damaged between inspection and test periods which may lead to sufficient deterioration resulting in a hose rupture when transferring pressurised LPG. Excess flow and non-return valves will isolate the flow of LPG; however, if these fail in addition to a hose rupture, LPG will be released resulting in an LPG vapour cloud. The operator may be able to respond and isolate the LPG transfer by activating an emergency stop button located on the tanker.

If the operator is incapacitated or unable to stop the transfer, the LPG will continue to flow developing a substantial cloud which may contact an ignition source and ignite which would result in a flash fire or explosion which would burn back to the release point and subsequent jet fire. It is noted the area is unconfined; hence, an explosion is unlikely to occur and would likely result in a flash fire.

The potential for a fatality to occur as a result of a flash fire is not considered credible as the mechanism for a fatality to occur from a flash fire is via combustion of flammable vapours at head height which results in oxygen within the lungs being consumed as the fuel burns. The impacted person will involuntarily inhale, as low oxygen is detected, resulting in inhalation of hot combustion products which burn the sensitive lining of the lungs. As LPG is a dense gas, any release will spread along at ground level and due to the open nature of the site it will not accumulate to a level where a person offsite will be fully engulfed; hence, a fatality is unlikely to occur.

While a flash fire may not be expected to cause significant harm, the impacts from a jet fire are likely to be substantial and would impact over the site boundary; hence, this incident has been carried forward for further analysis.

4.18 LPG Release and Ignition Causing Flash Fire or Explosion

In the event of an LPG release, LPG will vapourise forming a flammable atmosphere which may ignite. A review of the area indicates the tank will not be stored in an area where confinement will occur; hence, the atmosphere would not ignite as an explosion but would rather result in a flash fire.

As noted in **Section 4.17**, the mechanism for a fatality to occur from a flash fire is inhalation of hot combustion products when a person is fully engulfed in a vapour cloud when ignition occurs. As LPG is a dense gas it will spread out at ground level as there is no confinement to allow the gas to accumulate at height; therefore, it is unlikely that a vapour cloud would form to allow a person to be fully engulfed; hence, a fatality would be unlikely to occur.

Furthermore, AS/NZS 1596:2014 (Ref. [15]) has been developed with reference to the likely impact scenarios from storage of LPG in various tank sizes. Review of Table 6.1 of AS/NZS 1596:2014 (Ref. [15]) indicates for a 4.3 kL tank the separation distance to a protected place is <5 m. Therefore, the standard would consider that in open air, events resulting from a release from the tank would be unlikely to significantly impact >5 m.

A catastrophic failure of an LPG tank (i.e. rupture and full release of LPG) is considered incredible due to the manufacturing and regular testing of pressure vessels according to AS 1210:2010 (Ref. [16]).

As the area is unconfined and the location of the tank provides adequate separation to the site boundary and protected places it is considered that a fatality would not result from this incident; hence, this incident has not been carried forward for further analysis.

4.19 LPG Unloading Incident, Hose Rupture, LPG Release, Ignition and Jet Fire and Impact on LPG Delivery Tanker and BLEVE

Similarly, to the scenario described in **Section 4.18** the hose may rupture resulting in a jet fire. If this jet fire were aimed at the delivery tanker, the tanker shell would begin to heat, transferring the heat into the LPG within the tank which would begin to vaporise and increase the pressure within the tanker. At the design pressure of the tank, the pressure relief valve will begin to lift to relieve pressure within the tanker.

As the liquid level within the tanker drops, the impact zone of the jet fire may impact the vapour space in the tanker. The vapour will absorb less energy than the liquid which will result in localised heating of the tanker shell at the point of the jet fire impact. This may compromise the structural integrity of the tanker shell which may rupture resulting in a blast overpressure as the vessel fails and formation of an LPG vapour cloud which may also ignite resulting in a vapour cloud explosion known as a Boiling Liquid Expanding Vapour Explosion (BLEVE). This incident has been carried forward to assess the potential impact zone.

4.20 LPG Unloading Incident, Hose Rupture, LPG Release, Ignition and Jet Fire and Impact on LPG Tank and BLEVE

Similarly, to the scenario described in **Section 4.18** the hose may rupture resulting in a jet fire. If this jet fire were aimed at the tank, the tank shell would begin to heat, transferring the heat into the LPG within the tank which would begin to vaporise and increase the pressure within the tank which may result in a BLEVE as described in **Section 4.19**. Hence this incident has been carried forward for further analysis.

5.0 Consequence Analysis

5.1 Incidents Carried Forward for Consequence Analysis

The following incidents were identified to have potential to impact off site:

- Flammable liquid store, release, ignition and fire.
- LPG unloading incident, hose rupture, LPG release, ignition and jet fire.
- LPG unloading incident, hose rupture, LPG release, ignition and jet fire and impact on LPG delivery tanker and Boiling Liquid Expanding Vapour Explosion (BLEVE).
- LPG unloading incident, hose rupture, LPG release, ignition and jet fire and impact on LPG tank and BLEVE.

Each incident has been assessed in the following sections.

5.2 Flammable Liquid Store, Release, Ignition and Fire

There is the potential for a pool fire to occur in the flammable liquids store, and for the radiant heat from the fire to have off-site impacts. In the event of a fire, the sprinkler systems will activate, limiting the size of the pool fire to the size covered by the sprinkler array. The primary array (3 m by 3 m) should be able to suppress and control the fire; however, in the event the primary array is overwhelmed, it will likely be contained by the secondary array (9 m by 9 m). Hence, the radiant heat impact distances from a pool fire in the flammable liquid store was modelled as two scenarios:

- A base case: where the size of the pool fire is limited to the area covered by the primary sprinkler array, and
- A sensitivity analysis: where the size of the pool fire is limited to area covered by the secondary sprinkler array.

A detailed analysis has been performed in **Appendix B**. The store is constructed of fire walls with an FRL of 240/240/240, limiting the impact of radiant heat at ground level. Hence, the maximum heat radiation observed at ground level and its corresponding impact distance have been presented in **Table 5-1**, instead of the typical values which were not observed. The values calculated have been graphically presented in **Figure 5-1.**

Table 5-1: Heat Radiation Impact Distances for a Pool Fire in the Flammable Liquids Store

	Maximum Heat Radiation Observed at Ground Level (kW/m^2)	Impact Distance Radius (m)
Base Case	1.83	7.8
Sensitivity Analysis	4.65	8.8

The radiant heat impacts at 23 kW/m^2 and 4.7 kW/m^2 have been reviewed to determine the potential for incident propagation and fatality. A review of the 23 kW/m^2 impact distance indicates that this thermal value would not be observed at ground level due to the protection provided by the fire walls. Hence, incident propagation is not expected to occur. Similarly, a review of the 4.7 kW/m^2 impact distance indicates that this thermal value would not be observed at ground level; hence, a fatality would not be expected to occur at the site boundary.

As no offsite impact was observed from the 23 kWm^2 or 4.7 kW/m^2 contour, this incident has not been carried forward for further analysis.

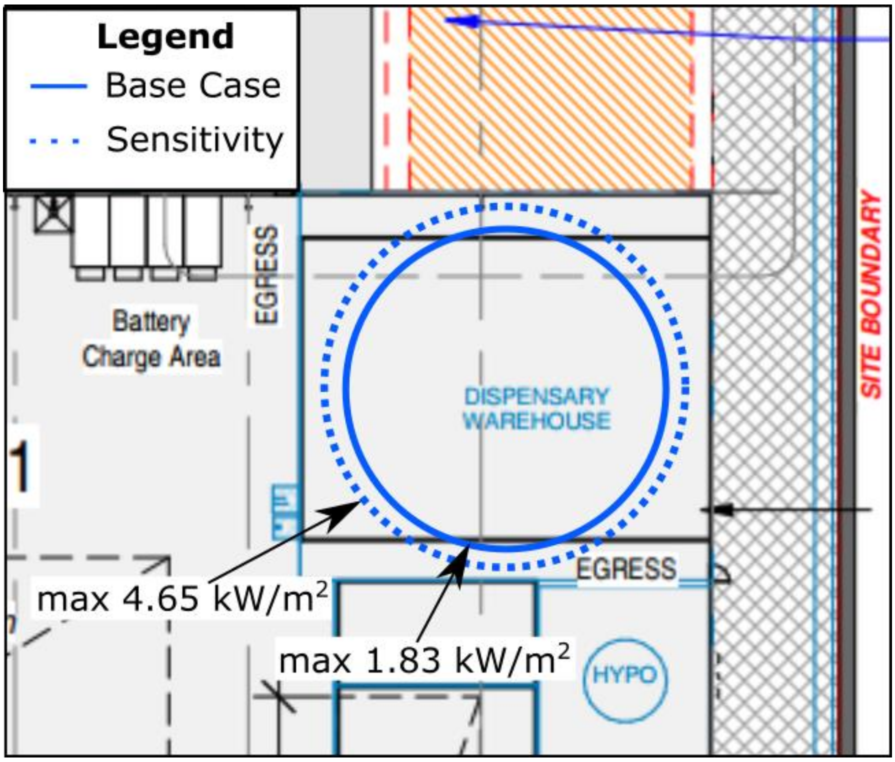

Figure 5-1: Sprinkler Controlled Flammable Liquid Fire Radiant Heat Contours

5.3 LPG Unloading Incident, Hose Rupture, LPG Release, Ignition and Jet Fire

There is the potential for a hose to rupture and release high pressure LPG if the excess flow valve on the tanker fails and operator intervention does not occur. If this stream ignited, a jet fire could occur. A detailed analysis has been conducted in **Appendix B7** for this scenario which indicates the jet fire would have an impact of distance of 38 m. The impact distances for this incident are shown in **Figure 5-2**.

There are several protection systems to prevent hose rupture including hose pressure testing and inspections, non-return valves on the tank and vehicle, excess flow valves on the tanker, earthing connections, ignition source controls. Therefore, it is unlikely that a release of LPG would occur and subsequent ignition.

Notwithstanding this, the impact distances from the jet fire would impact over the site boundary; hence, a fatality could occur. Therefore, this incident has been carried forward for further analysis.

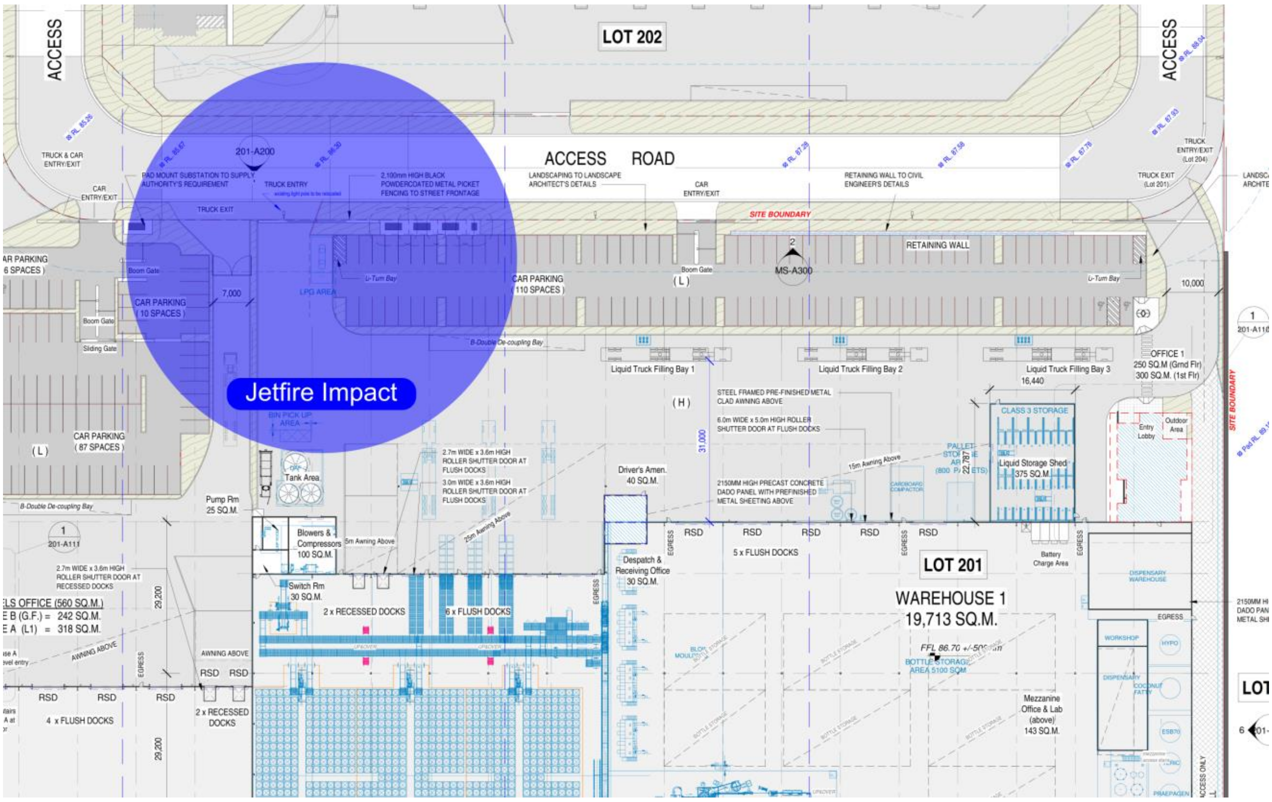

Figure 5-2: Impact from a Jet Fire

It is noted that while the incident impacts over the site boundary there are no areas where people may accumulate within the impact contour, nor does it impact high risk industries on adjacent land uses that may result in incident propagation. Therefore, it is considered the location of the LPG tank within the site to be appropriate.

5.4 LPG Unloading Incident, Hose Rupture, LPG Release, Ignition and Jet Fire and Impact on LPG Delivery Tanker and BLEVE

In the event of a jet fire and impingement on the delivery tanker there is potential for the LPG in the tanker to boil escalating to a BLEVE if intervention measures fail. A detailed analysis has been conducted in **Appendix B8** which indicates the diameter of the BLEVE would be 63.9 m and would last for 5.0 seconds. The impact distances for this incident are shown in **Figure 5-3**.

Similarly, to the jet fire scenario, several layers of protection are required to fail before the initiating event could occur. In addition, the jet fire would need to be impinged on the tanker before it could BLEVE which takes considerable time as the LPG must boil off such that the liquid level is below the impact point.

Notwithstanding this, the impact distances from the tanker BLEVE would impact over the site boundary; hence, a fatality could occur. Therefore, this incident has been carried forward for further analysis.

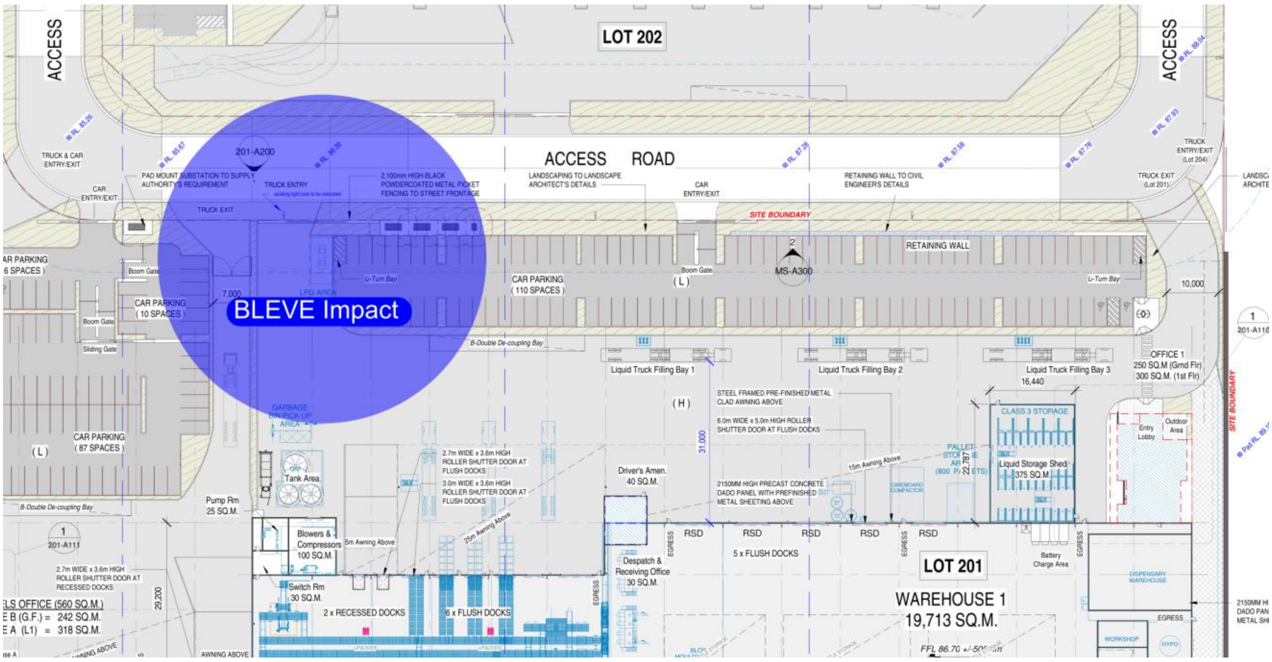

Figure 5-3: BLEVE Impact from a Tanker

It is noted that while the incident impacts over the site boundary there are no areas where people may accumulate within the impact contour, nor does it impact high risk industries on adjacent land uses that may result in incident propagation. Therefore, it is considered the location of the LPG tank within the site to be appropriate.

5.5 LPG Unloading Incident, Hose Rupture, LPG Release, Ignition and Jet Fire and Impact on LPG Tank and BLEVE

In the event of a jet fire and impingement on the LPG tank there is potential for the LPG in the tank to boil escalating to a BLEVE if intervention measures fail. A detailed analysis has been conducted in **Appendix B9** which indicates the diameter of the BLEVE would be 53.3 m and would last for 4.3 seconds. The impact distances for this incident are shown in **Figure 5-4**.

The impact distances from the Tank BLEVE would impact over the site boundary; hence, a fatality could occur. Therefore, this incident has been carried forward for further analysis.

It is noted that while the incident impacts over the site boundary there are no areas where people may accumulate within the impact contour, nor does it impact high risk industries on adjacent land uses that may result in incident propagation. Therefore, it is considered the location of the LPG tank within the site to be appropriate.

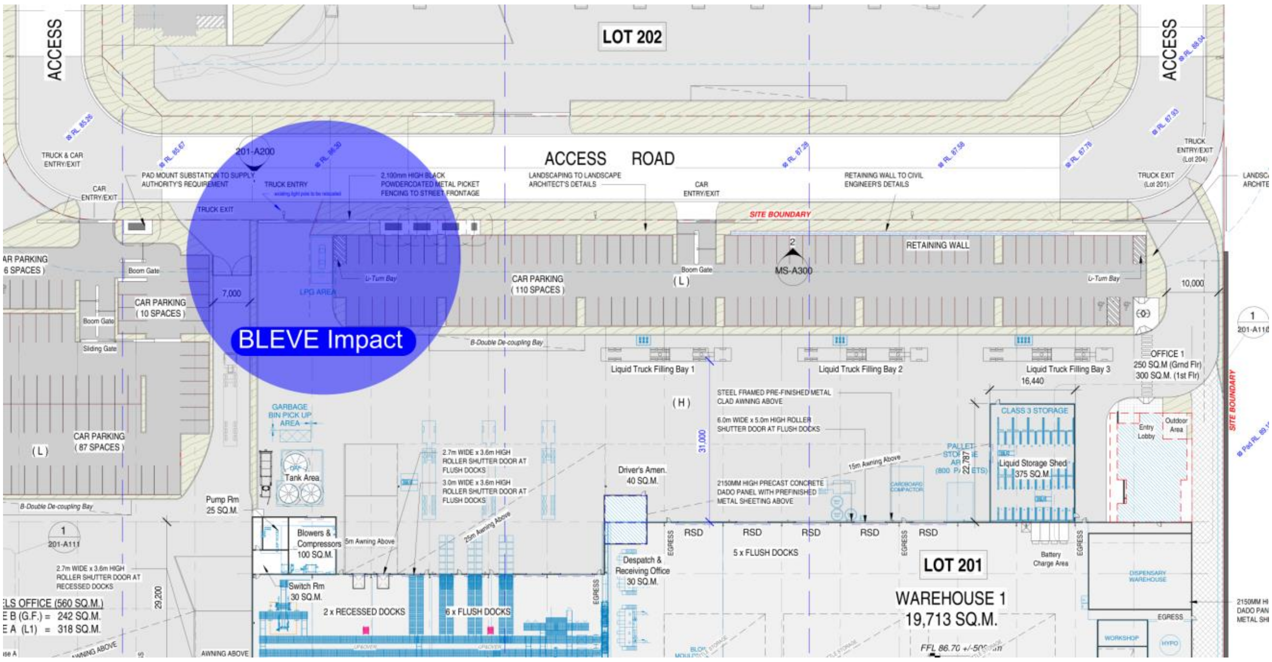

Figure 5-4: BLEVE Impact from a Tank

6.0 Frequency Analysis

6.1 Incidents Carried Forward for Frequency Analysis

The following item has been carried forwards for frequency analysis:

- LPG unloading incident, hose rupture, LPG release, ignition and jet fire.
- LPG unloading incident, hose rupture, LPG release, ignition and jet fire and impact on LPG delivery tanker and Boiling Liquid Expanding Vapour Explosion (BLEVE).
- LPG unloading incident, hose rupture, LPG release, ignition and jet fire and impact on LPG tank and BLEVE.

This incident has been assessed in the following section.

6.2 Probability of Failure on Demand

The failure rates for each component identified in the safety systems which protect against the scenarios in the following sections were sourced from 3rd party databases such as; OREDA, Exida, UK Health and Safety Executive (HSE). A summary of the failure rate information has been conducted in **Appendix C**. Also included in this appendix are the calculations for the probability of failure on demand (PFD) for each component which is estimated using **Equation 7-1**.

$$PFD = \frac{1}{2}\lambda_{du}t$$ **Equation 7-1**

Where:

- λ_{du} = dangerous undetected failures of a component
- t = 1/number of test intervals per annum

6.3 LPG Release and ignition and jet fire

For a jet fire to occur, it is necessary for several of the layers of protection to fail such that a high-pressure LPG release is present prior to ignition and jet fire. A review of the safety systems at the sites indicates the following items must fail for a jet fire to occur:

- Rupture of the hose.
- Failure of the excess flow valve.
- Failure of the non-return valve.
- Failure of the emergency stop button to activate the isolation valves.
- Failure of the isolation valves.

Failure rate information for each component has been taken from **Appendix C** and is summarised in **Table 6-1**.

Table 6-1: Failure Rate Data

Component	PFD
Hose	$1.04\text{x}10^{-5}$ (Frequency)

Component	PFD
Excess flow valve	$6.5x10^{-3}$
Non-return valve	$6.5x10^{-3}$
Emergency Stop	$2.71x10^{-5}$
Isolation Valves	$5x10^{-3}$

In addition to the components of the safety system to fail, it is necessary for the operator to fail to initiate an emergency stop and the release needs to ignite. HEART human error probabilities (Ref. [17]) and Human Factors in QRA (Ref. [18]) provide failure rates of operators for tasks similar to that required by an operator to initiate an emergency stop. These are;

- Routine, highly-practised, rapid task involving relatively low level of skill – 0.02;
- Restore or shift a system to original or new state following procedures, with some checking – 0.003; and
- A more complex task, less time variable, some care necessary – 0.01.

Based on a review of these documents a value toward the more conservative end of 0.01 has been selected for use in this assessment.

Ignition probabilities were sourced from Lees - Loss Prevention in the Process Industries (Ref. [19]) which provides ignition probabilities based on the number of ignition sources at the site. The site contains very few ignition sources; hence, from Lees, a conservative probability of ignition is estimated as 0.2.

The PFD for each piece of equipment, operation failure and ignition were input into a fault tree to determine the overall probability of a failure resulting in a jet fire. The fault tree is shown in **Figure 6-1**. The analysis indicates a jet fire will occur with a frequency of $4.04x10^{-10}$ chances per annum (p.a.). The very low frequency indicates that there are many layers of protection at the site, minimising the potential for incident.

It is noted that for conservatism, the automatic Isolation provided by the plastic air lines, operating the Isolation valves at the site, have not been included in this assessment. This would provide further reduction to the already low incident frequency.

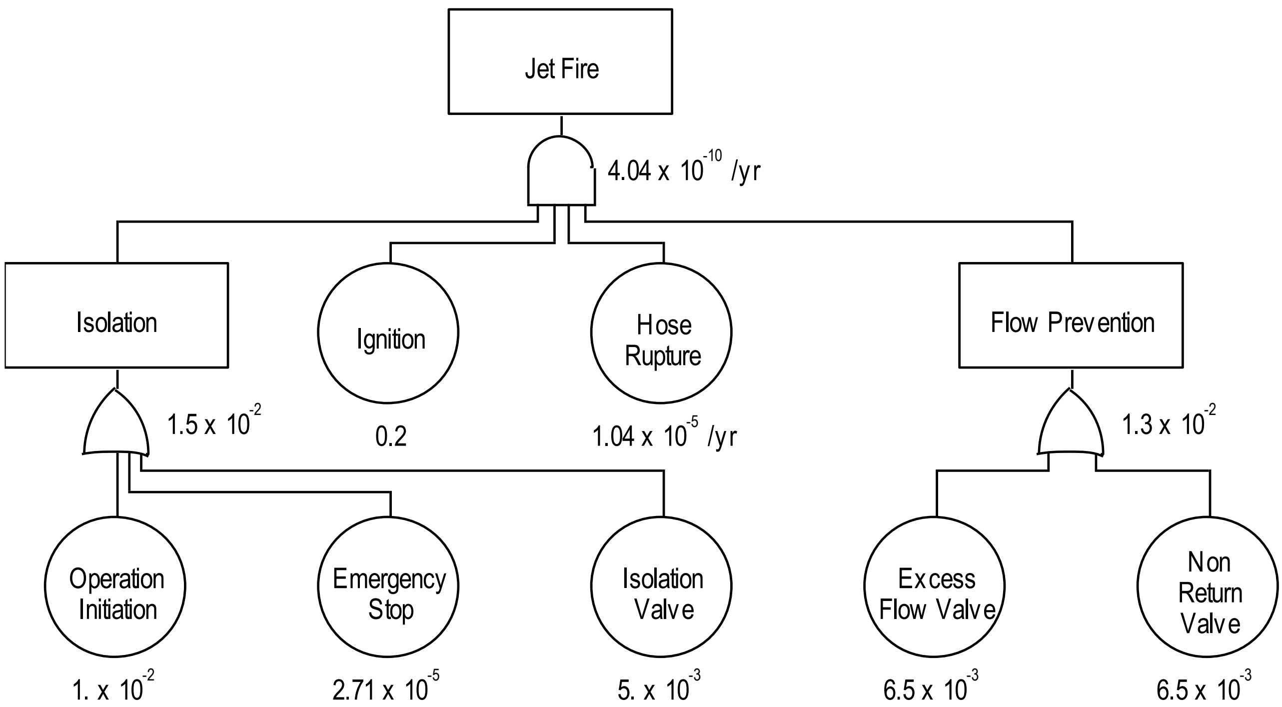

Figure 6-1: Jet Fire Frequency

6.4 LPG Unloading Incident, Hose Rupture, LPG Release, Ignition and Jet Fire and Impact on LPG Delivery Tanker and Boiling Liquid Expanding Vapour Explosion (BLEVE)

The initiating event for a tanker BLEVE is an incident involving a jet fire impinging on the delivery tanker; hence, for conservatism, a tanker BLEVE event frequency of 4.04×10^{-10} chances per annum (p.a.) has been selected. This is conservative as it does not take into account fire brigade intervention which may prevent the event from escalating; hence, lowering the event frequency.

6.5 LPG Unloading Incident, Hose Rupture, LPG Release, Ignition and Jet Fire and Impact on LPG Tank and BLEVE

The initiating event for a tank BLEVE is an incident involving a jet fire impinging on the delivery tanker; hence, for conservatism, a tank BLEVE event frequency of 4.04×10^{-10} chances per annum (p.a.) has been selected. This is conservative as it does not take into account fire brigade intervention which may prevent the event from escalating; hence, lowering the event frequency.

6.6 Total Fatality Risk

Provided in **Table 6-2** is a summary of the incidents which may result in a fatality at the site boundary. The total fatality risk at the site boundary was calculated to be 0.0012 chances per million per year (pmpy)

Table 6-2: Total Fatality Risk

Incident	Fatality Risk
Jet fire	4.04×10^{-10}
Tanker BLEVE	4.04×10^{-10}

Incident	Fatality Risk
Tank BLEVE	$4.04x10^{-10}$
Total	**$1.2x10^{-9}$**

6.7 Comparison Against Risk Criteria

The NSW Department of Planning and Environment has issued a guideline on the acceptable risk criteria (Ref. [2]). The acceptable risk criteria published in the guideline relates to injury, fatality and property damage. The values in the guideline present the maximum levels of risk that are permissible at the land use under assessment. The adjacent land use would be classified as an industrial site as it is restricted access and only industrial operations are permitted to occur in this area. For industrial facilities, the maximum permissible fatality risk is 50 pmpy. The assessed highest fatality risk is 0.0012 pmpy at the closest site boundary (eastern boundary); hence, the highest risk is within the permissible criteria and therefore all other risk points beyond the boundary would be within the acceptable criteria.

A review of the site area indicates there is a residential area to the south which would have an acceptable fatality risk criterion of 1 pmpy. The estimated site fatality risk was found to be 0.0012 pmpy which is below the risk criteria for residential areas.

Based on the estimated injury risk, conducted in the analysis above, the risks associated with injury and nuisances at the closest residential area are not considered to be exceeded.

6.8 Incident Propagation

The NSW Department of Planning and Environment has issued a guideline on the acceptable risk criteria (Ref. [2]) which indicates the risk for incident propagation is 50 chances pmpy. A review of the scenarios that may lead to incident propagation shows that there were no incidents with radiant heat exceeding 23 kW/m^2 impacting over the site boundaries. Therefore, incident propagation would not be expected to occur.

6.9 Cumulative Risk

A review of the proposed developments at the estate indicates there are no facilities currently proposed to exceed the SEPP 33 thresholds; hence, there would be no unacceptable cumulative risk within the estate. A review of the surrounding area further afield doesn't show there to be accumulations of facilities which would result in a cumulative impact based upon the proposed Jalco warehouse. Therefore, potential for cumulative risk to exceed the permissible criterion is not expected to occur.

7.0 Conclusion and Recommendations

7.1 Conclusions

A hazard identification table was developed for warehouse facility to identify potential hazards that may be present at the site as a result of operations or storage of materials. Based on the identified hazards, scenarios were postulated that may result in an incident with a potential for offsite impacts. Postulated scenarios were discussed qualitatively and any scenarios that would not impact offsite were eliminated from further assessment. Scenarios not eliminated were then carried forward for consequence analysis.

Incidents carried forward for consequence analysis were assessed in detail to estimate the impact distances. Impact distances were developed into scenario contours and overlaid onto the site layout diagram to determine if an offsite impact would occur. The consequence analysis showed that several incidents involving the LPG tanks had the potential to impact offsite which were carried forward for frequency analysis and risk assessment.

The frequency analysis and risk assessment showed that the incidents carried forward would have a fatality risk of 0.0012 chances per million per year (pmpy) at the site boundary, with lesser risk at further distances from the boundary. HIPAP No. 4 (Ref. [2]) publishes acceptable risk criteria at the site boundary of 50 pmpy (for industrial sites). Therefore, the probability of a fatality at the site boundary is within the acceptable risk criteria.

In addition, incidents exceeding 23 kW/m^2 were reviewed which indicated that the contours from such incidents would not impact any structures and thus propagation incidents would be not expected to occur based upon the analysis.

Based on the analysis conducted, it is concluded that the risks at the site boundary are not considered to exceed the acceptable risk criteria; hence, the facility would only be classified as potentially hazardous and would be permitted within the current land zoning for the site.

7.2 Recommendations

Notwithstanding the conclusions following the analysis of the facility, the following recommendations have been made:

- The warehouse and/or site boundaries shall be capable of containing 702 m3 which may be contained within the warehouse footprint, site stormwater pipework and any recessed docks or other containment areas that may be present as part of the site design.
- The civil engineers designing the site containment shall demonstrate the design is capable of containing at least 702 m3.
- A storm water isolation point (i.e. penstock isolation valve) shall be incorporated into the design. The penstock shall automatically isolate the storm water system upon detection of a fire (smoke or sprinkler activation) to prevent potentially contaminated liquids from entering the water course.

8.0 References

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Appendix A

Hazard Identification Table

Appendix A

A1. Hazard Identification Table

ID	Area/Operation	Hazard Cause	Hazard Consequence	Safeguards
1	Package store (Class 5.1, 6.1, 8 & 9)	• Dislodgement from racking • Forklift misalignment, resulting in puncture of package. • Package dropped from forklift	• Potential environmental release • Mix of incompatible goods (exothermic reaction)	• Bunding, complying with AS3780-2008 • Separate compounds for acids and bases • Operators are trained to safely operate forklifts • Racking is provided by a reputable supplier • Site stormwater containment
2	Flammable liquids store (Class 3)	• Dislodgement from racking • Forklift misalignment, resulting in puncture of package. • Package dropped from forklift	• Potential environmental release	• Bunding, complying with AS 1940-2017 • Operators are trained to safely operate forklifts • Racking is provided by a reputable supplier • Site stormwater containment
			• Pool of flammable liquid, immediate ignition and fire. • Delayed ignition of flammable liquid and flash fire or explosion.	• Ventilation complying with AS 1940-2017 • Sprinkler protection • Fire walls with FRL 240/240/240 • HAC, per AS/NZS 60079.10.1:2009 • Electrical equipment complying with AS/NZS 60079.14:2017 • Operators are trained to safely operate forklifts • Racking is provided by a reputable supplier • No smoking policy on site • Ignition source control placarding, complying with AS 1940-2017 • First attack firefighting equipment (hose reels and extinguishers), and hydrants.
3	Bulk Acids and Bases Tanks (Class 8)	• Tank leak (leaks from valves, fittings or pipework) • Overfilling of tank	• Environmental release • Mixing of incompatible goods (exothermic reaction)	• Site stormwater containment • Bunding, complying with AS3780-2008 • Separate compounds for acids and bases

ID	Area/Operation	Hazard Cause	Hazard Consequence	Safeguards
		• Potential impact from forklift, resulting in release • Operator error (mixing of incompatible goods)		• Barriers between acids and bases • Operators are trained to safely operate forklifts • Unique connection configuration for acids and bases • Overfill protection (high level sensors and alarms)
4	DAF	• Punctured or deteriorated IBC • Leak from dosing equipment	• Environmental release • Mixing of incompatible substances (exothermic reaction)	• Natural ventilation • Bunding complying with AS 3780-2008 • Site wide containment
5	LPG Tank	• Release of LPG from tank filling or cylinder filling • Tank leak (valves and fittings) • Vehicle collision and tank puncture • Over-pressurisation and pressure relief activation	• Formation of a vapour cloud, delayed ignition and explosion • Immediate ignition resulting in jet fire • Jet fire impingement on tank shell resulting in BLEVE • Jet fire impingement on delivery tank resulting in BLEVE	• Natural ventilation • System designed in accordance with AS/NZS 1596:2014 • ARMCO barriers to protect from impact • Operator can stop source of release (emergency stop during filling) • Operators trained in first attack firefighting • Operators are trained to safely operate forklifts • Separation distances complying with AS/NZS 1596:2014 • First attack firefighting equipment available (fire extinguishers and hose reels) • Hydrant protection • HAC, per AS/NZS 60079.10.1:2009 • Electrical equipment complying with AS/NZS 60079.14:2017 • No smoking policy on site • Ignition source control placarding, complying with AS/NZS 1596:2014

ID	Area/Operation	Hazard Cause	Hazard Consequence	Safeguards
				• Fire and Rescue may respond faster than BLEVE escalation
6	General warehouse	• Sprinkler water not contained	• Environmental contamination	• Site wide containment complying with the Best Practice Guidelines for Contaminated Water and Retention Systems (Ref. [13])

Appendix B

Consequence Analysis

Appendix B

B1. Incidents Assessed in Detailed Consequence Analysis

The following incidents are assessed for consequence impacts.

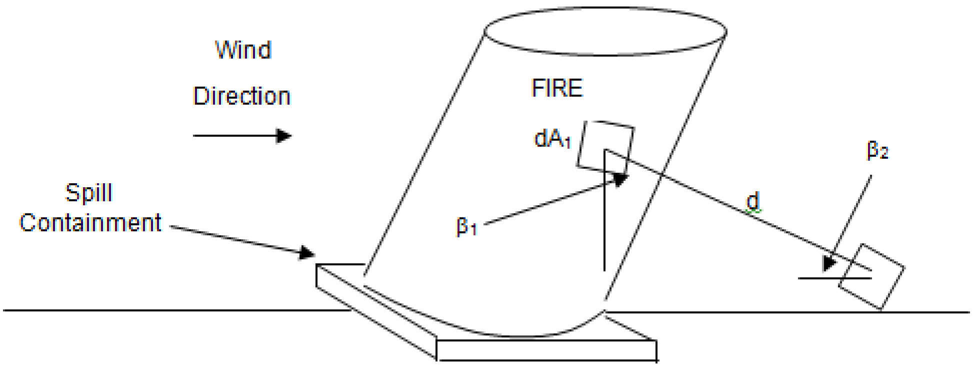
- Flammable liquid store, release, ignition and fire.
- LPG unloading incident, hose rupture, LPG release, ignition and jet fire.
- LPG unloading incident, hose rupture, LPG release, ignition and jet fire and impact on LPG delivery tanker and Boiling Liquid Expanding Vapour Explosion (BLEVE).
- LPG unloading incident, hose rupture, LPG release, ignition and jet fire and impact on LPG tank and BLEVE.

Each incident has been assessed in the sections below.

B2. Spreadsheet Calculator (SSC)

The SSC is designed on the basis of finite elements. The liquid flame area is calculated as if it is a circle to find the radius for input into the SSC model.

The SSC is designed on the basis of finite elements. The liquid flame area is calculated as if it is a circle to find the radius for input into the SSC model. **Appendix Figure B-1** shows a typical pool fire, indicating the target and fire impact details.



Appendix Figure B-1: Heat Radiation on a Target from a Cylindrical Flame

A fire in a bund or at a tank roof will act as a cylinder with the heat from the cylindrical flame radiating to the surrounding area. A number of mathematical models may be used for estimating the heat radiation impacts at various distances from the fire. The point source method is adequate for assessing impacts in the far field; however, a more effective approach is the view factor method, which uses the flame shape to determine the fraction of heat radiated from the flame to a target. The radiated heat is also reduced by the presence of water vapour and the amount of carbon dioxide in air. The formula for estimating the heat radiation impact at a set distance is shown in **Equation B-1** (Ref. [20]).

$$Q = EF\tau \qquad \textbf{Equation B-1}$$

Where:

- Q = incident heat flux at the receiver (kW/m^2)
- E = surface emissive power of the flame (kW/m^2)
- F = view factor between the flame and the receiver

- τ = atmospheric transmissivity

The calculation of the view factor (F) in **Equation B-1** depends upon the shape of the flame and the location of the flame to the receiver. F is calculated using an integral over the surface of the flame, S (Ref. [20]). The formula can be shown as:

$$F = \int\int_S \frac{\cos\beta_1 \cos\beta_2}{\pi d^2}$$ **Equation B-2**

Equation B-2 may be solved using the double integral **or** using a numerical integration method in spread sheet form. This is explained below.

For the assessment of pool fires, a Spread Sheet Calculator (SCC) has been developed, which is designed on the basis of finite elements. The liquid flame area is calculated as if the fire is a vertical cylinder, for which the flame diameter is estimated based on the fire characteristics (e.g. contained within a bund). Once the flame cylindrical diameter is estimated, it is input into the SSC model. The model then estimates the flame height, based on diameter, and develops a flame geometric shape (cylinder) on which is performed the finite element analysis to estimate the view factor of the flame. **Appendix Figure B-1** shows a typical pool fire, indicating the target and fire impact details.

The SSC integrates the element dA_1 by varying the angle theta θ (the angle from the centre of the circle to the element) from zero to 90^o in intervals of 2.5 degrees. Zero degrees represents the straight line joining the centre of the cylinder to the target (x0, x1, x2) while 90^o is the point at the extreme left hand side of the fire base. In this way the fire surface is divided up into elements of the same angular displacement. Note the tangent to the circle in plan. This tangent lies at an angle, gamma, with the line joining the target to where the tangent touches the circle (x4). This angle varies from 90^o at the closest distance between the liquid flame (circle) and the target (x0) and gets progressively smaller as θ increases. As θ increases, the line x4 subtends an angle phi Φ with x0. By similar triangles we see that the angle gamma γ is equal to 90- θ - Φ . This angle is important because the sine of the angle give us the proportion of the projected area of the plane. When γ is 90^o, sin(γ) is 1.0, meaning that the projected area is 100% of the actual area.

Before the value of θ reaches 90^o the line x4 becomes tangential to the circle. The fire cannot be seen from the rear and negative values appear in the view factors to reflect this. The SSC filters out all negative contributions.

For the simple case, where the fire is of unit height, the view factor of an element is simply given by the expression in **Equation B-3** (Derived from **Equation B-2**):

$$VF = \Delta A \frac{\sin\gamma}{\pi \times X4 \times X4}$$ **Equation B-3**

Where ΔA is the area of an individual element at ground level.

Note: the denominator (π. x4. x4) is a term that describes the inverse square law for radiation assumed to be distributed evenly over the surface of a sphere.

Applying the above approach, we see the value of x4 increase as θ increase, and the value of sin(γ) decreases as θ increase. This means that the contribution of the radiation from the edge of the circular fire drops off quite suddenly compared to a view normal to the fire. Note that the SSC adds up the separate contributions of **Equation B-3** for values of θ between zero until x4 makes a tangent to the circle.

It is now necessary to do two things: (i) to regard the actual fire as occurring on top of a fire wall (store) and (ii) to calculate and sum all of the view factors over the surface of the fire from its base to its top. The overall height of the flame is divided into 10 equal segments. The same geometric technique is used. The value of x4 is used as the base of the triangle and the height of the flame, as the height. The hypotenuse is the distance from target to the face of the flame (called X4'). The angle of elevation to the element of the fire (alpha α) is the arctangent of the height over the ground distance. From the cos(α) we get the projected area for radiation. Thus there is a new combined distance and an overall equation becomes in **Equation B-4 (**(Derived from **Equation B-3**):

$$VF = \Delta A \frac{\sin\gamma \times \cos\alpha}{\pi \times X4 \times X4}$$ **Equation B-4**

The SCC now turns three dimensional. The vertical axis represents the variation in θ from 0 to 90º representing half a projected circle. The horizontal axis represents increasing values of flame height in increments of 10%. The average of the extremes is used (e.g. if the fire were 10 m high then the first point would be the average of 0 and 1 i.e. 0.5 m), the next point would be 1.5 m and so on).

Thus the surface of the flame is divided into 360 equal area increments per half cylinder making 720 increments for the whole cylinder. Some of these go negative as described above and are not counted because they are not visible. Negative values are removed automatically.

The sum is taken of the View Factors in **Equation B-3**. Actually the sum is taken without the ∆A term. This sum is then multiplied by ∆A which is constant. The value is then multiplied by 2 to give both sides of the cylinder. This is now the integral of the incremental view factors. It is dimensionless so when we multiply by the emissivity at the "face" of the flame (or surface emissive power, SEP), which occurs at the same diameter as the fire base (pool), we get the radiation flux at the target.

The SEP is calculated using the work by Mudan & Croche (Ref. [19] & Ref. [20]) which uses a weighted value based on the luminous and non-luminous parts of the flame. The weighting is based on the diameter and uses the flame optical thickness ratio where the flame has a propensity to extinguish the radiation within the flame itself. The formula is shown in **Equation B-5**.

$$SEP = E_{max}e^{-sD} + E_s(1 - e^{-sD})$$ **Equation B-5**

Where;

E_{max} = 140

S = 0.12

E_s = 20

D = pool diameter

The only input that is required is the diameter of the pool fire and then estimation for the SEP is produced for input into the SSC.

The flame height is estimated using the Thomas Correlation (Ref. [20]) which is shown in **Equation B-6**.

$$H = 42d_p\left[\frac{\dot{m}}{\rho_a\sqrt{gd_p}}\right]^{0.61}$$ **Equation B-6**

Where;

d_p = pool diameter (m)

ρ_a = density of air (1.2 kg/m^3 at 20^{o}C)

$\dot{m}$ = burning rate (kg/m^2.s)

g = 9.81 m/s^2

The transmissivity is estimated using **Equation B-7** (Ref. [20]).

$$\tau = 1.006 - 0.01171(\log_{10} X(H_2O) - 0.02368(\log_{10} X(H_2O))^2 - 0.03188(\log_{10} X(CO_2) + 0.001164(\log_{10} X(CO_2))^2 \qquad \textbf{Equation B-7}$$

Where:

- τ = Transmissivity (%)
- X(H_2O) = $\frac{R_H \times L \times S_{mm} \times 2.88651 \times 10^2}{T}$
- X(CO_2) = $\frac{L \times 273}{T}$

and

- R_H = Relative humidity (% expressed as a decimal)
- L = Distance to target (m)
- S_{mm} = saturated water vapour pressure in mm of mercury at temperature (at 25^{o}C S_{mm} = 23.756)
- T = Atmospheric temperature (K)

B3. Jet Fire Modelling

The flow rate of a liquid from a hole may be calculated from **Equation B-8** (Ref. [20]).

$$m = C_d A (2\rho\Delta P)^{0.5} \qquad \textbf{Equation B-8}$$

Where:

- m = Mass flow rate (kg/s)
- C_d = Discharge coefficient (0.6 for irregular holes)
- A = area of the orifice (m^2)
- ρ = Density of the material (kg/m^3)
- ΔP = Pressure difference across the orifice (Pa).

The flame length and width, as a result of a release, can be estimated from the empirical formula published by Lees (Ref. [19]). The equations for the length and width are shown in **Equation B-9** and **Equation B-10**.

$$L = 9.1 {G_L}^{0.5} \qquad \textbf{Equation B-9}$$

Where:

- L = Length (m)

- G_L = Mass flow rate (kg/s)

$$W = 0.25L$$ **Equation B-10**

Where:

- W = Width (m)
- L = Length (m)

B4. BLEVE Modelling

The diameter of the fireball and the duration of the BLEVE may be estimated using the following formulae (Ref. [20]):

$$D = 6.48m^{0.325}$$ **Equation B-11**

$$t = 0.852m^{0.25}$$ **Equation B-12**

Where:

- D = diameter of the fire ball (m)
- m = mass of LPG in the tank (kg)
- t = duration of the BLEVE (seconds)

B5. Radiant Heat Physical Impacts

Appendix Table B-1 provides noteworthy heat radiation values and the corresponding physical effects of an observer exposed to these values (Ref. [2]).

Appendix Table B-1: Heat Radiation and Associated Physical Impacts

Heat Radiation (kW/m^2)	Impact
35	• Cellulosic material will pilot ignite within one minute's exposure • Significant chance of a fatality for people exposed instantaneously
23	• Likely fatality for extended exposure and chance of a fatality for instantaneous exposure • Spontaneous ignition of wood after long exposure • Unprotected steel will reach thermal stress temperatures which can cause failure • Pressure vessel needs to be relieved or failure would occur
12.6	• Significant chance of a fatality for extended exposure. High chance of injury • Causes the temperature of wood to rise to a point where it can be ignited by a naked flame after long exposure • Thin steel with insulation on the side away from the fire may reach a thermal stress level high enough to cause structural failure
4.7	• Will cause pain in 15-20 seconds and injury after 30 seconds exposure (at least second degree burns will occur)
2.1	• Minimum to cause pain after 1 minute

B6. Flammable Liquid Store, Release, Ignition and Fire

In the event that a flammable liquid package is damaged and flammable liquid is released the volatile component will vaporise which may contact an ignition source resulting in a pool fire. As the fire grows it may accelerate the deterioration of other packages resulting in failure and release of additional flammable material and combustion of packaging.

As heat and smoke is generated from the fire, the in-rack sprinklers and the SMSS will activate. Two sprinkler activation scenarios have been assessed:

- A base case scenario whereby the first row of the SMSS activates and controls the spread of a fire.
- A sensitivity scenario whereby the first row of sprinklers fails to activate and the fire is instead controlled by the second row of the SMSS.

The first row of sprinklers has an approximate diameter of 3 m with the second row having an approximate diameter of 9 m. These diameters are used to estimate the flame height and SEP for the fire scenarios. To estimate the flame height and SEP the following information was substituted into the models:

- Equivalent fire diameter: base – 3 m, Sensitivity - 9 m
- Burning rate – 0.0667 kg/m^2.s (this value encompasses a large range of flammable liquid burning rates and is considered conservative due to the nature of the flammable liquids stored, Ref. [19])
- Fire wall: 10 m

The selection of a flammable liquid burning rate is considered appropriate and conservative as a the fire will be composed of burning flammable liquids and packaging. The packaging is a solid material that will yield a lower burning rate than selected as it requires an additional phase change prior to combustion reducing the rate at which the product burns.

Furthermore, the analysis is considered incredibly conservative as it assumes a 100% burning area; however, as the subject areas will encompass aisle spaces, which will have no combustible material stored these locations. Therefore, it is considered the results generated from this analysis would substantially overestimate the radiant heat impacts from the identified scenarios.

The results for flame height and SEP for each scenario are summarised in **Appendix Table B-2**.

Appendix Table B-2: Flame Height and SEP for a Flammable Material Sprinkler Controlled Fire

Output	Base Case	Sensitivity
Flame Height (m)	7.7	16.5
SEP (kW/m^2)	103.7	60.8

The inputs summarised in **Appendix Table B-2** were input into the SSC with the results for each scenario shown in **Appendix Table B-3**.

Appendix Table B-3: Heat Radiation from a Flammable Material Sprinkler Controlled Fire

Heat Radiation (kW/m^2)	Distance (m)	
	Base Case	Sensitivity
35	Not observed due to fire wall	Not observed due to fire wall

Heat Radiation (kW/m²)	Distance (m)	
	Base Case	Sensitivity
23	Not observed due to fire wall	Not observed due to fire wall
12.6	Not observed due to fire wall	Not observed due to fire wall
4.7	Not observed due to fire wall	Not observed due to fire wall

Notwithstanding the above, the maximum radiant heat observed at ground level has been presented in **Appendix Table B-4** to demonstrate the peak radiant heat observed when a sensitive receptor moves away from the fire wall.

Appendix Table B-4: Maximum Radiant Heat Observed from a Sprinkler Controlled Fire

	Maximum Heat Radiation Observed at Ground Level (kW/m²)	Impact Distance Radius (m)
Base Case	1.83	7.8
Sensitivity Case	4.65	8.8

B7. LPG Unloading Incident, Hose Rupture, LPG Release, Ignition and Jet Fire

A hose rupture could occur and ignite which would result in a jet fire. To estimate the dimensions of a jet fire, the flow rate of the liquid from the hose must be estimated. The following data was input into **Equation B-8** to estimate the flow rate through the ruptured hose:

- C_d = Discharge coefficient (0.6 for irregular holes)
- A = 50 mm hose = $\frac{\pi D^2}{4} = \frac{\pi \times 0.050^2}{4} = 0.002\ m^2$
- ρ = 508 kg/m³
- ΔP = 8.6 bar = 860000 Pa

Substituting the information into **Equation B-8** gives a flow rate of 34.8 kg/s.

$$m = 0.6 \times 0.004 \times (2 \times 508 \times 860000)^{0.5} = 34.8\ \frac{kg}{s}$$

A liquid LPG release would be too fuel dense to ignite as it would be above the LEL so the only portion that could ignite would be the liquid that vapourises upon release. Assuming a flash fraction of 50%, the vapour flow rate from the release would be 0.5 x 34.8 = 17.4 kg/s.

Substituting the mass flow rate of vapour into **Equation B-9** gives a jet fire length of 38 m.

$$L = 9.1 \times 17.4^{0.5} = 38\ m$$

B8. LPG Unloading Incident, Hose Rupture, LPG Release, Ignition and Jet Fire and Impact on LPG Delivery Tanker and BLEVE

In the event of a jet fire and impingement on the delivery tanker there is potential for the LPG in the tanker to boil escalating to a BLEVE if intervention measures fail. It is assumed that impingement will occur at the 30% fill level of the tanker and that the tanker holds a maximum 7,500 L. A BLEVE will only occur once the liquid level falls below the impingement level; hence, the maximum volume of LPG that could be involved in the BLEVE is 2,250 L. As noted, the density of LPG is 508 kg/m3; therefore, the mass of LPG involved in the BLEVE is 1,143 kg.

Inputting the mass into **Equation B-11** and **Equation B-12** yields an impact diameter of 63.9 m and a resonance time of 5 seconds.

$D = 6.48 \times 1{,}143^{0.325} = 63.9\ m$

$t = 0.852 \times 1{,}143^{0.25} = 5\ s$

B9. LPG unloading Incident, Hose Rupture, LPG Release, Ignition and Jet Fire and Impact on LPG Tank and BLEVE

In the event of a jet fire and impingement on the above ground tank there is potential for the LPG in the tanker to boil escalating to a BLEVE if intervention measures fail. It is assumed that impingement will occur at the 30% fill level of the tank. The tank holds 4,300 L; hence, at the 30% fill level 1,290 L of LPG is involved in the BLEVE. As noted, the density of LPG is 508 kg/m3; therefore, the mass of LPG involved in the BLEVE is 655 kg.

Inputting the mass into **Equation B-11** and **Equation B-12** yields an impact diameter of 53.3 m and a resonance time of 4.3 seconds.

$$D = 6.48 \times 655^{0.325} = 53.3\ m$$

$$t = 0.852 \times 655^{0.25} = 43\ s$$

Appendix C

Warehouse Fire Frequency Estimation

Appendix C

C1. Estimation of the Frequency of a Full Warehouse Fire

A review of readily available warehouse fire frequency information was conducted and a number of direct sources were identified. These were:

- Health and Safety Executive (HSE) in the United Kingdom [Hymes & Flynn, UKAEA - SRD/HSE R578, 2002] – this document lists the major warehouse fire frequency to be 2.5×10^{-3} p.a.;
- Baldwin, Accident Analysis and Prevention (Vol.6) – indicates a serious fire frequency in warehouses to be in the order of 1×10^{-3} p.a.;
- Environmental Impact Assessment Report for the Commission of Inquiry into Proposed Manufacturing Plant by WR Grace Australia Ltd., Kurnell, Sydney, October 1987 – indicates a fire frequency of 4.6×10^{-3} per warehouse year; and
- VROM 2005, Guidelines for quantitative risk assessment CPR 18E (Purple Book), Publication Series on Dangerous Substances (PGS 3), The Netherlands. – 4×10^{-4} p.a.

It is noted that the mix of overseas data and local data (albeit some is dated) correlates to indicate a fire frequency in warehouses to be in the order of 1×10^{-3} to 4×10^{-4}. The data presented in the reports reviewed was for general warehouses, where stringent controls for spill and ignition sources (such as flame and explosion proof fittings, bunding, smoking and naked flame controls, isolation of power supplied on warehouse closure, etc.) were not part of the warehouse hazard controls. Hence, for a DG warehouse, containing specific ignition and fire control systems, it would be expected that a major fire would occur with a lesser frequency than that of general warehouses. Notwithstanding this, to ensure a conservative assessment has been provided within the study, the estimated initiating fire frequency for the facility has been estimated as 1×10^{-3} p.a. (i.e. the upper end of the range).

Selected Initiating Fire Frequency = 1×10^{-3} p.a.

Appendix D

Detailed Dangerous Goods List

ID	Class	PG	Correct Shipping Name	UN No	Product or Common Name	Quantity	Unit	Container	Location
1	3	II	Isopropanol	1219	Isopropyl Alchohol	400	L	Drums	Class 3 Store - (Package Storage)
2		II	Ethanol	1170	Ethyl Alcohol	2,000	L	IBC	
3	3	III	Dipentene	2052	D-Limonene	700	L	Drums	
4		III	Extracts, Aromatic, Liquid	1169	Perfumes	15,000	L	Drums	
5		III	Dipentene	2052	Pinechem 560	2,000	L	IBC's & Drums	
6		III	Flammable Liquid Corrosive, N.O.S.	2924	Armohib 18	400	L	Drums	
7		III	Flammable Liquid, N.O.S.	1993	Eucalyptus Compound & Oil	5,000	L	IBC	
8	8	II	Sulphuric Acid	1830	Sulphuric Acid 50%	1,000	L	IBC	Liquid Storage Shed
9		II	Hydrochloric Acid	1789	Hydrochloric Acid	1,000	L	IBC	
10		II	Acetic Acid Solution	2790	Acetic Acid Solution	400	L	Drum	
11		II	Corrosive Liquid Acidic, Organic, N.O.S.	3265	Lactic Acid	5,000	L	IBC	
12		II	Corrosive Liquid Acidic, Organic, N.O.S.	3265	Acticide Rs	3,000	L	IBC	
13		II	Formic Acid 75%	3412	Formic Acid	10,000	L	IBC	
14	8	III	Corrosive Liquid Acidic, N.O.S.	3149	Proxitane	400	L	Drum	
15		III	Phosphoric Acid Solution	1805	Phosphoric Acid	5,000	L	IBC	
16	5.1, 8	II	Hydrogen Peroxide, Aqueous Solution	2014	Hydrogen Peroxide 50%	44,000	L	IBC	
17	9	III	Environmentally Hazardous Substance, Liquid, N.O.S.	3082	Perfumes	5,000	L	Drum	
18		III	Misc. Chemicals	3082	-	15,000	L	IBC's & Drums	

ID	Class	PG	Correct Shipping Name	UN No	Product or Common Name	Quantity	Unit	Container	Location
19	C1	n/a	Perfumes	n/a	Perfumes	10,000	L	Drums	
20	8a	II	Corrosive Liquid, N.O.S.	1760	Gardiquat 1450	30,000	L	Tank	Tank Farm
21		III	Arylsulfonic Acid	2586	Gardilene Ssas	50,000	L	Tank	
22	8b	II	Sodium Hydroxide Solution	1824	Sodium Hydroxide	30,000	L	Tank	
23		III	Hypochlorite	1791	Sodium Hypochlorite	50,000	L	Tank	
24	C2	NDG	Glycerine	n/a	Glycerine	30,000	L	Tank	
25	8	II	Sulphuric Acid	1830	Sulphuric Acid 50%	1,000	L	IBC	Wastewater Treatment Plant
26	8	II	Hydrochloric Acid	1789	Hydrochloric Acid	1,000	L	IBC	
27	5.1, 8	II	Hydrogen Peroxide, Aqueous Solution	2014	Hydrogen Peroxide 50%	1,000	L	IBC	
28	2.1	n/a	Liquefied Petroleum Gas	1075	LPG	4,300	L	Tank	LPG tank