Preliminary Hazard Analysis

Precinct 3, Oakdale East Industrial Estate

Goodman Property Services (Aust.) Pty Ltd
Document No. RCE-21232_Goodman_PHA_Final_6Jun22_Rev(1)
Date 6/06/2022

Preliminary Hazard Analysis

Precinct 3, Oakdale East Industrial Estate

Goodman Property Services (Aust.) Pty Ltd

Prepared by

Riskcon Engineering Pty Ltd
37 Pogson Drive
Cherrybrook, NSW 2126
www.riskcon-eng.com
ABN 74 626 753 820

Riskcon engineering

Quality Management

Rev	Date	Remarks	Prepared By	Reviewed By
A	14 March 2022	Draft issue for comment	Renton Parker	Jason Costa
0	13 April 2022	Issued Final		
1	26 May 2022	Updated quantities and assessments		

Executive Summary

Background

A Goodman Property Services (Aust.) Pty Ltd (Goodman) has proposed to develop a warehouse for a tenant who will store materials classified as Dangerous Goods (DG) within a warehouse at Precinct 3, Oakdale East Industrial Estate (OEIE), Horsley Park. Secretary's Environmental Assessment Requirements (SEARs) have been issued for the site which require the preparation of Chapter 3 of the State Environmental Planning Policy (SEPP, Ref. [1]) assessment and if the thresholds are exceeded a Preliminary Hazard Analysis (PHA) is required to be prepared.

A review of the DG quantities indicates they will exceed the thresholds; hence, a PHA has been prepared to assess the risks associated with the development as part of the State Significant Development Application (SSDA) in accordance with the Hazardous Industry Planning Advisory Paper (HIPAP) No. 4 and No. 6 (Ref. [2] & [3]) for submission with the Development Application (DA).

Goodman has commissioned Riskcon Engineering Pty Ltd (Riskcon) to prepare the PHA for the facility. This document represents the PHA study for the site located within Precinct 3 of the OEIE, Horsley Park.

Conclusions

A hazard identification table was developed for the 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 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 scenarios would impact over the site boundary and into the adjacent land use; hence, these incidents were carried forward for frequency analysis and risk assessment.

The frequency analysis and risk assessment showed that the full warehouse fire would have a fatality risk of 7.06 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 from a full warehouse fire at the site boundary is within the acceptable risk criteria.

A review of the potential for incident propagation indicated the only incidents which exceeded propagation criteria were radiant heat impacts from Boiling Liquid Expanding Vapour Cloud Explosion (BLEVE) incidents associated with the Liquefied Petroleum Gas (LPG) tanks. However, such incidents are short-lived and are unlikely to result in sustained impact sufficient to result in incident propagation. As the potential for incident propagation was not considered credible, the criteria of 50 pmpy for incident propagation would not be exceeded.

Review of the estate proposal indicates this development is the only contributor to the risk profile at this stage; hence, cumulative risk is not a consideration at this stage. The cumulative risk at the site is therefore the reported 7.06 chances pmpy which is below the 50 chances pmpy limit.

Therefore, the development does not increase the cumulative risk of the estate to an unacceptable level.

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

- Notify SafeWork NSW that the site exceeds 10% of the Major Hazard Facility threshold.
- The site shall be designed to contain any spills or contaminated water from a fire incident within the boundaries of the site.
- Multiple spill kits be provided around the DG storage areas to ensure spills can be cleaned up immediately following identification.
- 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.

List of Figures

List of Tables

List of Appendix Figures

List of Appendix Tables

Abbreviations

Abbreviation	Description
ADG	Australian Dangerous Goods Code
AS	Australian Standard
BLEVE	Boiling Liquid Expanding Vapour Explosion
CBD	Central Business District
CCPS	Centre for Chemical Process Safety
DA	Development Application
DGs	Dangerous Goods
DGS	Dangerous Goods Store
DPIE	Department of Planning, Industry and Environment
HIPAP	Hazardous Industry Planning Advisory Paper
HSE	Health and Safety Executive
LPG	Liquefied Petroleum Gas
OEIE	Oakdale East Industrial Estate
PFD	Probability of Failure on Demand
PHA	Preliminary Hazard Analysis
Pmpy	Per million per year
RDC	Retail Distribution Centre
SEARs	Secretary’s Environmental Assessment Requirements
SEP	Surface Emissive Power
SEPP	State Environmental Planning Policy
SMSS	Storage Mode Sprinkler System

1.0 Introduction

1.1 Background

A Goodman Property Services (Aust.) Pty Ltd (Goodman) has proposed to develop a warehouse for a tenant who will store materials classified as Dangerous Goods (DG) within a warehouse at Precinct 3, Oakdale East Industrial Estate (OEIE), Horsley Park. Secretary's Environmental Assessment Requirements (SEARs) have been issued for the site which require the preparation of Chapter 3 of the State Environmental Planning Policy (SEPP, Ref. [1]) assessment and if the thresholds are exceeded a Preliminary Hazard Analysis (PHA) is required to be prepared.

A review of the DG quantities indicates they will exceed the thresholds; hence, a PHA has been prepared to assess the risks associated with the development as part of the State Significant Development Application (SSDA) in accordance with the Hazardous Industry Planning Advisory Paper (HIPAP) No. 4 and No. 6 (Ref. [2] & [3]) for submission with the Development Application (DA).

Goodman has commissioned Riskcon Engineering Pty Ltd (Riskcon) to prepare the PHA for the facility. This document represents the PHA study for the site located within Precinct 3 of the OEIE, Horsley Park.

1.2 Objectives

The objectives of the PHA project 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. [1]), and
- Demonstrate compliance of the site with the relevant codes, standards and regulations (i.e. NSW Planning and Assessment Regulation 1979, WHS Regulation, 2011 Ref. [4]).

1.3 Scope of Services

The scope of work is to complete a PHA study for the Warehouse located at Precinct 3, OEIE, Horsley Park, required by the Planning Regulations. The scope does not include any other assessments at the site nor any other facilities.

2.0 Methodology

2.1 Multi-Level Risk Assessment

The Multi-Level Risk Assessment approach (Ref. [4]) 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**.

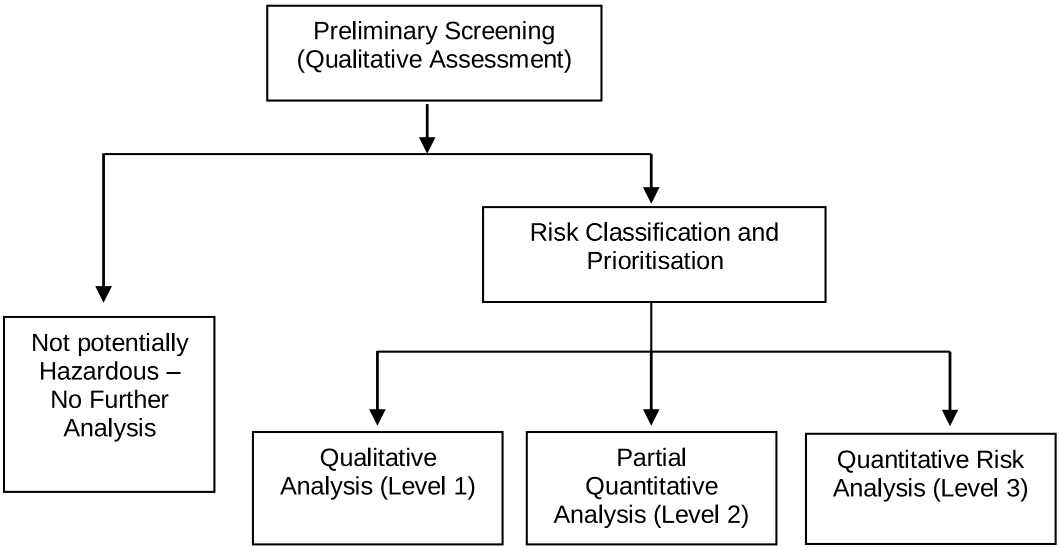


Figure 2-1: The Multi-Level Risk Assessment Approach

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 (DPE, 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 Goodman. A final report was then developed, incorporating the comments received by Goodman for submission to the regulatory authority.

3.0 Site Description

3.1 Site Location

The site is located at Precinct 3, OIEI, Horsley Park which is approximately 43 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 layout of the site in Horsley Park.

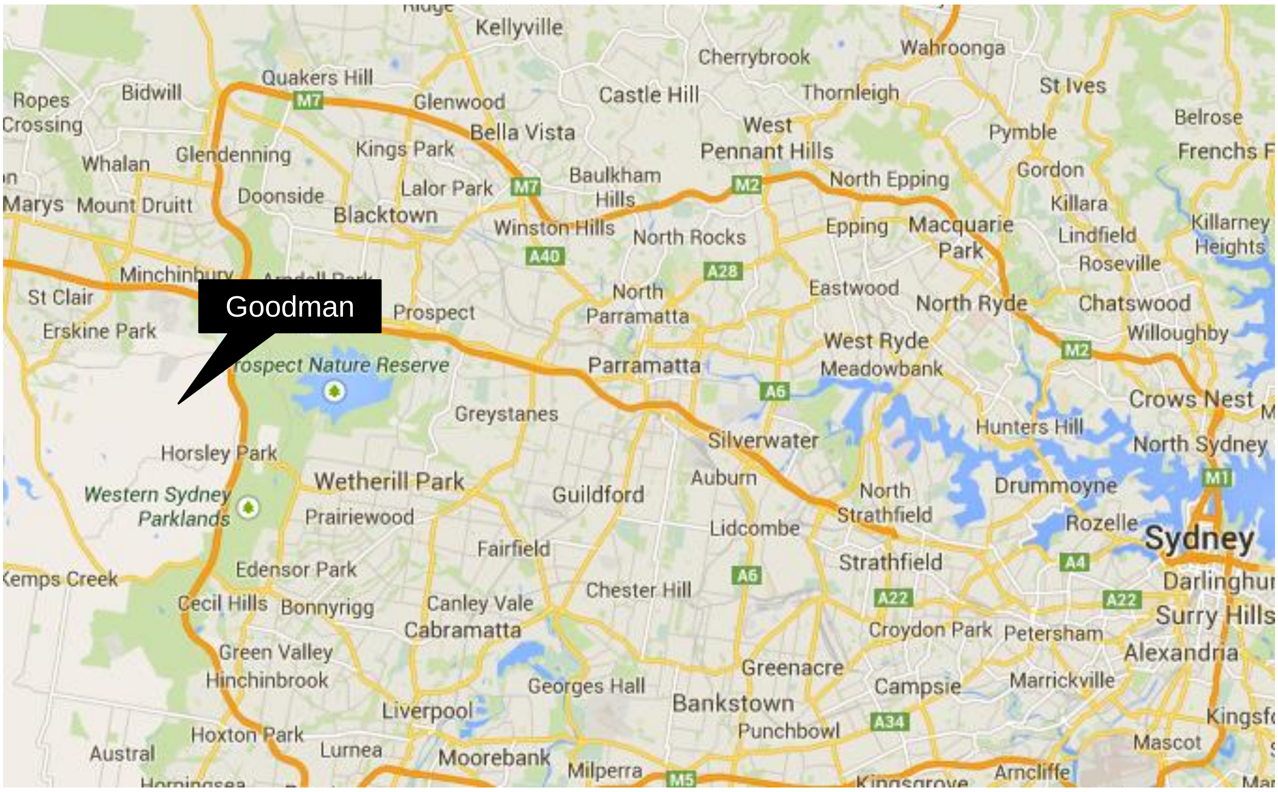


Figure 3-1: Site Location

3.2 Adjacent Land Uses

The land is located in an industrial area surrounded by the following land uses, which are adjacent to the site:

- North – Future freight corridor.
- South – Undeveloped land to be warehouses
- East – Undeveloped land to be warehouses
- West – Undeveloped land to be warehouses

3.3 Site Description

The warehouse will utilise an automated storage system which takes delivered pallets and stores them in high bay racking until required. The system stores products in a unique location which is tracked to allow accurate retrieval of products. Pallets can be collected from within the high bay storage and separated to form composite pallets containing numerous products for delivery to retailers.

The warehouse will store a range of DGs in retail packages and the facility will be designed to comply with AS/NZS 3833:2007 (Ref. [5]). Specifically, the facility will comply with the Retail Distribution Centre (RDC) section of the standard which accounts for the reduced risk posed by packages stored in restricted small volumes.

The warehouse will be protected by a bespoke automatic sprinkler system involving both ceiling mounted and in-rack sprinklers depending on commodities stored. The sprinklers which will activate upon fire detection which will suppress and control any fire that may occur. The warehouse will be naturally ventilated for occupation purposes which will provide adequate ventilation flow for preventing accumulation of any vapours released from packages in storage as required by AS/NZS 3833:2007 (Ref. [5]).

All DG products will be protected by base building specified Storage Mode Sprinkler System (SMSS) sprinklers and the aerosols and flammable liquids will be protected by in-rack sprinklers scheme A sprinkler systems designed according to AS 2118.1:2017 (Ref. [6]). All DG areas will be protected by hose reel coverage in addition to hydrant coverage. The aerosols will be stored in a cage to prevent rocketing of products.

The whole site will be capable of containing at least 90 minutes of potentially contaminated fire water as required by AS/NZS 3833:2007 (Ref. [5]) and the NSW "*Best Practice Guidelines for Contaminated Water and Retention Systems*" (Ref. [7]). The water will be contained via isolation of the stormwater system which is performed by the actuation of a penstock valve upon fire detection.

The site will be subject to a hazardous area classification per AS/NZS 60079.10.1:2009 (Ref. [8]) and any electrical equipment within the hazardous zone will be compliant per AS/NZS 60079.14:2017 (Ref. [9]) to minimise the potential for ignition of flammable vapours which may be released during storage.

The DG classes will be separated with guidance from AS/NZS 3833:2007 (Ref. [5]) with the ultimately aim of complying with the risk reduction measures of the Work Health and Safety Regulations 2017 (Ref. [10]). DGs will be stored throughout the warehouse in addition to dispersed throughout the warehouse as required (in lesser quantities).

3.4 Quantities of Dangerous Goods Stored and Handled

The classes and quantities to be approved in the facility are summarised **Table 3-1**. At this stage the exact storage locations within the warehouse are not fully defined; hence, it is difficult to allocate precise storage locations. Notwithstanding this, the DG classes will be segregated / separated in accordance with AS/NZS 3833. A DG report has been provided in **Appendix D** which provides direction to the building designers on how to achieve compliance with AS/NZS 3833.

Table 3-1: Maximum Classes and Quantities of Dangerous Goods Stored

Class	Packing Group	Description	Quantity (kg)
2.1	n/a	Flammable gas (aerosols)	460,000 / 115,000*
2.1	n/a	Flammable Gas (LPG Bullet)	7,500 L / 4,125 kg
2.2	n/a	Non-flammable, non-toxic	80,000
2.3	n/a	Ammonia	6,200
3	II & III	Flammable liquids	2,575,000
5.1	III	Oxidising agents	10,000

Class	Packing Group	Description	Quantity (kg)
8	II & III	Corrosive substances	175,000
9	III	Miscellaneous DGs	675,000
C1	III	Diesel refuelling & pumpset	300,000

*Note: This refers to the quantity of propellant within the aerosols and not the total package weight. The propellant content within the cannisters is typically around 25% of product weight.

3.5 Aggregate Quantity Ratio

Where more than one class of dangerous goods are stored and handled at the site an AQR exists. This ratio is calculated using **Equation 3-1:**

$$AQR = \frac{q_x}{Q_x} + \frac{q_y}{Q_y} + [\ldots] + \frac{q_n}{Q_n}$$ **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 quantity for each class is taken from Schedule 15 of the Work Health and Safety (WHS) Regulation 2017 (Ref. [10]). These are summarised in **Table 3-2** noting Class 8, is not subject to MHF legislation.

Table 3-2: Major Hazard Facility Thresholds

Class	Packing Group	Threshold (tonnes)	Storage (tonnes)
2.1	n/a	200	115
2.1	II & III	200	4.125
2.2	I & II	n/a	80
2.3	III	200	6.2
3	II & III	50,000	2,575
5.1	III	n/a	10
8	II & III	n/a	175
9	III	n/a	675
C1	n/a	n/a	300

A review of the thresholds and the commodities and packing groups listed in **Table 3-1** indicates only Class 2.1, 2.3, and 3 are assessable against the MHF thresholds. Therefore, substituting the storage masses into **Equation 3-1** the AQR is calculated as follows:

$$AQR = \frac{115}{200} + \frac{4.125}{200} + \frac{6.2}{200} + \frac{2{,}575}{50000} = 0.68$$

The AQR is less than 1; hence, the facility would not be classified as an MHF. The site would exceed 10% of the MHF threshold; hence, would require notification to SafeWork NSW as a potential MHF.

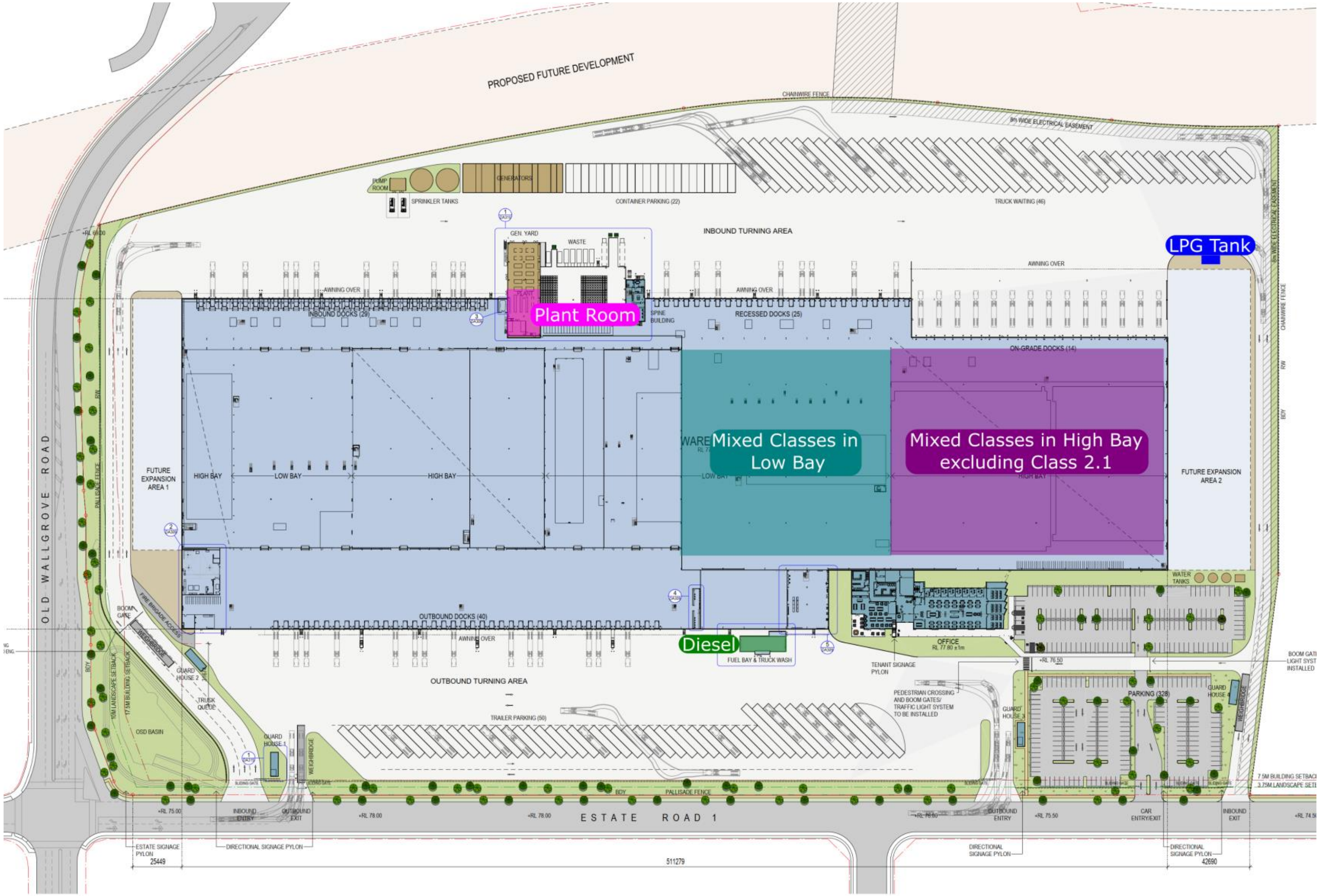


Figure 3-2: Site Layout

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 more than several hundred meters 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 over more than several hundred meters from the site.

- *Toxicity* – Toxic substances are proposed to be stored and have been assessed as part of the assessment based upon the toxicological effects of the products stored.

- *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 more than several hundred meters 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. Where gas released under pressure from a hole in a pressurised component is ignited, a jet fire may occur.
2.2 – Non-Flammable, Non-Toxic Gases	Class 2.2 includes non-flammable and non-toxic gases which are asphyxiant (dilute or replace the oxygen normally in the atmosphere).
2.3 – Toxic gases (Anhydrous Ammonia)	Ammonia is a colourless toxic gas which is highly hydroscopic (i.e. water soluble). At an ammonia concentration of 0.5% (5,000 ppm, Ref. [11]) a fatality will occur within minutes of exposure. Within concentration limits of 15% – 33.6% (150,000 – 336,000 ppm, Ref. [12]) ammonia can ignite given the right conditions, resulting in fire and/or explosion. It is noted that ignition of ammonia is difficult and can only be achieved by a high-energy source. In addition, sustained ignition of ammonia (i.e. burning) rarely occurs as the heat of the flame is less than the heat of ignition. Ammonia is used as a raw material for the synthesis of fertilisers, cleaning agent or refrigeration.
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.
5.1 -Oxidising Agents	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

Class	Hazardous Properties
	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.
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. [13]).

4.3 Hazard Identification

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

- Flammable liquid or gas release, delayed ignition and flash fire or explosion.
- Flammable material spill, ignition and racking fire.
- LPG release (from aerosol), ignition and racking fire.
- Full warehouse fire and radiant heat.
- Full warehouse fire and toxic smoke emission.
- Dangerous goods liquid spill, release and environmental incident.
- 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.
- Diesel tank, damage and release, ignition and fire.
- Diesel tank, damage and release to environment.
- Ammonia loss of containment, and toxic gas dispersion.

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

4.4 Flammable Liquid or Gas Release, Delayed Ignition and Flash Fire or Explosion

As noted in **Section 3.0**, flammable liquids will be held at the site for storage and distribution. There is potential that a flammable liquid spill could occur in the warehouse area due to an accident (packages dropped from forklift, punctured by forklift tines) or deterioration of packaging. If a flammable liquid spill occurred, the liquid may begin to evaporate (depending on the material flashpoint and ambient temperature). Where materials do evaporate, there is a potential for accumulation of vapours, forming a vapour cloud above the spill.

If the spill is not identified, the cloud may continue to accumulate, eventually contacting an ignition source. If the cloud is confined (i.e. pallet racking and stored products) the vapour cloud may explode if ignited, or, if it is unconfined, it may result in a flash fire which would burn back to the flammable liquid spill, resulting in a pool fire.

A similar scenario could occur with the release of Liquefied Petroleum Gas (LPG) from an aerosol; however, the formation of a gas cloud would occur immediately as the LPG would instantly flash to gas following release from the canister. It is noted that the potential for a release of LPG is low as aerosol canisters are pressure tested during manufacture and filling, hence, release would predominately result from damaged product rather than deterioration.

A review of the product list to be stored indicates the products are small retail packages as defined by AS/NZS 3833:2007 (Ref. [5]). Therefore, the release from a single flammable liquid container would result in a release <20 L. For flammable gas canisters, the quantity of flammable gas released would be <1 L in the worst-case release. The associated vapour cloud formed by the release of gas or flammable liquid would be insufficient to result in offsite impacts from ignition.

Packages are inspected for damage upon receipt at the loading dock before they are transported into the warehouse. This minimises the likelihood a damaged package is incorrectly stored. Once stored inside the warehouse, deterioration or damage are unlikely to occur.

To minimise the likelihood a flammable vapour cloud may contact an ignition source, the electrical equipment within the DG store hazardous zone will be installed according to the requirements of AS/NZS 60079.14:2017 (Ref. [9]).

It has been proposed to seek approval to operate the site 24 hours a day 7 days a week however the site will be unlikely to be used for these proposed hours of operation. Therefore, if a spill occurred, it would be identified by personnel working in the warehouse where it could be immediately cleaned up. To ensure appropriate cleaning equipment is available, the following recommendation has been made:

- Multiple spill kits be provided around the DG storage areas to ensure spills can be cleaned up immediately following identification.

Based on the warehouse design (controlled ignition sources, etc.), operation practices and the storage of small packages, the risk of a vapour cloud being generated that is large enough to ignite and impact over the site boundary, by way of a vapour cloud explosion or a flash fire, is considered to be low (if not negligible); hence, this hazard has not been carried forward for further analysis.

4.5 Flammable Material Spill, Ignition and Racking Fire

As noted in **Section 4.4**, it is considered that there is a low potential for a package to leak resulting in a flammable material spill and there are several controls in place to minimise the likelihood of a damaged container entering the warehouse and additional controls to minimise the potential that ignition of a flammable material spill could occur.

If a flammable material spill was to occur (e.g. dropped pallet or package during handling) and it was ignited (e.g. by the forklift), the fire would initially be small due to the majority of packages stored being 20 L or less. While a fire would be limited in size, heat generated may impact adjacent packages which may deteriorate and release their contents contributing additional fuel to the fire. As the fire grows Storage Mode Sprinkler System (SMSS) would activate controlling the fire within the sprinkler array and cooling adjacent packages preventing deterioration and reducing the potential for fire growth.

Based on the limited fire size, the design of the warehouse and the installed fire systems, the risks of this incident impacting over the site boundary are considered to be low. Notwithstanding this, this incident has been carried forward for further analysis to demonstrate that the likely impact of an SMSS controlled fire is within the site boundary.

4.6 LPG Release (from Aerosol), Ignition and Racking Fire

As noted in **Section 4.4**, the potential for release of LPG from an aerosol is considered low due to the quality assurance testing on aerosol canisters during the filling process. The release of LPG would likely result from damage to aerosols during transport and storage rather than from deterioration. Packages are inspected upon delivery and an accident involving aerosols would trigger an additional inspection to verify that damage had not occurred prior to storage within the warehouse.

Notwithstanding this, there is the potential for a release of LPG to occur within the storage racking. Due to the hazardous area rated equipment within the area and protocols, it is considered unlikely for an ignition to occur; however, in the event that an ignition of an LPG release did occur a fire could result.

The fire would consume the packaging with the generated heat impacting the adjacent aerosols. As the LPG within the adjacent aerosols expands the canisters may rupture releasing LPG which would ignite and rocket the canister throughout the aerosol cage potentially spreading the fire.

As the fire grows, the SMSS is expected to activate to suppress the fire and cool adjacent packages to minimise the potential for aerosol rupture and rocketing. Activation of this system would control the fire within the sprinkler array.

A sprinkler-controlled fire within the aerosol racking would be unlikely to impact over the site boundary; notwithstanding this, this incident has been carried forward for consequence analysis.

Notwithstanding the above, the following recommendation has been made:

- Aerosols shall be stored in a dedicated storage area which prevents rocketing cans from escalating the incident (i.e. storage in an aerosol cage, separate storage area, or in palletised aerosol cages).

4.7 Full Warehouse Fire and Radiant Heat

There is potential that if a fire occurred and the fire protection systems failed to activate, a small fire may escalate as radiant heat impacts adjacent packages resulting in deterioration and release of additional fuel. While it is considered unlikely for a fire to occur simultaneously with the sprinkler system failing to operate there is the potential for this scenario to occur. Therefore, this incident has been carried forward for further analysis.

4.8 Full Warehouse Fire and Toxic Smoke Emission

As discussed in **Section 4.7** there is the potential for a full warehouse fire to occur in the event of sprinkler failure. During combustion toxic products of combustion may be generated which will be dispersed in the smoke plume which may impact downwind from the site. Depending on the toxicity of the bi-products, this may result in injury or fatality. Therefore, this incident has been carried forward for further analysis.

4.9 Dangerous Goods Liquid Spill, Release and Environmental Incident

There is potential that a spill of the liquid DGs (Class 3, 5.1, 6.1, and 8) could occur at the site which if not contained could be released into the public water course resulting in a potential environmental incident.

To prevent spills escaping from the site per the requirements of AS/NZS 3833:2007 (Ref. [5]) the following recommendation has been made:

- The site shall be designed to contain any spills or contaminated water from a fire incident within the boundaries of the site.

The site will also be designed to prevent the release of any spills from the site, including potentially contaminated water. Therefore, the potential for a release is considered unlikely as this is expected to be contained within the footprint of the warehouse. Nonetheless, in the event of a catastrophic scenario and spills are released from the footprint of the warehouse, it will be necessary to prevent this from being released into the public water course. Therefore, the following recommendation has been made:

- 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.

As noted, the volumes of the packages are small (< 20 L) and the site will be designed with a drain isolation system, allowing the containment of any spills within the premises; hence, in the event of a release the full volume will be contained within the warehouse area. As a spill would be contained within the bund/site drainage there is no potential for an environmental incident to occur; hence, this incident has not been carried forward for further analysis.

4.10 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 6 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. [7]), 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.

As noted in **Section 4.9**, an automatic isolation valve has been recommended to be incorporated into the design to prevent the release of potentially contaminated water. Therefore, the volume within the stormwater system can also be used in calculation total volume contained.

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. [7]), hence, this incident has not been carried forward for further analysis.

4.11 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. [8]) 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.

4.12 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.

4.13 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 4.12**, 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 7.5 kL tank the separation distance to a protected place is approximately 6 m. Therefore, the standard would consider that in open air, events resulting from a release from the tank would be unlikely to significantly impact >6 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.

4.14 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 4.13** 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.

4.15 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 4.13** 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 4.14**. Hence this incident has been carried forward for further analysis.

4.16 Diesel Tank, Damage and Release, Ignition and Fire

Diesel will be stored in a small integrally bunded tanks for to be used in a generator set. The tank will be designed according to Clause 5.9 of AS 1940:2017 (Ref. [17]); hence, the tank will be capable of containing the full volume of the liquid within the separate tanks, should deterioration of the internal tank occur.

There is potential for overfilling to occur if the overfill sensors and alarms fail and the operator fails to respond to an overfill which may result in a spill. However, diesel is classified as a combustible liquid; hence, it does not emit flammable vapours at ambient temperatures and subsequently it is difficult to ignite.

Finally, a release may occur if a vehicle were to impact the tanks as this may damage both the primary and secondary tanks. The diesel tanks will be protected by impact protection which will prevent any wayward vehicles from contacting the tank; hence, catastrophic damage is unlikely to occur.

As the tanks have been designed to fully contain failure of the internal tank, the potential for releases externally to the tank is considered to be low. In addition, the potential for diesel to ignite is very low due to the high flash point; therefore, this incident has not been carried forward for further analysis.

4.17 Diesel Tank, Damage and Release to Environment

As discussed in **Section 4.16**, the potential for diesel to spill externally to the tank is low due to the double skinned nature of the tanks, the overfill protections, trained operators being present during transfers and impact protection. Therefore, a major release of diesel is not considered a credible event and is not carried forward for further analysis.

4.18 Ammonia Loss of Containment and Toxic Gas Dispersion

The proposed refrigeration system will utilise ammonia which is a Class 2.3 toxic gas. In the event of loss of containment (i.e. ruptured vessel, pipework, seals, etc.) there is the potential for ammonia to be released which would disperse downwind from the release point. Depending upon the flow rate of the release, the dispersion may have sufficient concentration to impact over the site boundary which may result in an injury or fatality.

The proposed quantity of ammonia to be stored is 6,200 kg which exceeds SEPP 33; however, the plant room is located centrally within the site with the shortest distance to the site boundary being approximately 90 m allowing substantial time for dispersion. The ventilation exhaust point from the plant room would be approximately 16 m above ground which would provide substantial vertical distance for dispersion in addition to the 90 m lateral distance. Therefore, it is considered that the majority of release scenarios from the plant room would be dispersed prior to impact ground level over the site boundary. Large releases (i.e. vessel failure) may result in sufficient concentration to impact over the site boundary and at ground level; however, these are low frequency events and would fall below the acceptable criteria.

The refrigeration system will be designed in accordance with AS 2022:2003 (Ref. [11]) which provides the design requirements to minimise the risks associated with an ammonia system by ensuring appropriate isolations and protections are incorporated into the design.

Based upon the location of the the plantroom and the release height, it is considered that there would be sufficient distance and height to result in sufficient dispersion to prevent unacceptable impacts at the site boundary; hence, this incident has not 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 material spill, ignition and racking fire.
- LPG release (from aerosol), ignition and racking fire.
- Full warehouse fire and radiant heat.
- Full warehouse fire and toxic smoke emission.
- 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 Material Spill, Ignition and Racking Fire

There is the potential for a fire to develop involving flammable material stored within the warehouse resulting in a racking fire. As the fire grows the SMSS would activate suppressing and controlling the fire while cooling adjacent packages minimising the potential for lateral spread due to radiant heat. A detailed analysis has been conducted in **Appendix B** and the radiant heat impact distances estimated for this scenario are presented in **Table 5-1** with the contours illustrated in **Figure 5-1.**

Table 5-1: Heat Radiation from a Flammable Liquid Racking Fire

Heat Radiation (kW/m^2)	Distance (m)	
	Base Case	Sensitivity
35	4.0	7.0
23	4.0	9.0
12.6	5.0	10.0
4.7	8.0	18.0

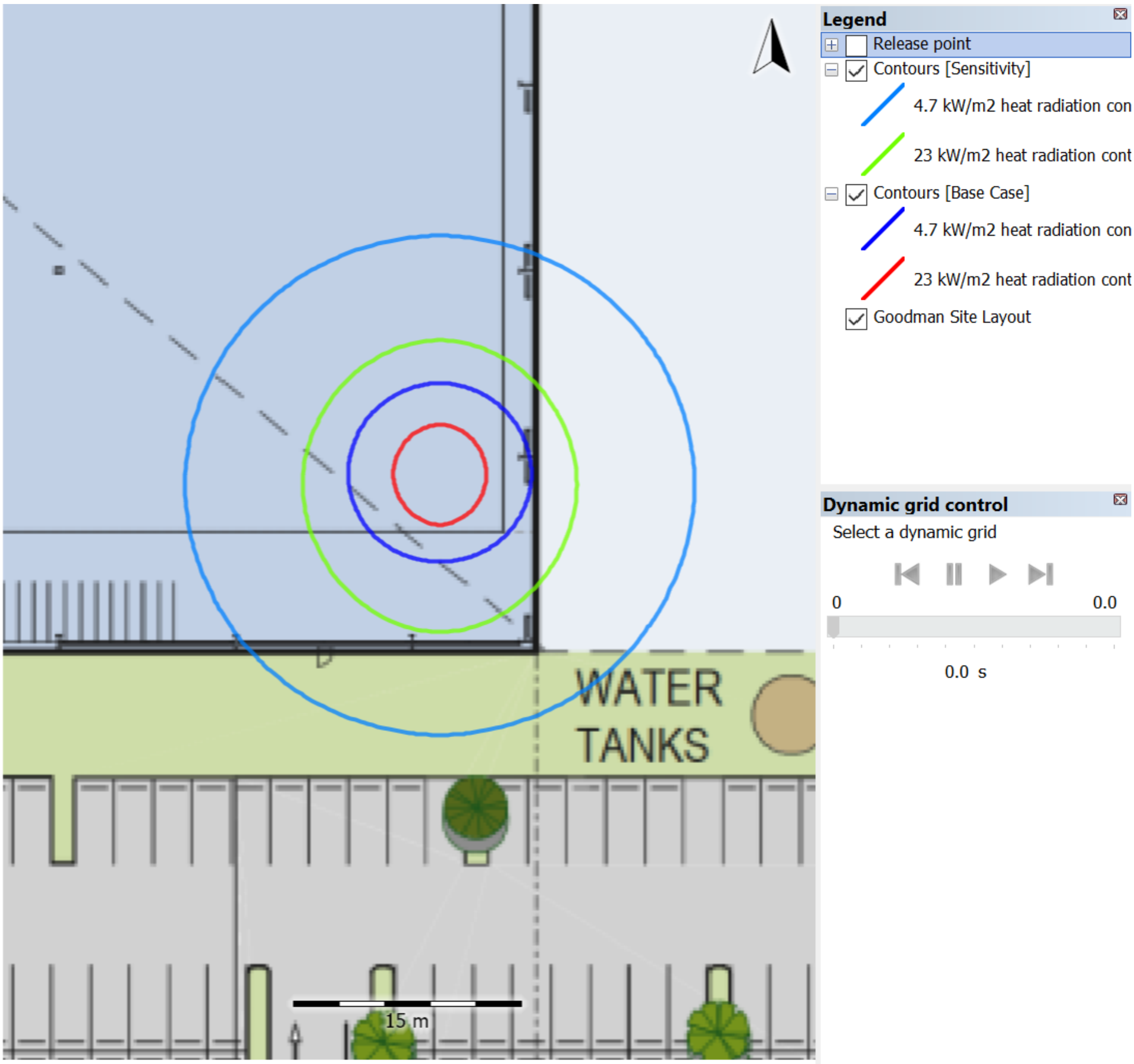


Figure 5-1: Sprinkler Controlled Flammable Material Fire Radiant Heat Contours

A review of the contours illustrated in **Figure 5-1** indicates that neither the 4.7 nor the 23 kW/m^2 contours impact over the site boundary. As there is no offsite impact, this incident has not been carried forward for further analysis.

5.3 LPG Release (from Aerosol), Ignition and Racking Fire

A damaged aerosol canister could result in the release of LPG which if ignited may result in a fire. As the fire grows the radiant heat may impact adjacent aerosol storage heating the LPG within aerosol cans which may rupture rocketing the canisters around the aerosol store. The heat generated from the fire will activate the SMSS which will suppress and control the fire while cooling adjacent packages minimising the potential for lateral fire spread due to radiant heat. A detailed analysis has been conducted in **Appendix B** and the radiant heat impact distances estimated for this scenario are presented in **Table 5-2.**

Table 5-2: Heat Radiation from an Aerosol Racking Fire

Heat Radiation (kW/m²)	Distance (m)	
	Base Case	Sensitivity
35	6.0	13.0
23	7.0	16.0
12.6	9.0	22.0
4.7	14.0	34.0

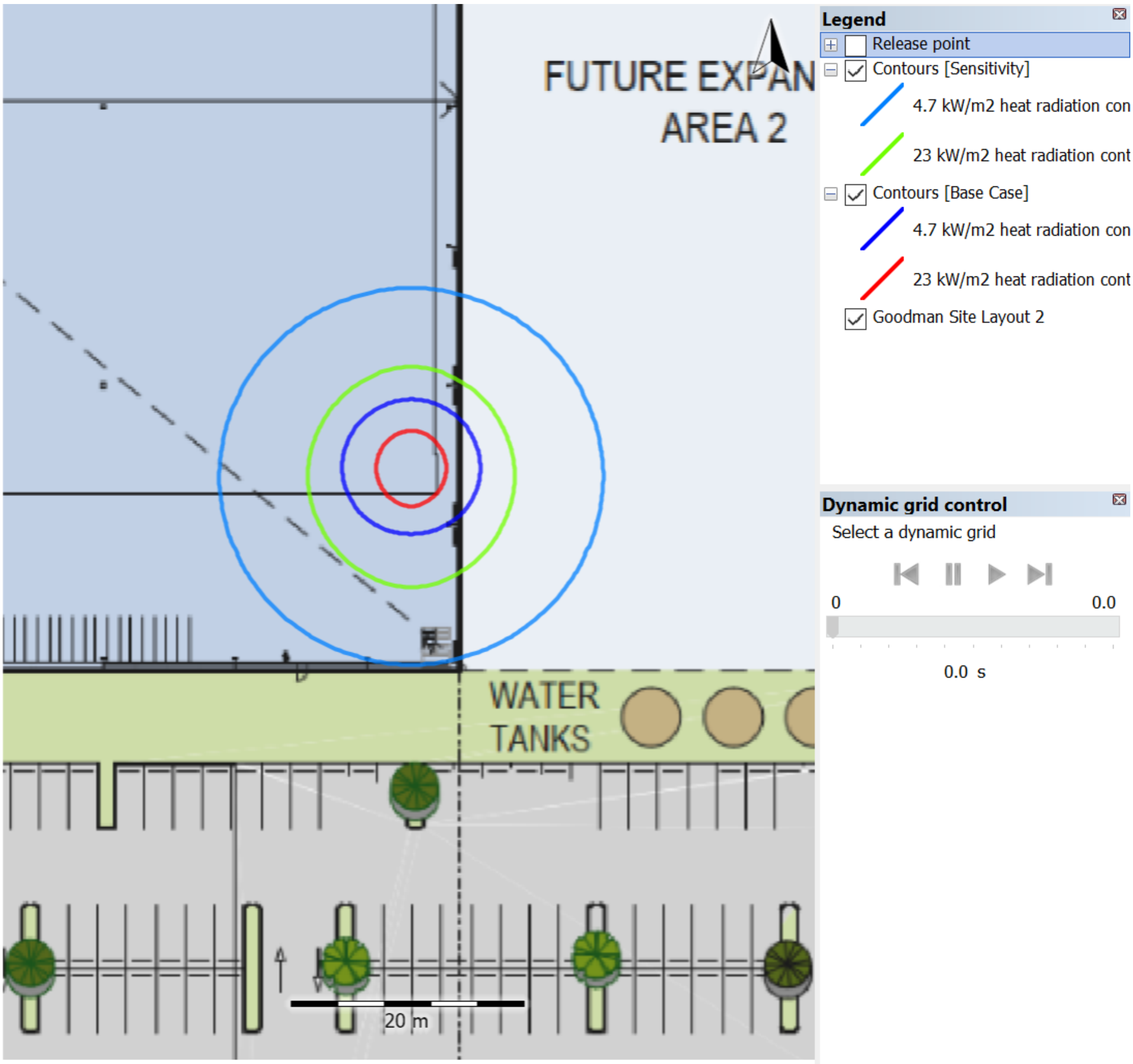


Figure 5-2: Sprinkler Controlled Aerosol Fire Radiant Heat Contours

A review of the contours illustrated in **Figure 5-2** indicates that neither the 4.7 kW/m² nor the 23 kW/m² contours impact over the site boundary. As there is no offsite impact, this incident has not been carried forward for further analysis.

5.4 Full Warehouse Fire and Radiant Heat

If a fire occurs within the DG store and the sprinkler systems fail to activate, the fire will spread throughout the warehouse and is unlikely to be contained and would likely consume the entire warehouse. A detailed analysis has been conducted in **Section B6** of **Appendix B** and the radiant heat impact distances estimated for this scenario are presented in **Table 5-3**.

Table 5-3: Radiant Heat Impact Distances from a Full Warehouse Fire

Heat Radiation (kW/m²)	Distance (m)	
	Western	Eastern
35	146	143
23	153	150
12.6	175	173
4.7	232	231

As shown in **Figure 5-3**, the radiant heat impacts at 4.7 kW/m² extend over the site boundary; hence, there is the potential for a fatality at the site boundary to occur. A review of the 23 kW/m² contour indicates it does not impact over the site boundary; therefore, incident propagation is not expected to occur. As there is the potential for an offsite impact to occur at 4.7 kW/m² there is the potential for a fatality to occur; hence, this incident has been carried forward for further analysis.

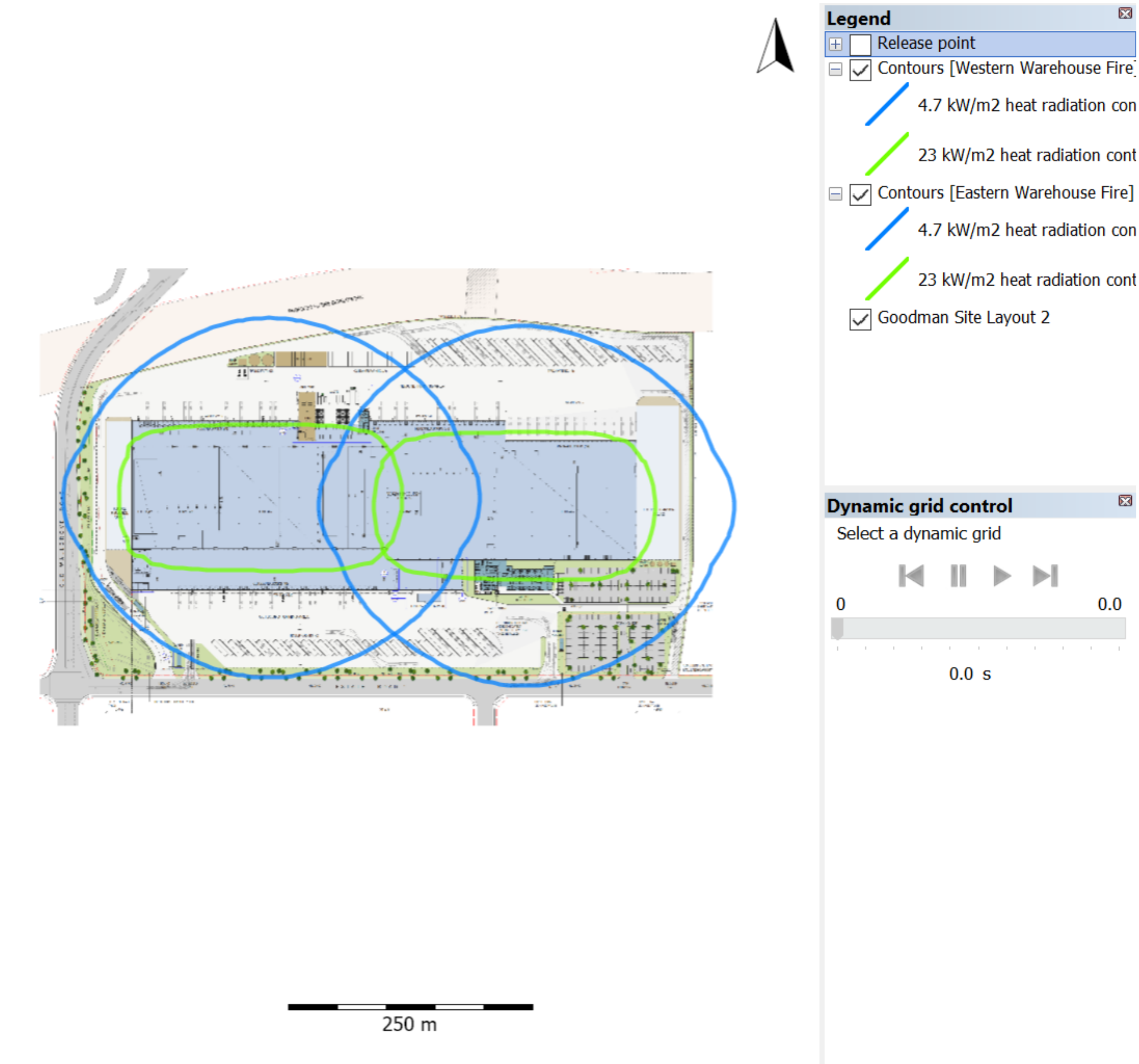


Figure 5-3: Full Warehouse Fire Radiant Heat Contours

5.5 Full Warehouse Fire and Toxic Smoke Emission

A detailed analysis has been performed in **Section B7** of **Appendix B** to estimate the impact of toxic bi-products of combustion on the surrounding area. The modelling identified four (4) primary pollutants of concern which may result in downwind impacts; nitrogen dioxide, sulphur dioxide, hydrogen chloride, and soot (carbon) with soot being more for visual disturbance to the surrounding area. The pollutant rates calculated for each pollutant has been shown in **Table 5-4**.

Table 5-4: Full Warehouse Fire Pollutant Release Rates

Material	Release Rate (kg/s)
Nitrogen Dioxide	52.6
Sulphur Dioxide	91.1
Hydrogen Chloride	46.2

Material	Release Rate (kg/s)
Soot (Carbon)	104.6

The model calculates the interaction of the plume with the inversion layer to determine whether a ground level impact would occur from a warehouse fire. The results of the analysis indicates that the heat generated from the fire would be sufficient to pierce the inversion irrespective of the atmospheric stability. As the plume cools it will settle above the inversion layer but would not re-enter below the inversion layer. Therefore, ground level impact is not expected to occur from the warehouse fire.

As the plume would not impact at ground level, the potential for injury or fatality is considered negligible and be unlikely to exceed the acceptable criteria. Notwithstanding the low potential for injury or fatality to occur downwind, this incident has been carried forward for conservatism.

5.6 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 B8** for this scenario which indicates the jet fire would have an impact of distance of 26.3 m. The impact distances for this incident are shown in **Figure 5-4**.

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.

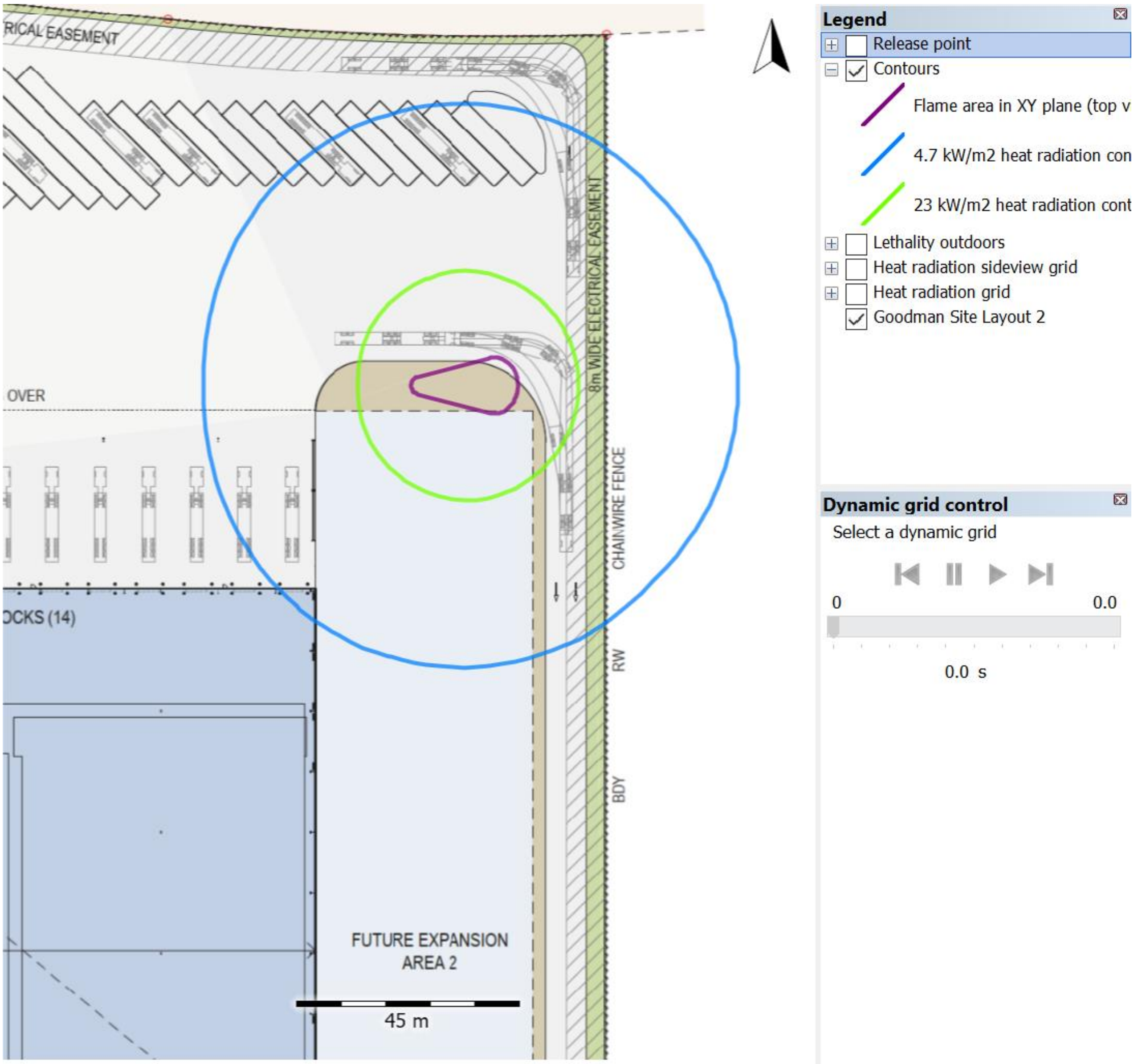


Figure 5-4: Impact from a Jet Fire

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.

5.7 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 B9**. The impact distances for this incident are shown in **Figure 5-5**.

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.

It is noted that the 23 kW/m[2] radiant heat contour from a BLEVE would impact over the site boundary which would normally require the assessment of incident propagation; however, the fireball is a short-lived event lasting a matter of seconds which is insufficient to result in sustained heating to result in incident propagation. Therefore, the potential for incident propagation to occur has not been carried forward for further analysis.

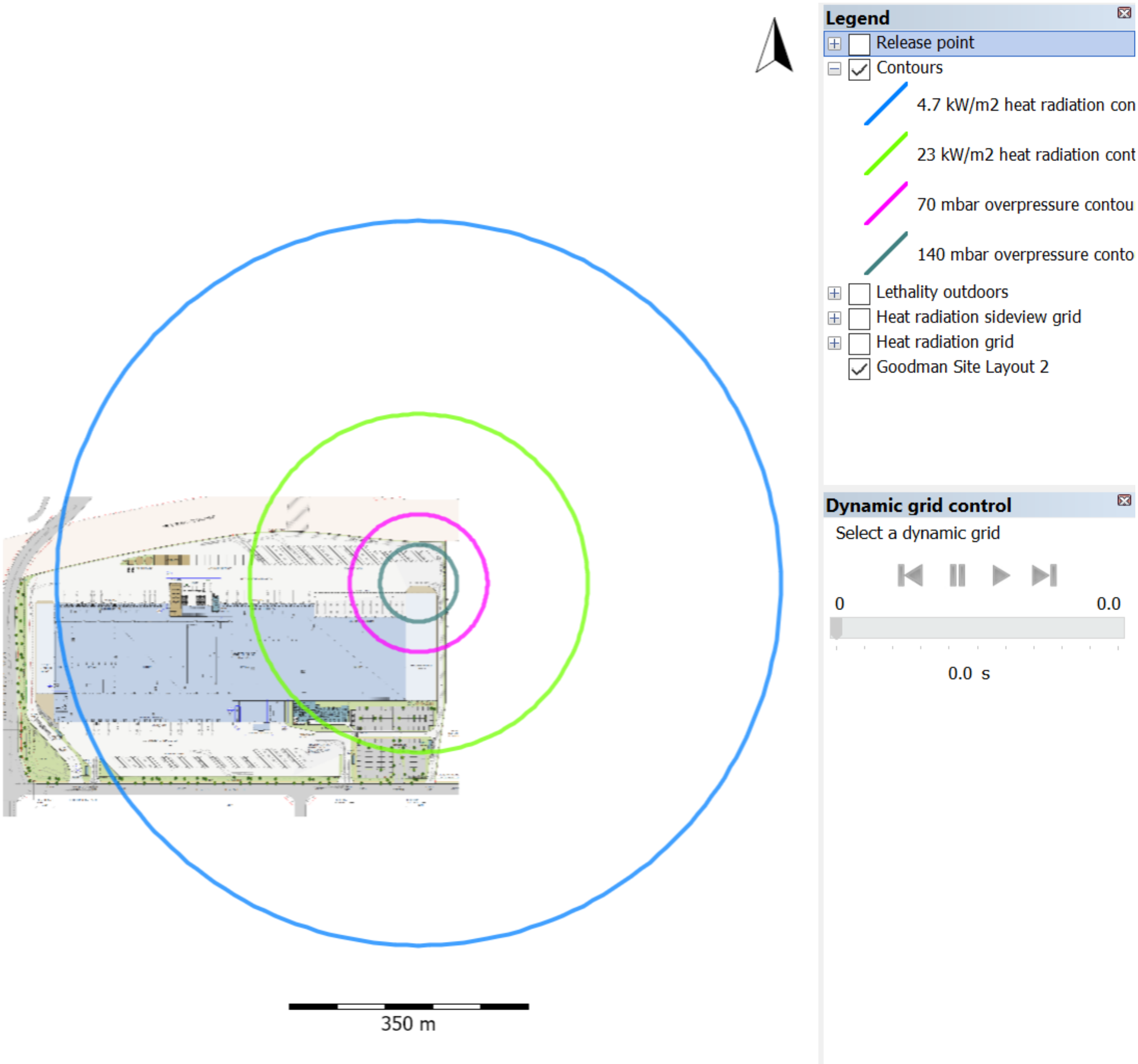


Figure 5-5: LPG Tanker BLEVE Impact Distances

5.8 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 B10** The impact distances for this incident are shown in **Figure 5-6** as this has the same fuel profile as the tanker scenario.

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 the 23 kW/m^2 radiant heat contour from a BLEVE would impact over the site boundary which would normally require the assessment of incident propagation; however, the fireball is a short-lived event lasting a matter of seconds which is insufficient to result in sustained heating to result in incident propagation. Therefore, the potential for incident propagation to occur has not been carried forward for further analysis.

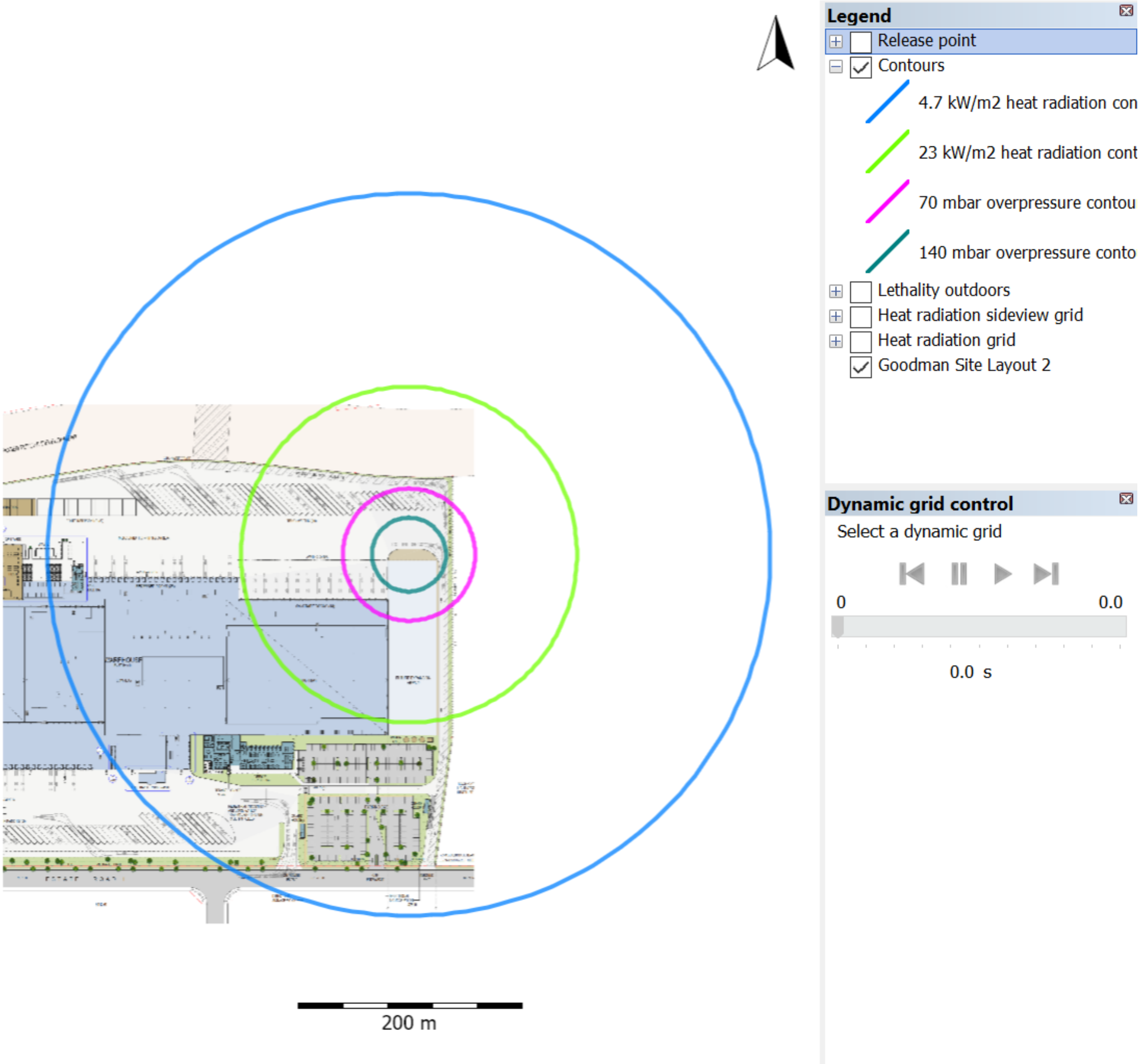


Figure 5-6: LPG Tank BLEVE Impact Distances

6.0 Frequency Analysis

6.1 Incidents Carried Forward for Frequency Analysis

The following item has been carried forwards for frequency analysis;

- Full warehouse fire and radiant heat.
- Full warehouse fire and toxic smoke emission.
- 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 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 Full Warehouse Fire Frequency and Risk Assessment

The frequency of a full warehouse fire at the site can be estimated from a number of sources (e.g. general warehouse fire frequencies or the summation of individual fire frequencies for each of the initiating fire events). As this is a preliminary hazard analysis, the fire frequency has been selected from general fire frequency data.

A detailed fire frequency analysis has been conducted in **Appendix C**. The results of this analysis indicate that an initiating fire frequency would be in the order of $1x10^{-3}$ p.a.

It is noted that the site is fitted with multiple automatic sprinkler systems that will initiate on fire detection, controlling the fire and preventing the fire growth to a full warehouse fire. The Centre for Chemical Process Safety (CCPS) provides failure rate data for water fire protection systems including all components (pump, distribution system, nozzles, seals, piping, controls and base plate) of 9.66 per 10^{6} hours (Ref. [18]). The hourly failure rate is converted to failures per annum by:

Failures per Annum = Failures per hour x 8760 hours per year

Failures per Annum = $9.66x10^{6}$ x 8760 = 0.085

The system will only operate when a fire is detected; hence, the system operates in demand mode. The protection system will be tested monthly totalling 12 tests per annum. The probability of failure on demand (PFD) is estimated using:

$$PFD = \frac{1}{2}\lambda_{du}\left(\frac{1}{t}\right)$$

Where:

λ_{du} = dangerous undetected failures of a component

t = 1/number of test intervals per annum

PFD = 0.5 (0.085) (1/12) = 0.00353

Hence, the frequency of a full fire within the warehouse is the frequency of an initiating fire x the probability of fail on demand (PFD) of the automatic fire fighting system as shown in **Figure 6-1**.

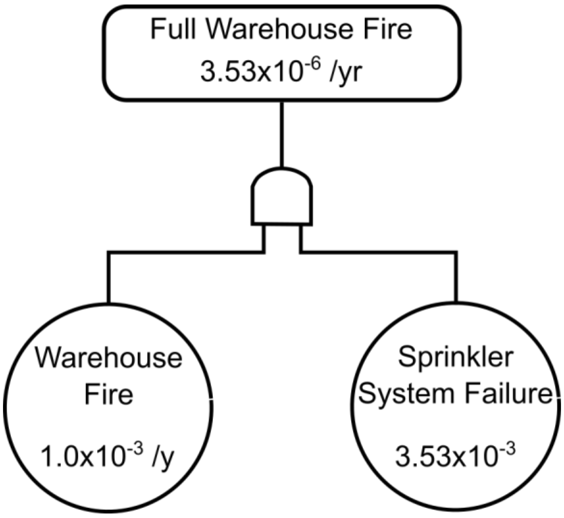


Figure 6-1: Full Warehouse Fire Fault Tree

Conservatively assuming a 100% chance of fatality at the site boundary for a person exposed to radiant heat from a full warehouse fire, the probability of fatality at the site boundary becomes 3.53×10^{-6} x 1 = 3.53×10^{-6} chances of fatality per year or 3.53 chances of a fatality in a million per year (pmpy).

6.4 Full Warehouse Fire and Toxic Smoke Emission Frequency and Risk Assessment

The toxic smoke emission (or toxic bi-products of combustion) is based on the initiating event which is the formation of a full warehouse fire. Therefore, the frequency of the toxic smoke emission is the same as that of the full warehouse which was identified to be 3.53×10^{-6} p.a.

For conservatism, it has been assumed exposure to the smoke will result in an fatality at the site boundary; therefore, the fatality risk of exposure to the toxic smoke becomes 3.53×10^{-6} x 1 = 3.53 chances pmpy.

6.5 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	1.04×10^{-5} (Frequency)
Excess flow valve	6.5×10^{-3}
Non-return valve	6.5×10^{-3}
Emergency Stop	2.71×10^{-5}
Isolation Valves	5×10^{-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. [19]) and Human Factors in QRA (Ref. [20]) 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. [21]) 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 6-2**. The analysis indicates a jet fire will occur with a frequency of 4.04×10^{-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.

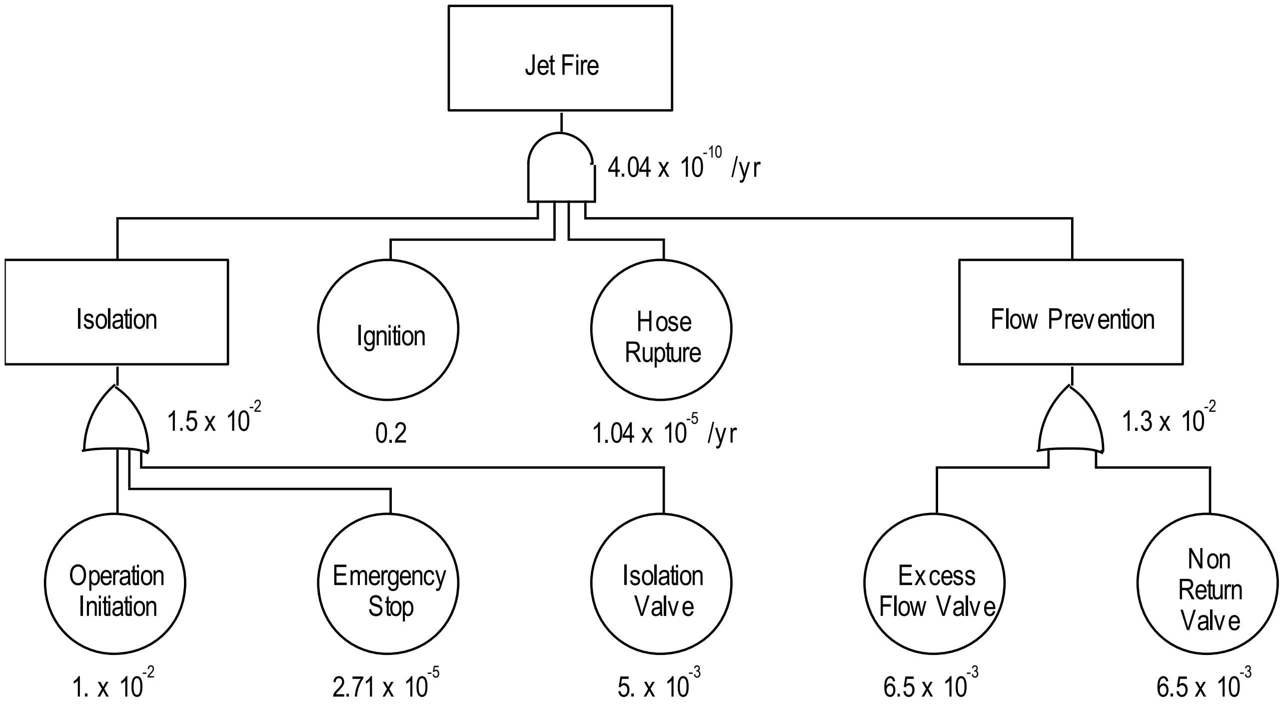


Figure 6-2: Jet Fire Frequency

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

6.7 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.

6.8 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 7.06 chances per million per year (pmpy)

Table 6-2: Total Fatality Risk

Incident	Fatality Risk
Full warehouse fire	3.53×10^{-6}
Smoke emission	3.53×10^{-6}
Jet fire	4.04×10^{-10}

Incident	Fatality Risk
Tanker BLEVE	4.04×10^{-10}
Tank BLEVE	4.04×10^{-10}
Total	**7.06×10^{-6}**

6.9 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 uses are 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 7.06 pmpy at the closest site boundary (northern 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.

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.

6.10 Cumulative Assessment

A review of the surrounding area indicates there are several warehouses within the vicinity; however, an understanding of the area indicates there are no warehouses storing substantial quantities of DGs within the area; hence, cumulative risks are not considered to be a risk at this stage.

7.0 Conclusion and Recommendations

7.1 Conclusions

A hazard identification table was developed for the 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 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 scenarios would impact over the site boundary and into the adjacent land use; hence, these incidents were carried forward for frequency analysis and risk assessment.

The frequency analysis and risk assessment showed that the full warehouse fire would have a fatality risk of 7.06 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 from a full warehouse fire at the site boundary is within the acceptable risk criteria.

A review of the potential for incident propagation indicated the only incidents which exceeded propagation criteria were radiant heat impacts from Boiling Liquid Expanding Vapour Cloud Explosion (BLEVE) incidents associated with the Liquefied Petroleum Gas (LPG) tanks. However, such incidents are short-lived and are unlikely to result in sustained impact sufficient to result in incident propagation. As the potential for incident propagation was not considered credible, the criteria of 50 pmpy for incident propagation would not be exceeded.

Review of the estate proposal indicates this development is the only contributor to the risk profile at this stage; hence, cumulative risk is not a consideration at this stage. The cumulative risk at the site is therefore the reported 7.06 chances pmpy which is below the 50 chances pmpy limit. Therefore, the development does not increase the cumulative risk of the estate to an unacceptable level.

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:

- Notify SafeWork NSW that the site exceeds 10% of the Major Hazard Facility threshold.
- The site shall be designed to contain any spills or contaminated water from a fire incident within the boundaries of the site.
- Multiple spill kits be provided around the DG storage areas to ensure spills can be cleaned up immediately following identification.

- 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.

8.0 References

[1] NSW Department of Planning and Environment, “Applying SEPP33 – Hazardous and Offensive Developments,” NSW Department of Planning and Environment, Sydney, 2011.

[2] Department of Planning, “Hazardous Industry Planning Advisory Paper No. 4 - Risk Criteria for Land Use Safety Planning,” Department of Planning, Sydney, 2011.

[3] Department of Planning, “Hazardous Industry Planning Advisory Paper No. 6 - Guidelines for Hazard Analysis,” Department of Planning, Sydney, 2011.

[4] Department of Planning, Multi-Level Risk Assessment, Sydney: Department of Planning, 2011.

[5] Standards Australia, “AS/NZS 3833:2007 - Storage and Handling of Mixed Classes of Dangerous Goods, in Packages and Intermediate Bulk Containers,” Standards Australia, Sydney, 2007.

[6] Standards Australia, “AS 2118.1:2017 - Automatic Fire Sprinkler Systems General Systems,” Standards Australia, Sydney, 2017.

[7] NSW Department of Planning, “Best Practice Guidelines for Contaminated Water Retention and Treatment Systems,” NSW Department of Planning, Sydney, 1994.

[8] Standards Australia, AS/NZS 60079.10.1:2009 - Explosive Atmospheres Part 10.1: Classification of Areas, Explosive Gas Atmospheres, Sydney: Standards Association of Australia, 2009.

[9] Standards Australia, AS/NZS 60079.14:2017 - Explosive Atmospheres Part 14: Electrical Installations, Design, Selection and Erection, Sydney: Standards Australia, 2017.

[10] SafeWork NSW, “Work Health and Safety Regulation,” SafeWork NSW, Lisarow, 2017.

[11] Standards Australia, “AS/NZS 2022:2003 - Anhydrous Ammonia - Storage and Handling,” Standards Australia, Sydney, 2003.

[12] Standards Australia, “AS/NZS 60079.20.1:2012 - Material characteristics for gas and vapour classification - test methods and data,” Standards Australia, Sydney, 2012.

[13] Road Safety Council, The Australian Code for the Transport of Dangerous Goods by Road and Rail Edition 7.7, Canberra: Road Safety Council, 2020.

[14] Road Safety Council, The Australian Code for the Transport of Dangerous Goods by Road and Rail Edition 7.4, Canberra: Road Safety Council, 2016.

[15] Standards Australia, AS/NZS 1596:2014 - The Storage and Handling of LP Gas, Sydney: Standards Australia, 2014.

[16] Standards Australia, "AS 1210:2010 - Pressure Vessels," Standards Australia, Sydney, 2010.

[17] Standards Australia, AS 1940-2017 - Storage and Handling of Flammable and Combustible Liquids, Sydney: Standards Australia, 2017.

[18] Centre for Chemical Process Safety, "Guidelines for Process Equipment Reliability Data with Data Tables," Centre for Chemical Process Safety, 1989.

[19] Health and Safety Executive, Health Failure Rate and Event Data for use within Risk Assessments, United Kingdom: Health and Safety Executive, 2012.

[20] J. C. Williams, A Data Based Method for Assessing and Reducing Human Error, Proceedings of IEEE 4th Conference on Human Factors in Power Plants, Monteray, California, 1988.

[21] F. P. Lees, Loss Prevention in the Process Industries, London: Butterworth-Heinemann, 2005.

[22] Standards Australia, "AS 1692-2006 - Steel tanks for flammable and combustible liquids," Standards Australia, Sydney, 2006.

[23] Standards Australia, "AS/NZS 5149:2016 - Refrigerating systems and heat pumps - Safety and environmental requirements Definitions, classification and selection criteria," Standards Australia, Sydney, 2016.

[24] I. Cameron and R. Raman, Process Systems Risk Management, San Diego: Elsevier, 2005.

[25] Rockwell Automation, Funcation Safety Data Sheet, SAFETY-SR001B-EN P, Rockwell Automation, 2010.

Appendix A

Hazard Identification Table

A1. Hazard Identification Table

ID	Area/Operation	Hazard Cause	Hazard Consequence	Safeguards
1	Warehouse	• Dropped pallet • Damaged packaging (receipt or during storage) • Deterioration of packaging	• Release of Class 2.1, 3, 5.1, 6.1, 8, and 9 to the environment	• Small retail sized packages (< 20 L) • Inspection of packages upon delivery to the site. • Trained forklift operators (including spill response training). • Storage of DGs within AS/NZS 3833:2007 compliant store (Ref. [5])
2		• Dropped pallet • Damaged packaging (receipt or during storage) • Deterioration of packaging	• Spill of flammable liquids, evolution of flammable vapour cloud ignition and vapour cloud explosion/flash fire • Spill of flammable liquids, ignition and pool fire/racking fire	• Small retail sized packages (< 20 L) • Inspection of packages upon delivery to the site • Control of ignition sources according to AS/NZS 60079.14:2017 (Ref. [9]) • Automatic fire protection system (in-rack and SMSS per AS 2118.1:2017 (Ref. [6])) • First attack fire-fighting equipment (e.g. hose reels & extinguishers) • Fire detection systems • Storage of DGs within AS/NZS 3833:2007 compliant store (Ref. [5])
3		• Heating of Class 2.1 from a general warehouse fire	• Rupture, ignition and explosion/rocketing of cylinder within warehouse spreading fire	• In-rack sprinklers according to AS 2118.1:2017 (Ref. [6]) • Automatic fire protection system • Aerosols stored within a caged area.
4	Sprinkler activation	• Fire activates SMSS resulting in fire water release and potential contaminated fire water offsite	• Environmental impact to surrounding areas (e.g. stormwater drainage)	• Dangerous Goods Stores are bunded to contain in excess of the maximum required fire water, per AS/NZS 3833:2007 (Ref. [5])

ID	Area/Operation	Hazard Cause	Hazard Consequence	Safeguards
				• Site drainage to comply with the Best Practice Guide for Potentially Contaminated Water Retention and Treatment Systems (Ref. [7])
5	Pallet Loading/Unloading	• Dropped containers from the pallet • Impact damage to containers on the pallet (collision with racks or other forklifts)	• Spill of flammable liquids, evolution of flammable vapour cloud ignition pool, fire under the pallet • Full pallet fire as a result of fire growth	• Trained & licensed forklift drivers • First attack fire-fighting equipment (hose reels & extinguishers) • SMSS if incident occurs internally • No potential for fire growth beyond the single pallet (limited stock externally)
6	Diesel Tank	• Loss of containment of diesel fuel during fuel transfers. • Loss of hose connection during fuel transfers. • Loss of containment of diesel storage tank. • Loss of containment of tanker vehicle. • Overfilling of tank. • Vehicle collision resulting in damage.	• Release of diesel to the environment.	• Storage area to comply with AS 1940-2017 (Ref. [17]). • Storage tank to comply with AS 1692-2006 (Ref. [22]). • Spill containment for delivery vehicles. • Self-bunded tank. • Vehicle impact protection. • Overfill protection.
7			• Release of diesel, ignition and fire.	• Storage area to comply with AS 1940-2017 (Ref. [17]). • Storage tank to comply with AS 1692-2006 (Ref. [22]). • Spill containment for delivery vehicles. • Self-bunded tank. • Vehicle impact protection. • Overfill protection.

ID	Area/Operation	Hazard Cause	Hazard Consequence	Safeguards
				• Low ignition probability due to high flash point of diesel (i.e. flash point above ambient conditions).
8	LPG Tanks	• Releases from pipework due to corrosion, flange leaks, hose/pump leaks, weld failure, operator error, maintenance error, mechanical damage (e.g. tanker impact on fill point) etc. • Overfilling of tank due to operator error (incorrect tank reading). • Overfilling of tanker due to equipment fault or procedures not followed (e.g. leaving operation unattended). • Hose failure or coupling failure or coupling not properly engaged during transfers due to mechanical damage or undetected wear and tear or operator error. • Drive away with hoses attached.	• Minor leak (5 mm hole) • Major leak (50 mm hole) • If ignition then: ○ Flash fire, jet fire, pool fire, VCE or BLEVE (tanker), possible explosion if enters drains, and potentially hazardous heat radiation, direct fire involvement, and/or overpressure/ projectiles. ○ Potential fire spreading to adjacent sites. •	• LPG facilities to be designed to comply with AS/NZS 1596:2014 (Ref. [15]) and will be installed by an experienced LPG facility supply company. • Tank and associated pipework/fitting will be pressure tested in accordance with the requirements of the pressure vessels code • Ignition source control including earthing to prevent static sparks. • Hoses tested annually as per AS/NZS 1596:2014 and the ADG (Ref. [13]). • Excess flow valves installed in pipework. • Valves to fill point closed until air connected to truck. • Valves shut on breaking of air connection to truck. • All staff including contract drivers will be trained in the specific transfer operations at the site. • Tanker fitted with Emergency Shut Down. • Excess flow valve on tanker. • Manual shutdown valve. • Non-return valve on delivery line. • Emergency Shutdown on delivery line. • Manual valve on delivery line. • Overfill protection device. • Fusible link on tanker and vessel.

ID	Area/Operation	Hazard Cause	Hazard Consequence	Safeguards
9	Anhydrous Ammonia (Refrigeration Plant)	• Loss of containment of anhydrous ammonia refrigeration system • Leaking flanges / valves / pipes / pumps • Loss of containment of compressors • Failure of pumps • Loss of containment of heat exchangers / condensers	• Potential for release of toxic ammonia gas • Potential for injuries and/or fatalities (onsite and offsite)	• Ammonia system to comply with AS/NZS 5149 (Ref. [23]) • Gas detection and alarms • Safety interlocks and SCADA system • Emergency Response and Evacuation Plans • Wind sock • Emergency shutdown system • Fire detection and suppression (dilution of ammonia gas with fire water) • Appropriate ventilation system for plant room
10	Anhydrous ammonia (refrigeration plant)	• Loss of containment of NH_3 above LEL • Presence of ignition sources	• Fire and / or explosion resulting in potential injuries onsite and potentially offsite	• Ammonia system to comply with AS/NZS 5149 (Ref. [23]) • HAC in accordance with AS/NZS 60079.10.1:2009 (Ref. [8]) • Exclusion of ignition sources in hazardous areas

Appendix B

Consequence Analysis

Appendix B

B1. Incidents Assessed in Detailed Consequence Analysis

The following incidents are assessed for consequence impacts.

- Flammable material spill, ignition and racking fire.
- LPG release (from aerosol), ignition and racking fire.
- Full warehouse fire and radiant heat.
- Full warehouse fire and toxic smoke emission.
- 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. Gexcon - Effects

The modelling was prepared using Effects which is proprietary software owned by Gexcon which has been developed based upon the TNO Coloured books and updated based upon CFD modelling tests and physical verification experiments. The software can model a range of incidents including pool fires, flash fires, explosions, jet fires, toxic dispersions, warehouse smoke plumes, etc.

B3. Radiant Heat Physical Impacts

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

Appendix Figure 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

B4. Flammable Material Spill, Ignition and Racking 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 – 7 m^2, Sensitivity – 63.6 m^2
- Burning rate – 0.02 $kg/m^2.s$ (burning rate for ethanol based upon perfumery products which are ethanol based being stored)

The selection of a flammable liquid burning rate is considered appropriate and conservative as 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 Figure B-2**.

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

Output	Base Case	Sensitivity
Flame Height (m)	7.6	16.4
SEP (kW/m^2)	103.7	60.8

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

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

Heat Radiation (kW/m^2)	Distance (m)	
	Base Case	Sensitivity
35	3	9
23	3	10
12.6	4	12

Heat Radiation (kW/m²)	Distance (m)	
	Base Case	Sensitivity
4.7	6	17

B5. LPG Release (From Aerosol), Ignition and Racking Fire

The release of LPG from a damaged package could result in a fire if the release ignited. The fire would begin to grow expanding LPG within other aerosols which may rupture, ignite and rocket around the aerosol store. The store is fitted with SMSS and in-rack sprinklers to suppress the fire and cool adjacent packages to minimise the potential for rocketing.

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 bas 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 sprinkler 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 – 7 m^2, Sensitivity – 63.6 m^2
- Burning rate – 0.099 $kg/m^2.s$ (the burning rate for LPG, Ref. [21]).

The selection of a LPG burning rate is considered appropriate and conservative as a fire involving aerosols will be composed predominantly of packaging (i.e. plastic wrapping and cardboard) which will be punctuated by rupturing of cans and combustion of the released LPG. 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, there will be no combustible material stored in 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 Figure B-4**.

Appendix Figure B-4: Flame Height and SEP for Class 2.1 Sprinkler Controlled Scenarios

Output	Base Case	Sensitivity
Flame Height (m)	10.8	23.2
SEP (kW/m²)	103.7	60.8

The inputs summarised in **Appendix Figure B-4** were input into Effects with the results for each scenario shown in **Appendix Figure B-5**.

Appendix Figure B-5: Heat Radiation from Class 2.1 Sprinkler Controlled Scenarios

Heat Radiation (kW/m^2)	Distance (m)	
	Base Case	Sensitivity
35	6.0	13.0
23	7.0	16.0
12.6	9.0	22.0
4.7	14.0	34.0

B6. Full Warehouse Fire

A full warehouse fire would consume the combustible load stored within the warehouse which covers an approximate area of 54,200 m^2. A burning rate of 0.054 kg/m^2.s has been selected which is considered conservative as the majority of product stored within the warehouse is non-DG and this burning rate reflects that of relatively flammable material.

Due to the aspect limitations of the model, the fire has been modelled as Eastern and Western fires roughly breaking the warehouse in half. The input parameters entered into the model have been shown in **Appendix Figure B-6** and **Appendix Figure B-7**.

Parameters	
Inputs	
Process Conditions	
Chemical name	Diesel Sample (Sample mixtures)
Calculation Method	
Type of pool fire calculation	Two zone model Rew & Hulbert
Type of pool fire source	Instantaneous
Soot definition	Calculate/Default
Source Definition	
Total mass released (kg)	1E05
Temperature of the pool (°C)	20
Process Dimensions	
Type of pool shape (pool fire)	Polygon
Non burning area within pool (m2)	0
Height of the confined pool above ground level (m)	0
Include shielding at bottomside flame	No
Meteo Definition	
Wind speed at 10 m height (m/s)	3
Predefined wind direction	W
Environment	
Ambient temperature (°C)	20
Ambient pressure (bar)	1.0151
Ambient relative humidity (%)	60
Amount of CO2 in atmosphere (-)	0.0004

Appendix Figure B-6: Western Side Full Warehouse Fire Input File

Parameters	
Inputs	
Process Conditions	
Chemical name	Diesel Sample (Sample mixtures)
Calculation Method	
Type of pool fire calculation	Two zone model Rew & Hulbert
Type of pool fire source	Instantaneous
Soot definition	Calculate/Default
Source Definition	
Total mass released (kg)	1E05
Temperature of the pool (°C)	20
Process Dimensions	
Type of pool shape (pool fire)	Polygon
Non burning area within pool (m2)	0
Height of the confined pool above ground level (m)	0
Include shielding at bottomside flame	No
Meteo Definition	
Wind speed at 10 m height (m/s)	3
Predefined wind direction	W
Environment	
Ambient temperature (°C)	20
Ambient pressure (bar)	1.0151
Ambient relative humidity (%)	60
Amount of CO2 in atmosphere (-)	0.0004

Appendix Figure B-7: Eastern Side Full Warehouse Fire Input File

The results for flame height and SEP for each scenario are summarised in **Appendix Table B-1**.

Appendix Table B-1: Flame Height and SEP for a Full Warehouse Fire

Item	Output	
	Western	Eastern
Flame Height (m)	104	104.5
SEP Sooty Flame (kW/m^2)	22	22

Appendix Table B-2 summarises the radiant heat impact distances calculated for the model.

Appendix Table B-2: Heat Radiation from a Full Warehouse Fire

Heat Radiation (kW/m^2)	Distance (m)	
	Western	Eastern
35	146	143
23	153	150
12.6	175	173
4.7	232	231

B7. Full Warehouse Fire and Smoke Emission

During the fire, uncombusted toxic products may be present in the smoke plume or toxic bi-products may be generated which will be dispersed in the smoke plume. It is necessary to assess the associated impacts of the smoke plume downwind of the facility as it may have far reaching impacts on the wider community. When assessing the downwind impacts of the fire plume, the main contributors to the dispersion are:

- The fire size (diameter) and energy released as convective heat

- The atmospheric conditions such as wind speed, relative humidity, atmospheric stability and ambient temperature.

These parameters interact to determine the buoyancy of the smoke plume (vertical rise) which is controlled by the convective energy within the smoke plume in addition to the atmospheric conditions. The atmospheric conditions will vary from stable conditions (generally night time) to unstable conditions (high insolation from solar radiation) which results in substantial vertical mixing which aids in the dispersion. Contributing to this is the impact of wind speed which will limit the vertical rise of a plume but may exacerbate the downwind impact distance.

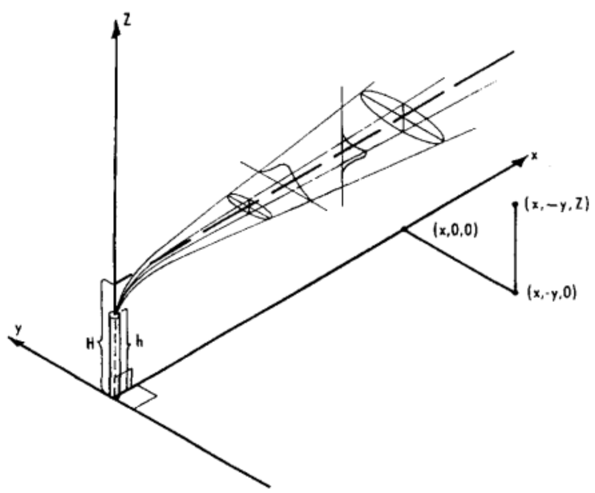
The atmospheric conditions are classified as Pasquill Guifford's Stability categories which are summarised in **Appendix Figure B-8** (Ref. [24]).

Appendix Figure B-8: Pasquill's Stability Categories

Surface wind speed at 10 m height (m/s)	Insolation			Night	
	Strong	Moderate	Slight	Thinly overcast or ≥50% cloud	<50% cloud.
<2	A	A-B	B	-	-
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
>6	C	D	D	D	D

Generally, the most onerous conditions are F conditions which result in stable air masses and typically have inversion characteristics. Inversion characteristics occur when a warm air mass sits above a cold air mass. Typically, hot air will rise due to lower density than the bulk air; however, in an inversion, a warm air mass sits above the cooler denser air; hence, as the warm air rises through the cold mass it hits a 'wall' of warmer air preventing vertical mixing above this point. In a fire scenario, the hot smoke plume will cool as it rises; however, if it encounters an inversion, it will begin to run along this boundary layer preventing vertical mixing and allowing the smoke plume to spread laterally for substantial distances.

A smoke plume is buoyant, and will disperse laterally and vertically as it rises essentially following a Gaussian dispersion as shown in **Appendix Figure B-9** (Ref. [24]).



Appendix Figure B-9: Co-ordinate System for Gas Dispersion

RiskEffects has been used to model a smoke plume arising from the warehouse. The model has been developed based on a Gaussian dispersion model accounting for modifications to the plume drag coefficients required to model a plume dispersion from a warehouse fire.

The model requires several inputs which have been summarised in **Appendix Figure B-10** with the associated value input as part of this modelling exercise. F1.5 conditions have been used to model the plume dispersion.

Parameters	
Inputs	
Process Conditions	
Phase	Solid
Average molecular formula	Translation for "ParameterValues.C390H850O106Cl046N117S051P135" is missing!
Calculation Method	
NO2 conversion fraction (-)	0.35
Fraction combustion heat radiated (-)	0.35
Fraction of soot (unburned carbon) (-)	0.8
Source Definition	
Total mass released (kg)	5E07
Surface area of the fire (m2)	54200
Environment	
Ambient temperature (°C)	20

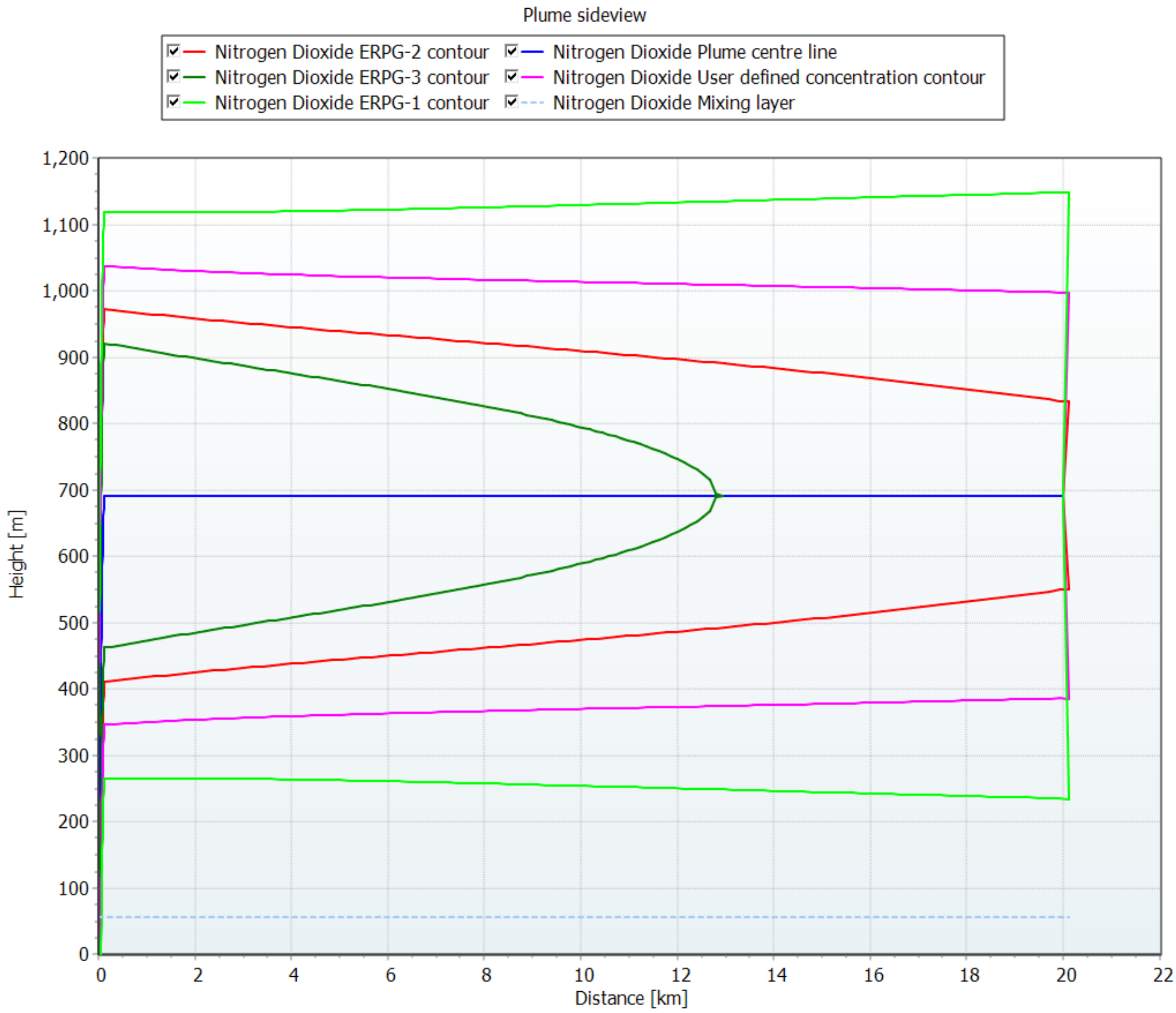
Appendix Figure B-10: Input Data for Plume Gaussian Dispersion

The warehouse was modelled based upon solid product stored within the warehouse and the default settings for solid product within the warehouse was adopted which is based upon typical warehouse configurations within the Netherlands which would be expected to be similar to those expected in Australia. The model then generates the bi-products which may be released from the combustion of the mass which are then individually modelled for each component. Provided in **Appendix Figure B-11** is a summary of the pollutant release rates generated by the model.

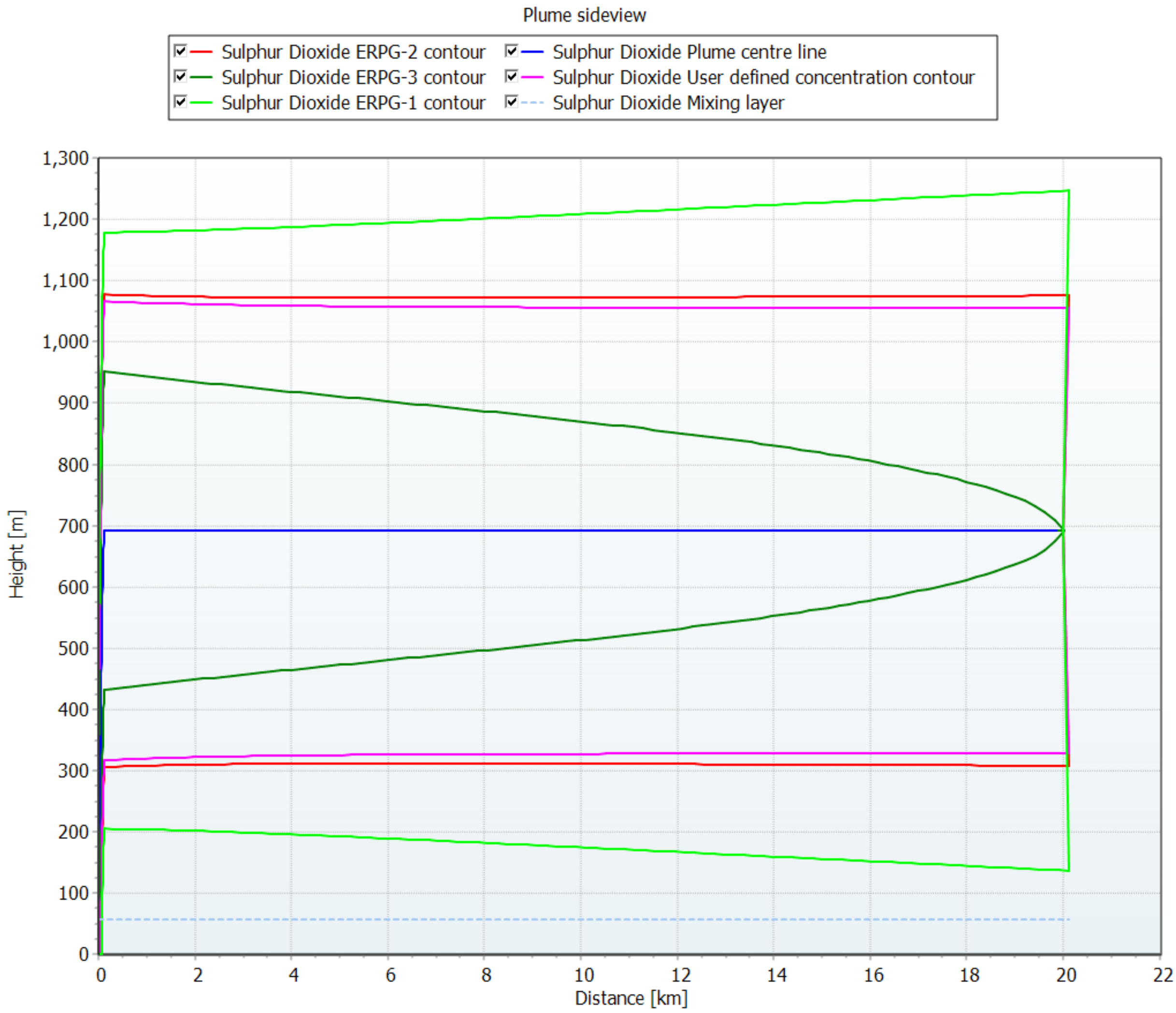
Appendix Figure B-11: Pollutant Release Rates

Material	Release Rate (kg/s)
Nitrogen Dioxide	156.7
Sulphur Dioxide	271.3
Hydrogen Chloride	137.7
Soot (Carbon)	311.4

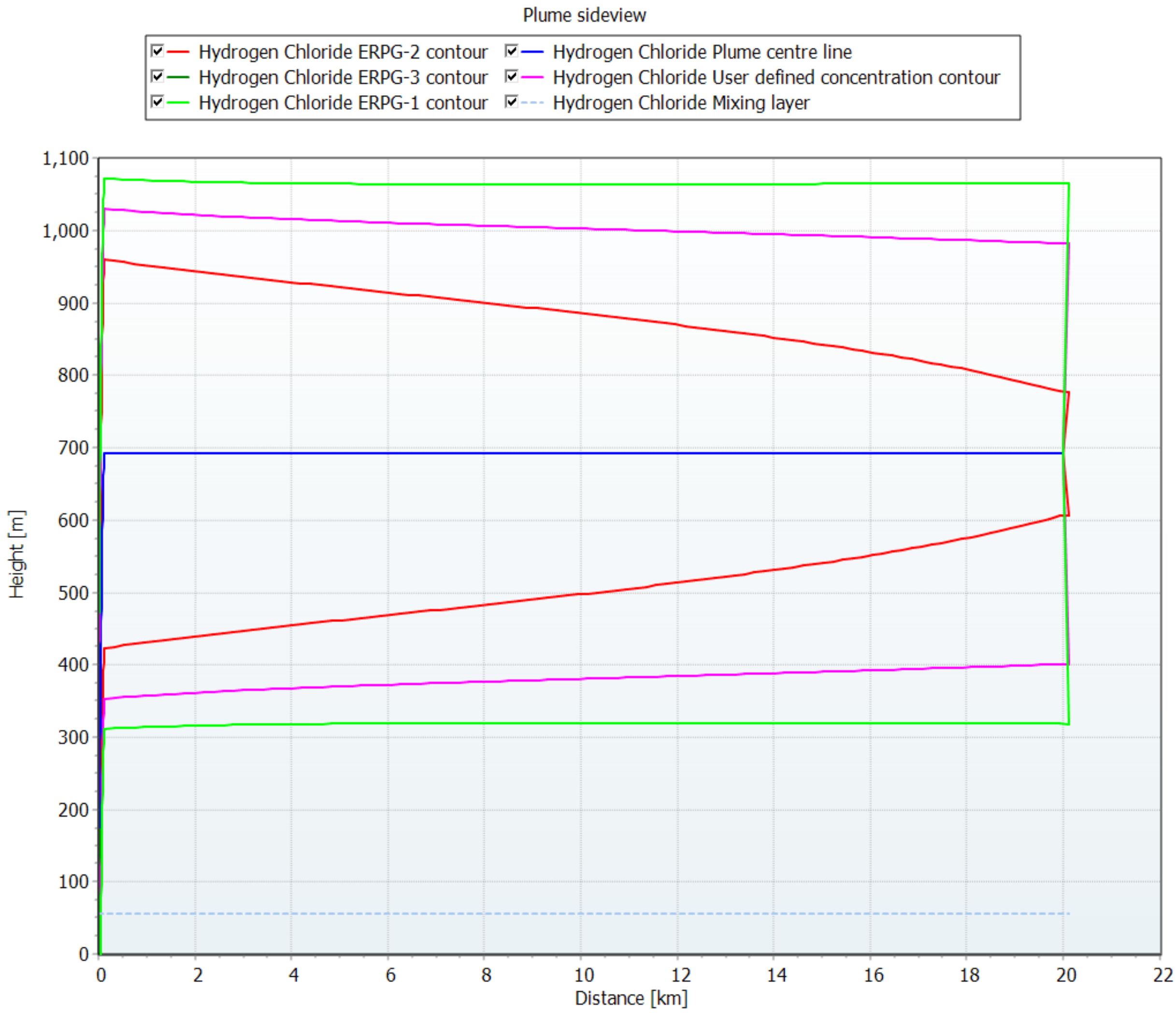
Each of the pollutants were modelled to determine their plume shape and determine whether the plume would puncture through an inversion layer and what the downwind dispersion would look like as the plume cools and settles in the atmosphere. The plume shapes are shown in **Appendix Figure B-12** to **Appendix Figure B-15**.



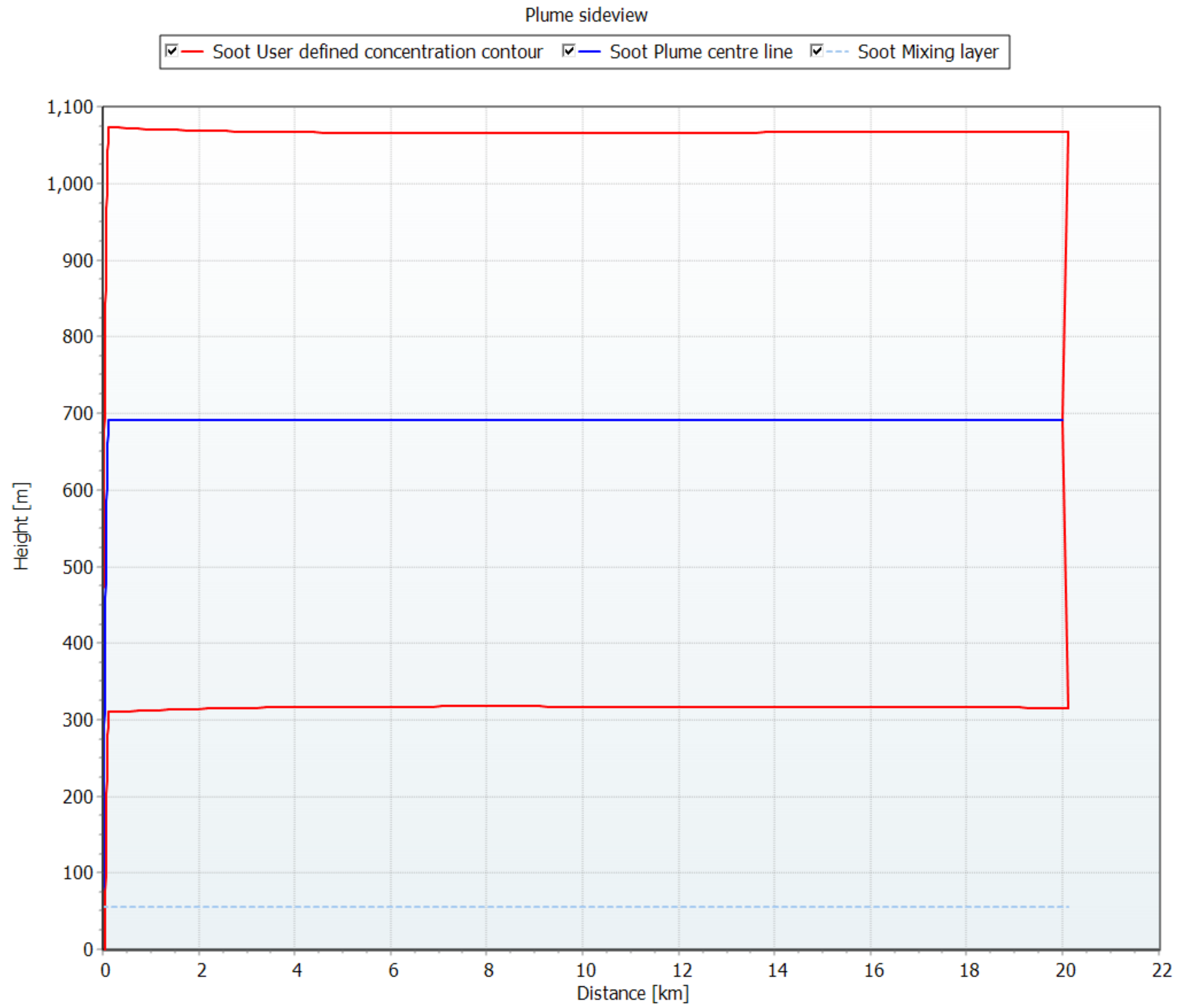
Appendix Figure B-12: Nitrogen Dioxide Downwind Plume Dispersion



Appendix Figure B-13: Sulphur Dioxide Downwind Plume Dispersion



Appendix Figure B-14: Hydrogen Chloride Downwind Plume Dispersion



Appendix Figure B-15: Soot (Carbon) Downwind Plume Dispersion

B8. 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. The jet fire was modelled using the input parameters in **Appendix Figure B-16**.

Parameters	
Inputs	
Process Conditions	
Chemical name	LPG Sample (Sample mixtures)
Exit temperature (°C)	7.1881
Exit pressure (bar)	5.528
Calculation Method	
Fraction of the flame covered by soot (-)	0
Source Definition	
(Calculated) Mass flow rate (kg/s)	12.455
Process Dimensions	
Hole diameter (mm)	50
Hole rounding	Sharp edges
Outflow angle in XZ plane (0°=horizontal; 90°=vertical) (deg)	90
Release height (stack height) (m)	1
Meteo Definition	
Meteorological data	Pasquill
Pasquill stability class	F (Very Stable)
Wind speed at 10 m height (m/s)	1.5
Predefined wind direction	W
Environment	
Ambient temperature (°C)	20
Ambient pressure (bar)	1.0151
Ambient relative humidity (%)	60
Roughness length description	Parkland, bushes; numerous obstacles, x/h < 15.
Amount of CO2 in atmosphere (-)	0.0004

Appendix Figure B-16: Jet Fire Modelling Inputs

The model calculated a jet flame length of 26.3 m. The radiant heat emitted from the flame is shown in **Appendix Table B-3**.

Appendix Table B-3: Heat Radiation from a Jet Fire

Radiant Heat (kW/m^2)	Distance (m)
35	25
23	31
12.6	41
4.7	63

B9. LPG Unloading Incident, Hose Rupture, LPG Release, Ignition and Jet Fire and Impact on LPG Delivery Tanker and BLEVE

In the event that a jet fire impinges upon the delivery tanker the liquid will absorb the heat from the impact point and begin boiling which will be vented from the pressure relief valves on the tank. As the liquid level decreases it will fall below the impingement point and heat will not be removed allowing for the metal to heat up directly. As the metal continues to heat it will become less rigid ultimately to the point where it is unable to contain the pressure of the LPG rupturing as a BLEVE.

It is noted that it's physically impossible to have a BLEVE and a 100% full tank; however, the DPIE has indicated a preference for modelling BLEVEs with 100% tank volume; hence, the BLEVE has been modelled as a 100% full 20 tonne tanker (36.4 m^3 using a density of 550 kg/m^3). The input parameters for the BLEVE modelling are shown in **Appendix Figure B-17.**

Parameters	
Inputs	
Process Conditions	
Chemical name	LPG Sample (Sample mixtures)
Initial temperature in vessel (°C)	20
Burst pressure vessel (bar)	25
Calculation Method	
Type of BLEVE calculation	Dynamic BLEVE model
Include BLEVE overpressure effects	Yes
Process Dimensions	
Vessel volume (m3)	36.4
Filling degree (%)	100
Height of the vessel (fireball offset Z) (m)	0
Environment	
Ambient temperature (°C)	20
Ambient relative humidity (%)	60
Ambient pressure (bar)	1.0151

Appendix Figure B-17: LPG Tanker BLEVE Input Parameters

The overpressure impacts calculated from the model have been summarised in **Appendix Table B-4** while the radiant heat impacts have been summarised in **Appendix Table B-5**.

Appendix Table B-4: Overpressure from an LPG Tanker BLEVE

Overpressure (kPa)	Distance (m)
70	13
35	25
21	39
14	56
7	100

Appendix Table B-5: Radiant Heat Impacts from an LPG Tanker BLEVE

Radiant Heat (kW/m^2)	Distance (m)
35	198
23	245
12.6	330
4.7	526

B10. LPG Unloading Incident, Hose Rupture, LPG Release, Ignition and Jet Fire and Impact on LPG Tank And BLEVE

Similar to the LPG tanker BLEVE, there is the potential for impingement on the LPG tanks themselves which could escalate as a BLEVE. These have been modelled at 100% full for the purposes of this exercise.

The input parameters for the BLEVE modelling are shown in **Appendix Figure B-18**.

Parameters	
Inputs	
Process Conditions	
Chemical name	LPG Sample (Sample mixtures)
Initial temperature in vessel (°C)	20
Burst pressure vessel (bar)	25
Calculation Method	
Type of BLEVE calculation	Dynamic BLEVE model
Include BLEVE overpressure effects	Yes
Process Dimensions	
Vessel volume (m3)	7.5
Filling degree (%)	100
Height of the vessel (fireball offset Z) (m)	0
Environment	
Ambient temperature (°C)	20
Ambient relative humidity (%)	60
Ambient pressure (bar)	1.0151

Appendix Figure B-18: LPG Tank BLEVE Input Parameters

The overpressure impacts calculated from the model have been summarised in **Appendix Table B-6** while the radiant heat impacts have been summarised in **Appendix Table B-7.**

Appendix Table B-6: Overpressure from an LPG Tank BLEVE

Overpressure (kPa)	Distance (m)
70	8
35	15
21	23
14	33
7	59

Appendix Table B-7: Radiant Heat Impacts from an LPG Tank BLEVE

Radiant Heat (kW/m^2)	Distance (m)
35	121
23	150
12.6	202
4.7	322

Appendix C

Frequency Data

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.

C2. Summary of Failure Rate Data

Component	Failure Rate	Reference	Modifier	PFD
Hose	$2x10^{-7}$ per operation*	HSE FR1.2.3 (Ref. [19])	$= 2x10^{-7}$ x 52 = $1.04x10^{-5}$	-
Excess flow valve	$1.3x10^{-2}$ per demand	HSE FR1.2.1 (Ref. [19])	Not modified	=0.5 x $1.3x10^{-2}$ = $6.5x10^{-3}$
Non-return valve	$1.3x10^{-2}$ per demand	HSE FR1.2.1 (Ref. [19])	Not modified	=0.5 x $1.3x10^{-2}$ = $6.5x10^{-3}$
Emergency stop	$1.03x10^{9}$ hours	Rockwell Automation (Ref. [25]	$1.03x8760/10^{9} = 0.009$	$PFD_{e\text{-}stop} = (\lambda^{2}xt^{2})/3$ 0.009^{2} x $1^{2}/3 = 2.7x10^{-5}$
Isolation valves	$1x10^{-2}$ per demand	HSE FR1.2.1 (Ref. [19])	Not modified	= 0.5 x $1x10^{-2}$ = $4x10^{-3}$

Appendix D

Dangerous Goods Design Report

Appendix D

Dangerous Goods Report

Precinct 3, Oakdale East Industrial Estate

Goodman Property Services (Aust.) Pty Ltd
Document No. RCE-21232_Goodman_DGReport_Final_31May22_Rev(0)
Date 31/05/2022

Dangerous Goods Report

Precinct 3, Oakdale East Industrial Estate

Goodman Property Services (Aust.) Pty Ltd

Prepared by

Riskcon Engineering Pty Ltd
37 Pogson Drive
Cherrybrook, NSW 2126
www.riskcon-eng.com
ABN 74 626 753 820

Quality Management

Rev	Date	Remarks	Prepared By	Reviewed By
A	14 March 2022	Draft issue for comment	Renton Parker	Jason Costa
0	31 May 2022	Issued Final		

Executive Summary

Background

A Confidential Customer has proposed to lease warehouse space within the proposed Oakdale East Industrial Estate (OEIE) to house an automated storage and distribution operation to service the business' retail outlets. While the majority of the goods to be stored and handled at the site are non-Dangerous Goods (DGs) there will be a portion of goods which are classified as DGs; hence, the site is subject to the Work Health and Safety Regulation 2017 (Ref. [1]) which requires the risks associated with the storages to be assessed and minimised So Far As Is Reasonably Practicable (SFAIRP). Demonstrating the risks have been minimised may be achieved via compliance with an applicable design standard.

Goodman, on behalf of the customer, has commissioned Riskcon Engineering Pty Ltd (Riskcon) to prepare a DG assessment of the facility to list the items which are required to be included within the design of the facility to achieve compliance. This document represents the assessment of the DG storages at the proposed warehouses.

Conclusions

A review of the quantities of DG storage areas for the warehouse was conducted to identify the storage areas and provide design guidance to ensure the storage areas comply with the applicable standard. The warehouse was assessed using AS/NZS 3833:2007 as the facility operates as a Retail Distribution Centre (RDC) along with other anciliary areas which were subject to individual standard assessment.

The report was developed to assist the project team to design the DG storages with the aim of minimising the risk of the storages as required by the NSW WHS Regulation. It is concluded that if the advice documented in this report is followed the DG storages at the Goodman warehouse will comply with the standard and thus the NSW WHS Regulation.

Recommendations

The following recommendations have been made for the facility:

- The design requirements detailed within this report shall be adhered to in the development of the design for the facility.
- The DGs stored in the warehouse are to be per the requirements of this report.

DG Documents:

Ensure the following documentation is supplied on site in accordance with the Work Health and Safety Regulation 2017:

- A DG Register, indicating the type of chemical, any notations that may be required from the risk assessment and the Safety Data Sheet for the chemical.
- A Manifest.
- Notification to SafeWork NSW.
- A DG Risk Assessment of the storage and handling area.
- A Placard Schedule.
- An Emergency Response Plan (ERP).

- An Emergency Services Information Package (ESIP)
- A Hazardous Area Classification (HAC).
- A Hazardous Area Verification Dossier (HAVD).

Table of Contents

List of Tables

Abbreviations

Abbreviation	Description
AQR	Aggregate Quantity Ratio
CBD	Central Business District
DGs	Dangerous Goods
ERP	Emergency Response Plan
ESIP	Emergency Services Information Package
HAC	Hazardous Area Classification
HAVD	Hazardous Area Verification Dossier
LPG	Liquefied Petroleum Gas
OEIE	Oakdale East Industrial Estate
PCBU	Person Conducting a Business or Undertaking
RDC	Retail Distribution Centre
SFAIRP	So Far As Is Reasonably Practicable
WHS	Work Health and Safety

1.0 Introduction

1.1 Background

A Confidential Customer has proposed to lease warehouse space within the proposed Oakdale East Industrial Estate (OEIE) to house an automated storage and distribution operation to service the business' retail outlets. While the majority of the goods to be stored and handled at the site are non-Dangerous Goods (DGs) there will be a portion of goods which are classified as DGs; hence, the site is subject to the Work Health and Safety Regulation 2017 (Ref. [1]) which requires the risks associated with the storages to be assessed and minimised So Far As Is Reasonably Practicable (SFAIRP). Demonstrating the risks have been minimised may be achieved via compliance with an applicable design standard.

Goodman, on behalf of the customer, has commissioned Riskcon Engineering Pty Ltd (Riskcon) to prepare a DG assessment of the facility to list the items which are required to be included within the design of the facility to achieve compliance. This document represents the assessment of the DG storages at the proposed warehouses.

1.2 Objectives

The objectives of the study are to provide a design document for the DG storages at the warehouse to assist the project team to design compliant DG storages and to review the unique hazards associated with the automation system.

1.3 Scope of Services

The scope of work is to prepare a DG design document for the proposed warehouse to be located within the OEIE. The assessment does not include any other sites nor additional work which may be identified in the course of the assessment.

2.0 Methodology

The following methodology was adopted for this study:

- Review the DG classes and quantities to be stored and the locations where they are to be stored within the facility.
- Review the relevant DG standards to identify the most applicable standard for the warehouse.
- Review the WHS Regulation 2017 (Ref. [1]) to identify the requirements for the facility based on the quantity of DGs stored.
- Prepare a report detailing the findings of the design assessment for submission to assist the project team design a compliant facility.

3.0 Site Description

3.1 Site Location

The site is located at Precinct 3 at the OEIE which is approximately 44 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 layout of the site in Horsley Park.

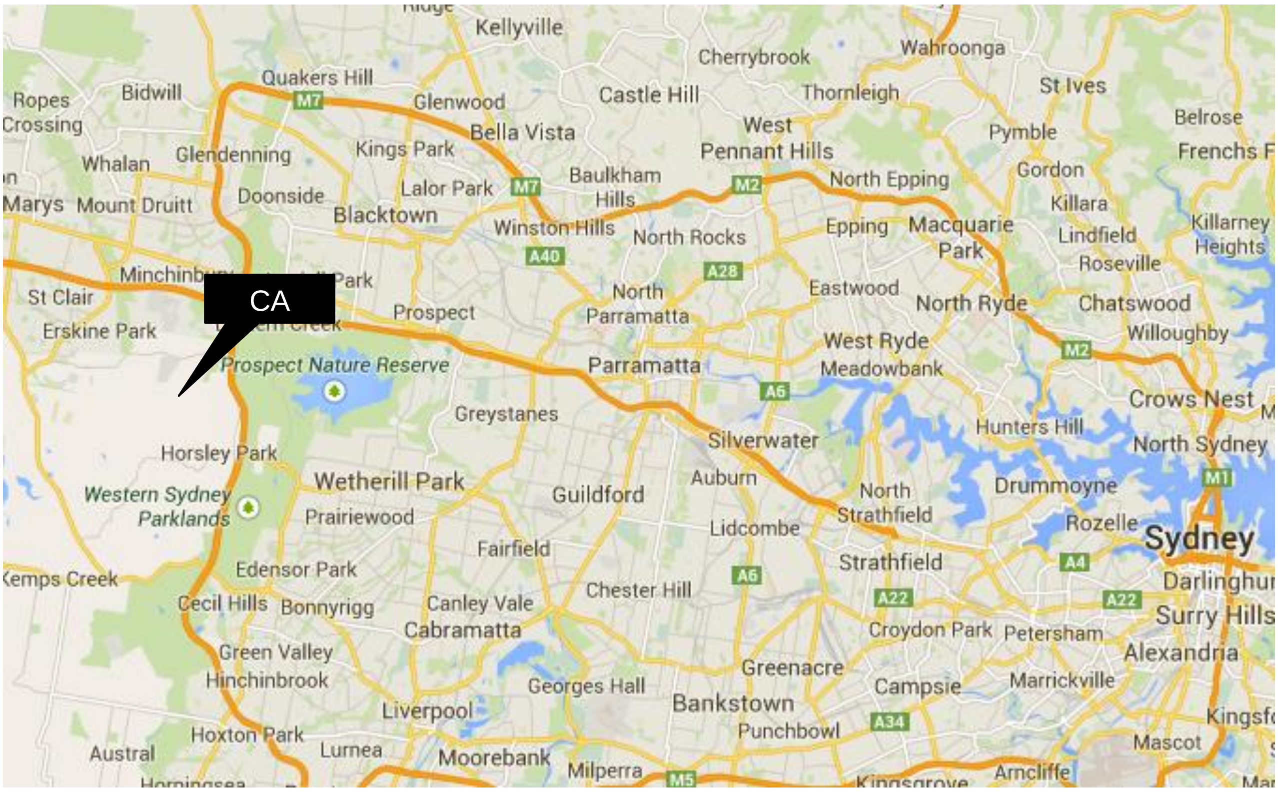


Figure 3-1: Site Location

3.2 Adjacent Land Uses

The land is located in an industrial area surrounded by the following land uses, which are adjacent to the site:

- North – Easement
- South – Industrial warehousing
- East – Industrial warehousing
- West – Industrial warehousing

3.3 Warehouse Detailed Description

The warehouse will utilise an automated storage system which takes delivered pallets and stores them in high bay racking until required. The system stores products in a unique location which is tracked to allow accurate retrieval of products. Pallets can be collected from within the high bay storage and separated to form composite pallets containing numerous products for delivery to retailers.

The warehouse will store a range of DGs in retail packages and the facility will be designed to comply with AS/NZS 3833:2007 (Ref. [2]). Specifically, the facility will comply with the Retail Distribution Centre (RDC) section of the standard which accounts for the reduced risk posed by packages stored in restricted small volumes.

The warehouse will be protected by a bespoke automatic sprinkler system involving both ceiling mounted and in-rack sprinklers depending on commodities stored. The sprinklers which will activate upon fire detection which will suppress and control any fire that may occur. The warehouse will be naturally ventilated for occupation purposes which will provide adequate ventilation flow for preventing accumulation of any vapours released from packages in storage as required by AS/NZS 3833:2007 (Ref. [2]).

In the event of a fire, spills and sprinkler discharge will be contained within the site via activation of a stormwater isolation valve to prevent release of potentially contaminated water. Water will be stored within the site boundaries via a strategy yet to be determined by the design team.

The site will be subject to a hazardous area classification per AS/NZS 60079.10.1:2009 (Ref. [3]) and any electrical equipment within the hazardous zone will be compliant per AS/NZS 60079.14:2017 (Ref. [4]) to minimise the potential for ignition of flammable vapours which may be released during storage.

3.4 Quantities of Dangerous Goods Stored and Handled

The dangerous goods stored at the warehouse are for various customers and may fluctuate with customer requirements. The classes and quantities to be approved in the facility are summarised **Table 3-1**.

Table 3-1: Maximum Classes and Quantities of Dangerous Goods Stored

Class	Packing Group	Description	Quantity (kg)
2.1	n/a	Flammable gas (aerosols)	460,000 / 115,000*
2.1	n/a	Flammable Gas (LPG Bullet)	7,500 L / 4,125 kg
2.2	n/a	Non-flammable, non-toxic	80,000
2.3	n/a	Ammonia	6,200
3	II & III	Flammable liquids	2,575,000
5.1	III	Oxidising agents	10,000
8	II & III	Corrosive substances	175,000
9	III	Miscellaneous DGs	675,000
C1/C2	III	Diesel	300,000

*Note: This refers to the quantity of LPG within the aerosols and not the total package weight. The LPG content within the cannisters is typically around 25% of product weight.

3.5 Aggregate Quantity Ratio

Where more than one class of dangerous goods are stored and handled at the site an AQR exists. This ratio is calculated using **Equation 3-1:**

$$AQR = \frac{q_x}{Q_x} + \frac{q_y}{Q_y} + [\ldots] + \frac{q_n}{Q_n}$$ **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 is taken from Schedule 15 of the Work Health and Safety (WHS) Regulation 2017 (Ref. [1]). These are summarised in **Table 3-2** noting Class 2.2, 5.1(III), 8, 9 and combustible liquids are not subject to MHF legislation.

Table 3-2: Major Hazard Facility Thresholds

Class	Packing Group	Threshold (tonnes)	Storage (tonnes)
2.1	n/a	200	115
2.1	II & III	200	4.125
2.2	I & II	n/a	80
2.3	III	200	6.2
3	II & III	50,000	2,575
5.1	III	n/a	10
8	II & III	n/a	175
9	III	n/a	675
C1/C2	n/a	n/a	300

A review of the thresholds and the commodities and packing groups listed in **Table 3-1** indicates only Class 2.1, 2.3, and 3 are assessable against the MHF thresholds. Therefore, substituting the storage masses into **Equation 3-1** the AQR is calculated as follows:

$$AQR = \frac{115}{200} + \frac{4.125}{200} + \frac{6.2}{200} + \frac{2{,}575}{50000} = 0.68$$

The AQR is less than 1; hence, the facility would not be classified as an MHF. The site would exceed 10% of the MHF threshold; hence, would require notification to SafeWork NSW as a potential MHF.

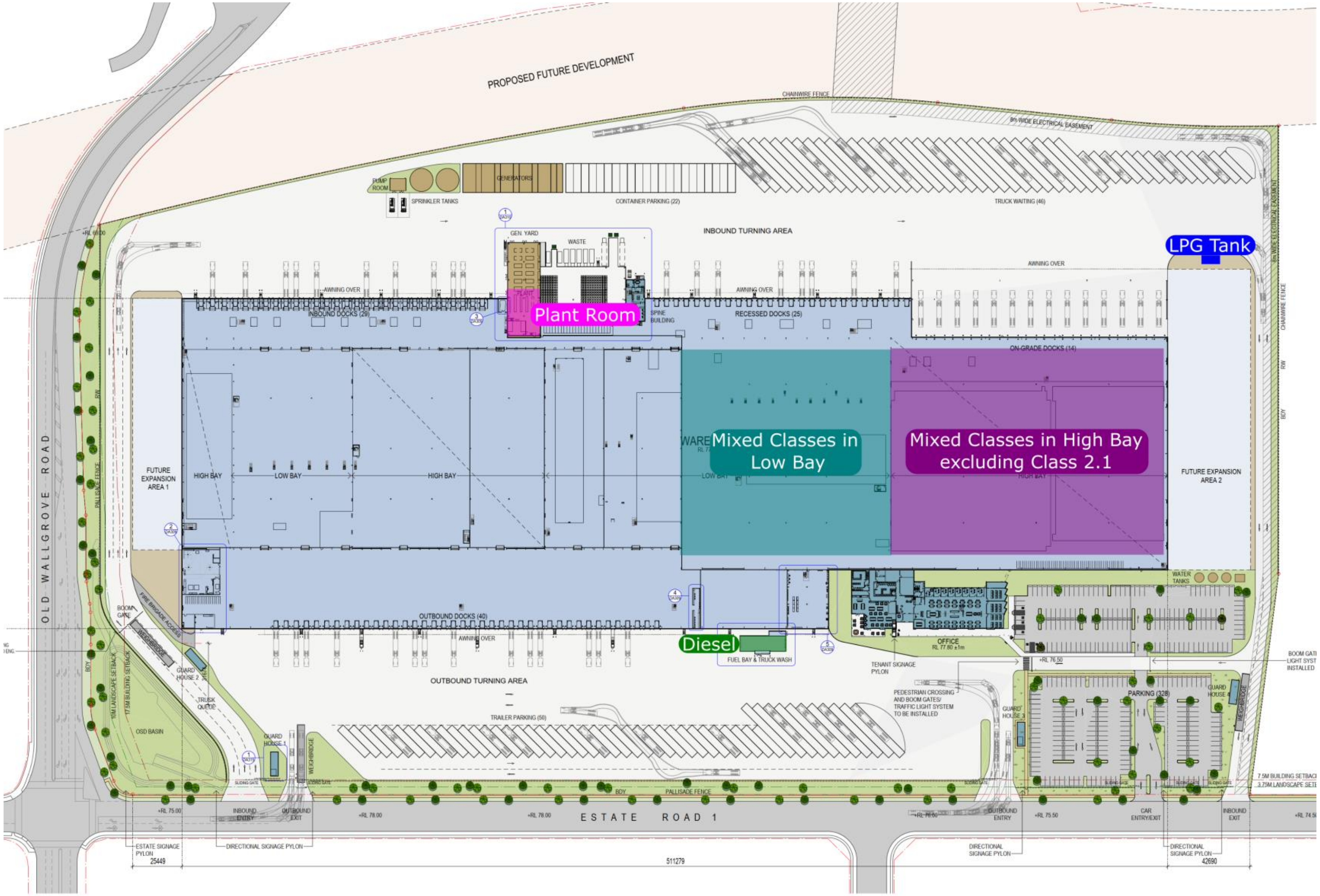


Figure 3-2: Site Layout

4.0 Assessment

4.1 Introduction

A review of the proposed DG storages indicates the following areas require assessment

- Warehouse storage
- LPG Tank
- Diesel Storage
- Ammonia refrigeration system

Each of these have been assessed in detail in the following sections.

4.2 Warehouse Storage

4.2.1 Introduction

The general warehouse will be used to store mixed classes of DGs throughout the automated system in high bay racking. The quantities of flammable materials stored in this location are summarised in **Table 4-1**.

The flammable liquids to be stored are in retail packages which would comply with the requirements of the Retail Distribution Centre (RDC) section of AS/NZS 3833:2007 (Ref. [2]

Table 4-1: Dangerous Goods Stored within the General Warehouse

Class	Packing Group	Description	Quantity (kg)
2.1	n/a	Flammable gas (aerosols)	460,000 / 115,000
2.2	n/a	Non-flammable, non-toxic	80,000
3	II & III	Flammable liquids	2,575,000
5.1	III	Oxidising agents	10,000
8	II & III	Corrosive substances	175,000
9	III	Miscellaneous DGs	675,000
		Total	3,975,000

4.2.2 Design

The general warehouse will require the design requirements summarised in **Table 4-2** based on AS/NZS 3833:2007 and the area being classified as Retail Distribution Centre.

Table 4-2: General Warehouse Design Requirements

Item	Requirement
Ventilation	• The warehouse shall be adequately ventilated, compliance with the occupational requirements of AS/NZS 1668.2:2002 (Ref. [5]) is taken to provide adequate ventilation.
Spill Containment	• All spills shall be contained within the site premises which may be achieved by spill kits due to the low volumes.

Item	Requirement
Walls	• n/a
Electrical Equipment	• All electrical wiring and lighting within the store shall comply with IP 65 in accordance with AS 60529 • All electrical equipment shall be installed in accordance with AS/NZS 3000:2018 (Ref. [6]) • Electrical equipment with a hazardous area rating as required by hazardous area zoning per AS/NZS 60079.10.1:2009 (Ref. [3]). • Electrical equipment installed per the requirements of AS/NZS 60079.14:2017 (Ref. [4]). • Electrical equipment installed by an appropriate qualified/certified hazardous area electrician. • Hazardous area verification dossier prepared documenting all hazardous area equipment.
Fire Protection	• Fire extinguishers (dry chemical, rated 2A 60 B(E)) located to provide accessible coverage by personnel within the store. • Fire hose reel coverage to all DG storages. Flammable liquid storages will require hose reels with foam making capabilities. • Fire hydrant coverage to all parts of the storage area. • Automated sprinkler system in accordance with AS 2118.1:2017 (Ref. [7]). It is noted that the DG standards do not provide detailed guidance upon the sprinkler setup. Therefore, a fire protection designer should be engaged to determine whether the fire protection system can adequately protect against the commodities proposed to be stored.
Placarding	• The store shall be placarded in accordance with the WHS Regulation.
Aerosols	Aerosols shall be stored in cage as follows: • Aerosol cage protecting aerosols ensuring no gaps occur within the cage structure (i.e. mesh to be taken to roof height, walls where applicable, etc.) • The cage mesh shall have a maximum aperture of 50 mm. • The thickness of cage wiring shall be a minimum of 3 mm. • The aerosol cage shall have a sliding gate which loses upon fire detection (i.e. gate is held open by electromagnetic link which deenergises upon fire trip).
Separation	DGs shall be separated in accordance with **Section 4.7** or based upon risk assessment.

4.3 LPG Tank

4.3.1 Introduction

The LPG tank will be stored in a dedicated storage area outside the warehouse, separate to the rest of the DGs on site. Based on a review of the relevant DG standards, it was determined that the most applicable standard for governing the storage of LPG was AS/NZS 1596:2014 – The Storage and Handling of LP Gas (Ref. [8]). A summary of the quantity of LPG to be stored is provided in **Table 4-3**.

Table 4-3: LPG Storage Quantity

Class	PG	Description	Quantity (L)
2.1	n/a	Liquefied Petroleum Gas	7,500

4.3.2 Design

The storage would be considered a tank system, as outlined in Sections 5 and 6 of the standard. Based on the requirements of these sections, the design points to be included within the report have been summarised in **Table 4-4**.

Table 4-4: LP Gas Storage Requirements per AS/NZS 1596:2014

Item	Requirement
Storage Location	The tank shall be stored outside and have a minimum distance of 5 m to a public place or railway line, and 8 m to a protected place. It shall not be less than 1 m from a site boundary.
Hazardous Areas	A HAC shall be performed for the storage area as per AS/NZS 60079.10.1:2009 and AS/NZS 60079.14:2017.
Storage of Other DGs	The following distances are required between the LP gas tank and other materials: • Above ground tank, package store or filling area for flammable or combustible liquids: 6 m. • Top of the bund of a compound for flammable or combustible liquids: 3 m. • A store of any oxidising substance: 6 m.
Ground Conditions	The tanks shall be stored on flat ground, with any bunding permitting spillage to flow away from the immediate vicinity of the tank.
Vehicle Filling	The area and system for vehicle filling shall be designed by a reputable contractor in accordance with the relevant standards.
Fire Protection	• At least one portable powder type fire extinguisher with a rating of 2A 60B(E) shall be provided which is readily accessible in an emergency. • Other fire protection requirements shall be designed by a reputable fire engineer in accordance with the relevant standards.

4.4 Diesel Storage

The diesel tank will be stored as part of the energy complex outside the warehouse, separate to the rest of the DGs on site. Diesel is a combustible liquid and is therefore subject to AS 1940:2017 - "Storage and handling of flammable and combustible liquids" (Ref. [9]). A summary of the quantity of diesel to be stored is provided in **Table 4-5**.

Table 4-5: Diesel Storage Quantities

Class	PG	Description	Quantity (L)
C1	n/a	Diesel Tanks Storage	200,000
		Diesel pumpset	1,500

4.4.1 Design

The diesel stored within the pumpset is considered in use and is not subject to the requirements of the Work Health and Safety Regulation 2017 and has therefore not been assessed. However, the diesel stored for refuelling activities would be considered a tank system, as outlined in Sections 5.9 of the AS 1940:2017 (Ref. [9]) . Based on the requirements of these sections, the design points to be included within the report have been summarised in **Table 4-4**.

Table 4-6: Diesel Storage Requirements per AS 1940:2017

Item	Requirement
Storage Location	Tanks shall be separated by at least 600 mm. Tanks shall be protected from vehicular damage (i.e. ARMCO barriers or guards)
Separation distances	The following separation distances shall be complied with: • Fill points, platforms or package storages: Tank diameter or 7.5 m whichever is less, but at least 3 m • Office buildings, warehouses, workshops or amenities: 7 m • Security fence: Tank diameter or 7.5 m whichever is less, but at least 3 m
Ground Conditions	The tanks shall be stored on flat ground, with any bunding permitting spillage to flow away from the immediate vicinity of the tank.
Fill points	Each fill point shall be provided with containment with a minimum volume of 15 L.
Tank design	The majority of the requirements for Clause 5.9 relate to tank design. Selection of a tank from a reputable supplier is considered to achieve the tank design requirements,
Fire Protection	• Two portable powder type fire extinguisher with a rating of 2A 60B(E) shall be provided. • Hose reels with foam making capabilities to be provided which can cover the whole tank storage area.

4.5 Ammonia Refrigeration System

The ammonia store is used solely for refrigeration purposes. The anhydrous ammonia standard (AS 2022-2003) is only applicable for cylinders and/or tanks, and therefore cannot be applied to refrigeration systems (Ref. [10]). As such, the refrigeration system will be designed by the relevant contractor. Furthermore, application of any of the DG standards which refer to ammonia would result in design guidance which would contradict the design of the refrigeration system. A design prepared by a reputable contractor should incorporate the required safety protections to ensure safe storage and handling in accordance with the NSW WHS Regulations (Ref. [1]).

Notwithstanding the above, ammonia is a flammable gas and therefore requires the risks associated with ignition to be assessed and minimised to comply with the Regulation. Therefore, the following would be required:

- A hazardous area classification in accordance with AS/NZS 60079.10.1:2009 (Ref. [3])
- Where electrical equipment is installed within the hazardous area it shall comply with AS/NZS 60079.14:2017 (Ref. [4]).

- Electrical equipment shall be installed by a hazardous area qualified electrician.
- A hazardous area verification dossier shall be prepared in accordance with AS/NZS 60079.14:2017 (Ref. [4]).

4.6 General Design Items

The following will be required for the site:

- Containment of potentially contaminated water for 90 minutes of activation: 3 hydrant hoses x 0.6 m^3/min x 90 + 6 x 90 = 702 m^3. Note: This may be contained within the warehouse footprint, recessed docks, or hardstand, storm water system, etc. to achieve the intent of the requirement.
- Site drainage to flow toward one location which is fitted with a penstock valve which can close on fire trip.
- Smoke extraction / exhaust system per Fire Engineer's requirement.

4.7 Separation of DGs

4.7.1 Separation

Provided in **Table 4-7** is a summary of the prescriptive separation distances required between each class of DGs within the automated system. It is noted that these distances do not take into account consideration of the reduced risk from retail sized packages. A detailed risk assessment may be conducted to reduce the separation distances as required based upon a review of the package size, classes, quantities and movement throughout the system.

Table 4-7: Separation Distances for DGs within the DG Store

	2.1	2.2	3	5.1	8	9
2.1	n/a	3	3	5	3	n/a
2.2	3	n/a	3	3	3	n/a
3	3	3	n/a	5	3	n/a
5.1	5	3	5	n/a	3	n/a
8	3	3	3	3	n/a	n/a
9	n/a	n/a	n/a	n/a	n/a	n/a

5.0 Work Health and Safety Regulation

5.1 Introduction

In addition to the requirements of the relevant standards, a Person Conducting a Business or Undertaking (PCBU) must also satisfy several obligations outlined in Chapter 7 of the Work Health and Safety (WHS) Regulation 2017 (Ref. [1]). The relevant requirements are dependent on the quantities of DGs stored on site. The DG quantities and the placard and manifest thresholds have been outlined in **Table 5-1**. As the DG stores exceed the manifest threshold, the site is classified as a Manifest site.

It is noted that compliance with the following items are operational issues specific to the PCBU (i.e. Confidential Customer).

Table 5-1: Manifest and Placard DG quantities

Class	PG	Description	Quantity (kg)	Placard Quantity (L)	Manifest Quantity (L)	Classification
2.1	n/a	Flammable gas (aerosols)	460,000 / 115,000	5,000	10,000	Manifest
2.1	n/a	Flammable Gas (LPG Bullet)	7,500	250	2,500	n/a
2.2	n/a	Non-flammable, non-toxic	80,000	5,000	10,000	Manifest
2.3	n/a	Ammonia	4,500	50	500	Manifest
3	II & III	Flammable liquids	2,575,000	250	2,500	Manifest
5.1	III	Oxidising agents	10,000	1,000	10,000	Manifest
8	II & III	Corrosive substances	175,000	250	2,500	Manifest
9	III	Miscellaneous DGs	675,000	n/a	n/a	n/a
C1	III	Diesel	201,500	10,000	100,000	Manifest

5.2 Applicable WHS Clauses

The applicable clauses for a manifest site from the WHS Regulation 2017 (Ref. [1]) have been outlined in **Table 5-2**.

Table 5-2: Relevant WHS Clauses and Requirements

Clause	WHS Requirement
346	A Hazardous Chemicals [*Dangerous Goods*] register shall be prepared which must include; • A list of hazardous chemicals stored, used or handled • The current Safety Data Sheet (SDS) for DGs stored, used or handled, unless the hazardous chemical is a consumer product (e.g. hand sanitiser). The register must be readily accessible to workers involved in handling or storing the chemicals, and anyone who is likely to be affected by the chemicals.
347	A manifest of chemicals stored on site shall be prepare in accordance with Schedule 12 of the regulation.

Clause	WHS Requirement
348	A notification shall be made to the regulator of the DGs that exceed the manifest quantities detailed in Schedule 11 of the Regulation.
349 & 350	PCBU shall ensure placards are displayed for all chemicals which exceed placard quantity of Schedule 11, and that placards comply with Schedule 13, as shown in **Figure 5-1** and **Figure 5-2**. A Placard Schedule shall be prepared to indicate the placard requirements. A PCBU shall ensure an outer warning placard shall is prominently displayed at the site. The placard is to show the words "HAZCHEM" in red lettering on white or silver background and shall have minimum dimensions 120 mm x 600 mm, in compliance with Schedule 13, as shown in **Figure 5-3.**
351 & 354	A PCBU must manage the risk to health and safety associated with using and storing a hazardous chemical [*Dangerous Good*] and have regard of the following: • Hazardous properties of the chemical • Reactions between chemicals (physical) or between the chemical and other substances/materials; • The nature of the work to be carried out with the hazardous chemical; • Any structure, plant or system of work used in the handling, generation or storage of the hazardous chemical [Dangerous Good] or that could react with the hazardous chemical [Dangerous Good] at the workplace. In order to comply with this requirement, it is necessary to conduct a risk assessment and to identify those hazards and risks associated with the storage and handling of the hazardous chemicals [*Dangerous Goods*]. The following recommendation has been made: • A risk assessment of the hazardous chemical [*Dangerous Good*] storage areas be conducted, including the use of the chemicals in the manufacturing areas; or • If there is an existing risk assessment, it should be reviewed.
353	A PCBU must display safety signs required to control an identified risk in relation to using, handling or storing hazardous chemicals. The safety signs must warn of a particular hazard associated with the hazardous chemical, and be located next to hazard, clearly visible to a person approaching the hazard.
355	A PCBU must ensure ignition sources are not introduced to areas which where there is a possibility of fire or explosion in a hazardous area. In the flammable liquids containers, there is potential for vapours to accumulate and ignite. Therefore, the following recommendation has been made: • A Hazardous Area Classification (HAC) report and associated drawings should be prepared for flammable liquid in accordance with AS/NZS 60079.10.1:2009 (Ref. [3]). • A Hazardous Area Dossier shall be prepared prior to occupation in accordance with AS/NZS 3000:2007 (Ref. [6]).
357	A PCBU must ensure, SFARP, that where there is a risk from a spill or leak of a hazardous chemical, a spill containment system contains the resulting effluent within the workplace. • The containment system must not create a hazard by bringing together incompatible chemicals. The containment system must provide for the clean-up and disposal of hazardous chemicals.
358	A PCBU must ensure containers of hazardous chemicals are protected against impact damage and damage from excessive load.

Clause	WHS Requirement
359	A PCBU shall ensure that a workplace is provided with fire protection and firefighting equipment that is designed and built for the types of hazardous chemicals at the workplace. • The PCBU shall have regard to the fire load of the hazardous chemicals and from other sources, and the compatibility of the hazardous chemicals with other substances on site. • The equipment shall be compatible with firefighting equipment used by Local Fire Brigades Fire protection and firefighting equipment shall be properly installed, tested and maintained, and a dated record shall be kept of the latest testing results.
361	A PCBU must prepare an emergency response plan (ERP) and submit it to the primary service organisation (Fire and Rescue NSW)
364	A PCBU must ensure that containers in which hazardous chemicals are used, handled, or stored in bulk shall have stable foundations and supports, and be secured to the foundations and supports to prevent movement and subsequent damage to the container.

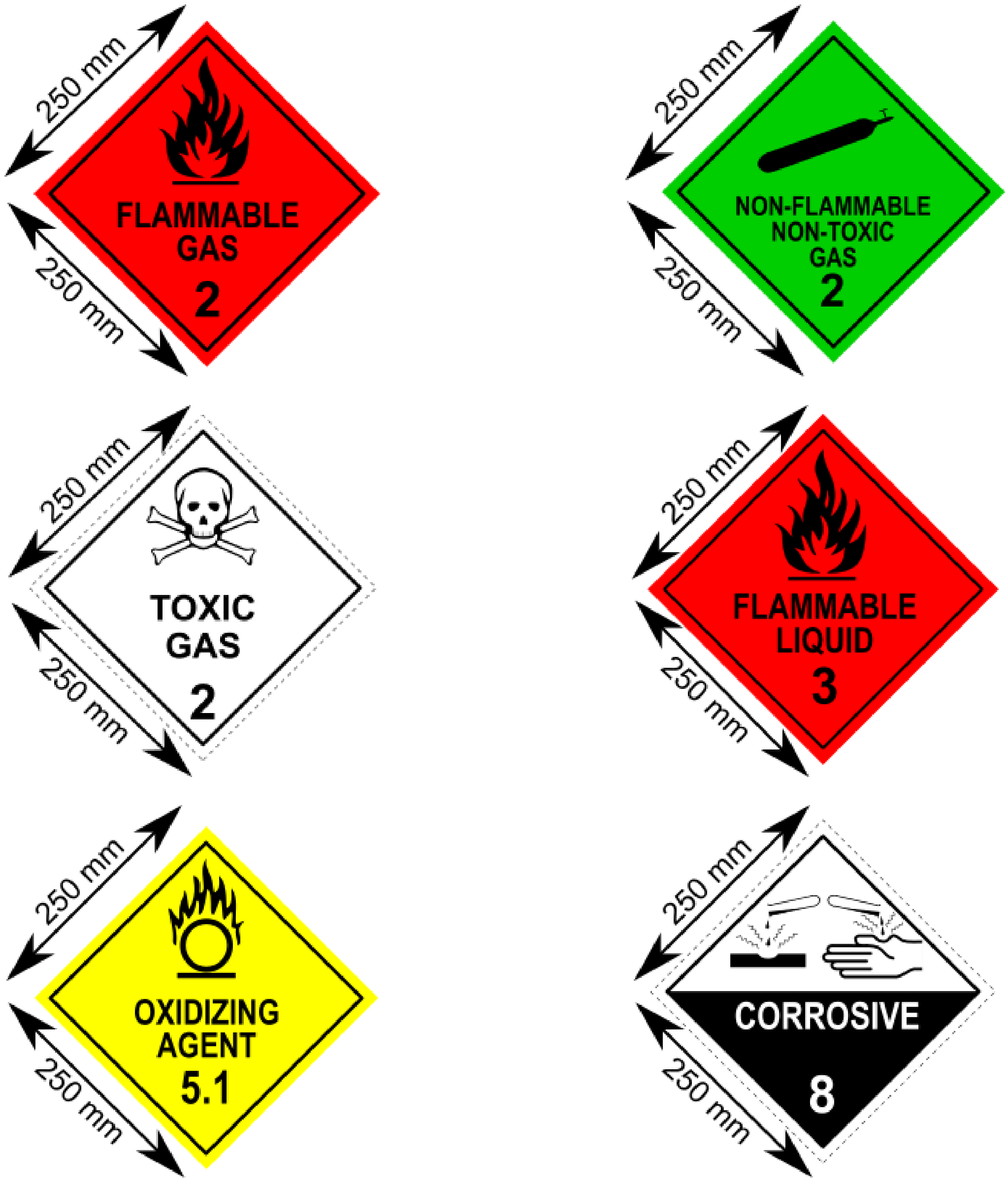


Figure 5-1: DG Placards

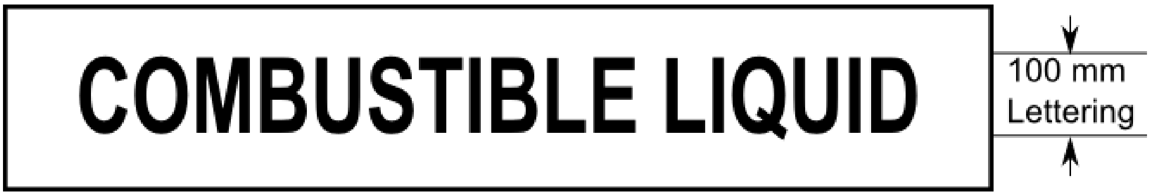


Figure 5-2: Combustible Liquid Placard

Figure 5-3: HAZCHEM Placard

5.3 Summary of Requirements

In summary, the site will require the following:

- A DG Register, indicating the type of chemical, any notations that may be required from the risk assessment and the Safety Data Sheet for the chemical.
- A Manifest.
- Notification to SafeWork NSW.
- A DG Risk Assessment of the storage and handling area.
- A Placard Schedule.
- An Emergency Response Plan (ERP).
- An Emergency Services Information Package (ESIP)
- A Hazardous Area Classification (HAC).
- A Hazardous Area Verification Dossier (HAVD).

6.0 Conclusion and Recommendations

6.1 Conclusions

A review of the quantities of DG storage areas for the warehouse was conducted to identify the storage areas and provide design guidance to ensure the storage areas comply with the applicable standard. The warehouse was assessed using AS/NZS 3833:2007 as the facility operates as a Retail Distribution Centre (RDC) along with other anciliary areas which were subject to individual standard assessment.

The report was developed to assist the project team to design the DG storages with the aim of minimising the risk of the storages as required by the NSW WHS Regulation. It is concluded that if the advice documented in this report is followed the DG storages at the Goodman warehouse will comply with the standard and thus the NSW WHS Regulation.

6.2 Recommendations

The following recommendations have been made for the facility:

- The design requirements detailed within this report shall be adhered to in the development of the design for the facility.
- The DGs stored in the warehouse are to be per the requirements of this report.

DG Documents:

Ensure the following documentation is supplied on site in accordance with the Work Health and Safety Regulation 2017:

- A DG Register, indicating the type of chemical, any notations that may be required from the risk assessment and the Safety Data Sheet for the chemical.
- A Manifest.
- Notification to SafeWork NSW.
- A DG Risk Assessment of the storage and handling area.
- A Placard Schedule.
- An Emergency Response Plan (ERP).
- An Emergency Services Information Package (ESIP)
- A Hazardous Area Classification (HAC).
- A Hazardous Area Verification Dossier (HAVD).

7.0 References

[1] SafeWork NSW, "Work Health and Safety Regulation," SafeWork NSW, Lisarow, 2017.

[2] Standards Australia, "AS/NZS 3833:2007 - Storage and Handling of Mixed Classes of Dangerous Goods, in Packages and Intermediate Bulk Containers," Standards Australia, Sydney, 2007.

[3] Standards Australia, AS/NZS 60079.10.1:2009 - Explosive Atmospheres Part 10.1: Classification of Areas, Explosive Gas Atmospheres, Sydney: Standards Association of Australia, 2009.

[4] Standards Australia, AS/NZS 60079.14:2017 - Explosive Atmospheres Part 14: Electrical Installations, Design, Selection and Erection, Sydney: Standards Australia, 2017.

[5] Standards Australia, "AS/NZS 1668.2:2002 - The Use of Ventilation and Airconditioning in Buildings - Ventilation Design for Indoor Air Contaminant Control," Standards Australia, Sydney, 2002.

[6] Standards Australia, "AS/NZS 3000:2018 - Wiring Rules," Standards Australia, Sydney, 2018.

[7] Standards Australia, "AS 2118.1:2017 - Automatic Fire Sprinkler Systems General Systems," Standards Australia, Sydney, 2017.

[8] Standards Australia, AS/NZS 1596:2014 - The Storage and Handling of LP Gas, Sydney: Standards Australia, 2014.

[9] Standards Australia, AS 1940:2017 - Storage and Handling of Flammable and Combustible Liquids, Sydney: Standards Australia, 2017.

[10] Standards Australia, "AS/NZS 2022:2003 - Anhydrous Ammonia," Standards Australia, Sydney, 2003.