Preliminary Hazard Analysis

Lot 1 DP 1274322 Eastern Creek Drive, Eastern Creek

Charter Hall
Document No. RCE-21201_CH_PHA_Final_9Feb22_Rev(1)
Date 9/02/2022

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Quality Management

Rev	Date	Remarks	Prepared By	Reviewed By
A	23 November 2021	Draft issue for comment	Jason Costa	Renton Parker
0	7 December 2021	Issued Final		
1	9 February 2022	Included additional assessments		

Executive Summary

Background

A Charter Hall proposes the construction and 24/7 operation of a warehouse at Lot 1 DP 1274322 Eastern Creek Drive in Eastern Creek, NSW comprising;

- minor earthworks involving cut and fill works;
- site preparation works and servicing;
- warehouse, main office, ancillary office, dock office, loading docks, carparking, forklift charging room;
- external hardstands and landscaping.

As shown in **Figure 1-1**.

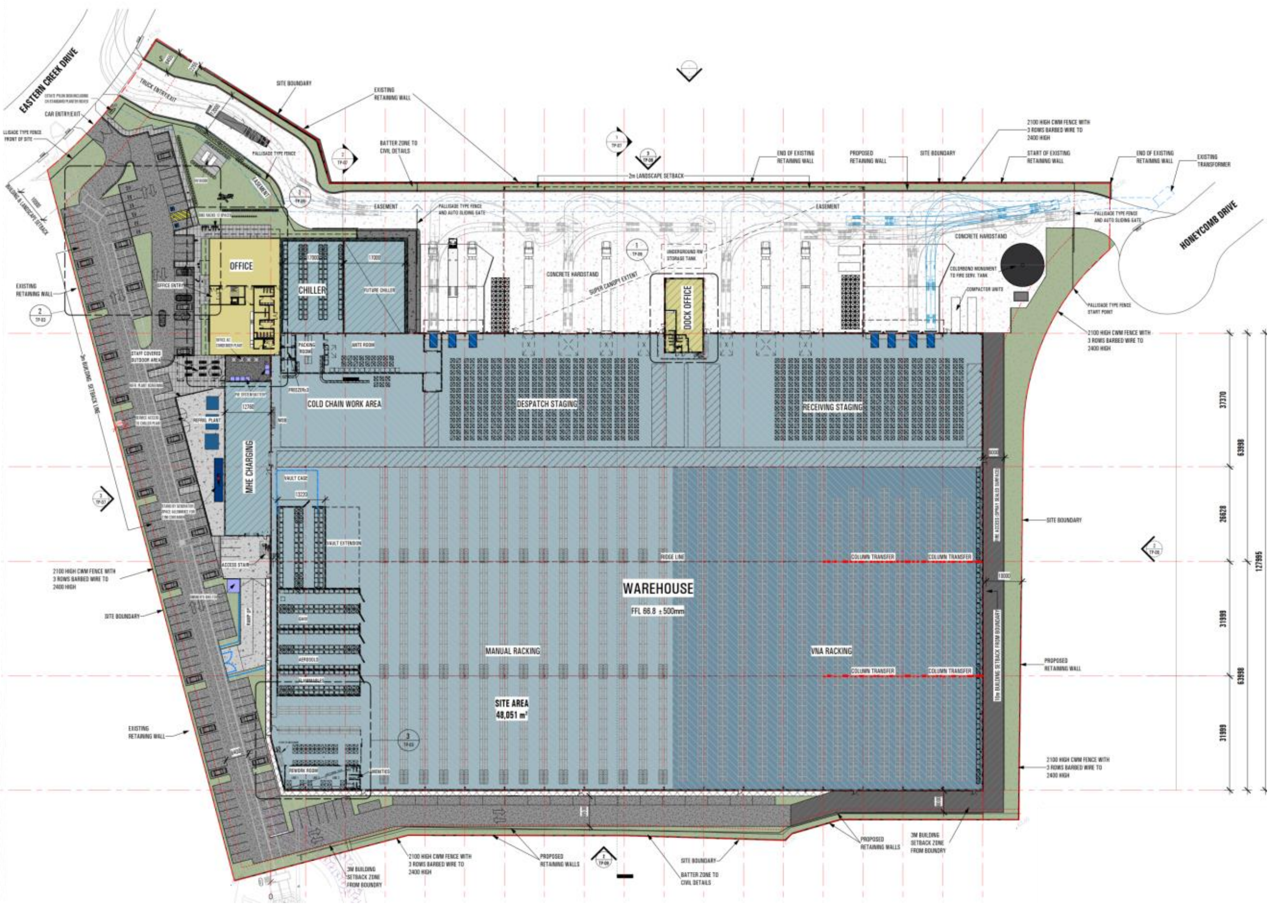

Figure 1-1: Site Layout

In addition, the warehouse will store and handle aerosol products which are classified as Dangerous Goods (DGs) for storage prior to distribution.

The Secretary's Environmental Assessment Requirements (SEARs) require the facility to be reviewed against the State Environmental Planning Policy No. 33 (SEPP33, Ref. [1]) and if the relevant thresholds within SEPP 33 are exceeded, a Preliminary Hazard Analysis (PHA) is required to be prepared as part of the Development Application.

Table 1-1: SEARs Items

Key Issue No. & Description	Issue & Assessment Requirements	How It Is Addressed	Location Within This Report
Issue 15: Hazards and Risks	• Where there are dangerous goods and hazardous materials associated with the development provide a preliminary risk screening in accordance with SEPP 33.	Preliminary risk screening not necessary as quantities easily exceed SEPP 33	n/a
	• Where required by SEPP 33, provide a Preliminary Hazard Analysis prepared in accordance with Hazardous Industry Planning Advisory Paper No. 6 – Guidelines for Hazard Analysis.	SEPP 33 exceeded, PHA prepared	This report
	• If the development is adjacent to or on land in a pipeline corridor, report on consultation outcomes with the operator of the pipeline, and prepare a hazard analysis	n/a	n/a

A review of the application guide to SEPP 33 indicates the facility would exceed the threshold criteria for the storage of DGs resulting in a classification for the site of potentially hazardous. To demonstrate that the facility is not in fact hazardous, it is necessary to prepare a PHA for the site in support of the DA.

Tactical Group, on behalf of the Charter Hall, has commissioned Riskcon Engineering Pty Ltd (Riskcon) to prepare a PHA for the facility. This document represents the PHA study for the Charter Hall Compass 2 Warehouse and Distribution at Eastern Creek.

Conclusions

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

Incidents carried forward for consequence analysis were assessed in detail to estimate the impact distances. Impact distances were developed into scenario contours and overlaid onto the site layout diagram to determine if an offsite impact would occur. The consequence analysis showed that one of the scenarios (full warehouse fire) would impact over the site boundary and into the adjacent land use; hence, this incident was 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.

In addition, the only incident which may result in impacts to adjacent structures was a full warehouse fire. Due to the fire size there will be considerable smoke emitted which would obscure the flame surface reducing the average surface emissive power (SEP) and subsequently it would not exceed 23 kW/m^2. In addition, the distance to the closest buildings is 23 m which would allow attenuation of radiant heat from of luminous spots and would not result in sustained radiant heat such that propagation to adjacent facilities would occur.

Review of the estate proposal indicates this development is the only contributor to the risk profile as other entities involving the storage of DGs are below the SEPP 33 thresholds; hence, cumulative risk has not been considered any further. 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 of the Compass 2 Warehouse and Distribution Centre 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:

- 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.
- Where a penstock isolation valve is incorporated into the design, it shall be able to isolate automatically upon fire detection.
- Where a penstock isolation valve is incorporated into the design, it shall be capable to manually operate the isolation valve.
- 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.
- The flammable liquid storage shall be subject to hazardous area classification in accordance with AS/NZS 60079.10.1:2009.
- Where a hazardous area is identified around the flammable liquid storage, any electrical equipment installed within the hazardous area shall be installed in accordance with AS/NZS 60079.14:2017.

- 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).
- Aerosol storage shall be subject to hazardous area classification in accordance with AS/NZS 60079.10.1:2009.
- Where a hazardous area is identified around the aerosol storage, any electrical equipment installed within the hazardous area shall be installed in accordance with AS/NZS 60079.14:2017.
- The HFC refrigeration systems shall be subject to a hazardous area classification in accordance with AS/NZS 60079.10.1:2009.
- Where a hazardous area is identified around the HFC refrigeration system, any electrical equipment installed within the hazardous area shall be installed in accordance with AS/NZS 60079.14:2017.

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Abbreviations

Abbreviation	Description
ADG	Australian Dangerous Goods Code
AS	Australian Standard
CBD	Central Business District
CCPS	Centre for Chemical Process Safety
DA	Development Application
DGs	Dangerous Goods
DGS	Dangerous Goods Store
DPE	Department of Planning and Environment
FRNSW	Fire and Rescue New South Wales
HIPAP	Hazardous Industry Planning Advisory Paper
HSE	Health and Safety Executive
LPG	Liquefied Petroleum Gas
PFD	Probability of Failure on Demand
PHA	Preliminary Hazard Analysis
Pmpy	Per million per year
RDC	Retail Distribution Centre

Abbreviation	Description
SEP	Surface Emissive Power
SEPP	State Environmental Planning Policy
SMSS	Storage Mode Sprinkler System
SSC	Spread Sheet Calculator
VF	View Factor

1.0 Introduction

1.1 Background

A Charter Hall proposes the construction and 24/7 operation of a warehouse at Lot 1 DP 1274322 Eastern Creek Drive in Eastern Creek, NSW comprising;

- minor earthworks involving cut and fill works;
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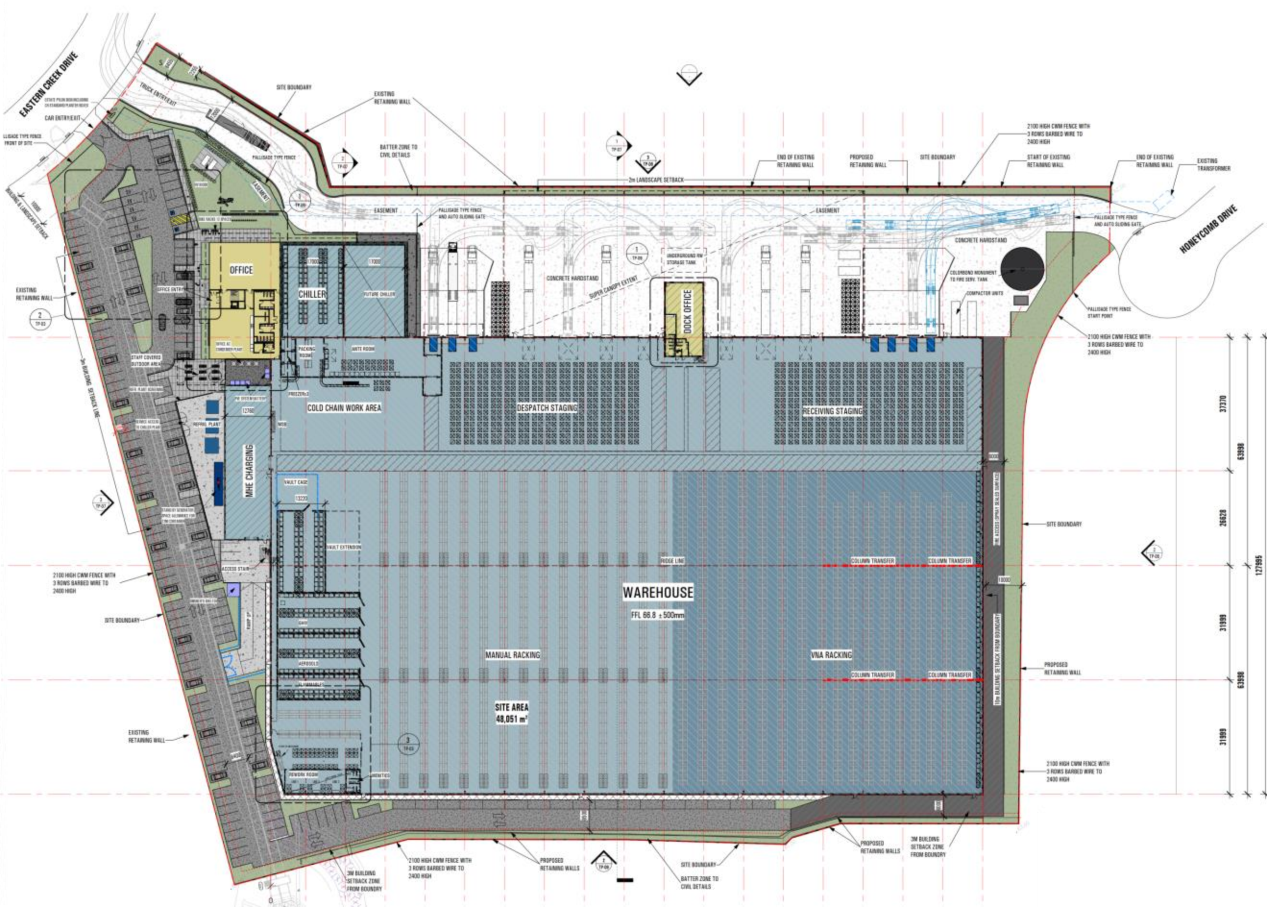

Figure 1-1: Site Layout

In addition, the warehouse will store and handle aerosol products which are classified as Dangerous Goods (DGs) for storage prior to distribution.

The Secretary's Environmental Assessment Requirements (SEARs) require the facility to be reviewed against the State Environmental Planning Policy No. 33 (SEPP33, Ref. [1]) and if the relevant thresholds within SEPP 33 are exceeded, a Preliminary Hazard Analysis (PHA) is required to be prepared as part of the Development Application.

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A review of the application guide to SEPP 33 indicates the facility would exceed the threshold criteria for the storage of DGs resulting in a classification for the site of potentially hazardous. To demonstrate that the facility is not in fact hazardous, it is necessary to prepare a PHA for the site in support of the DA.

Tactical Group, on behalf of the Charter Hall, has commissioned Riskcon Engineering Pty Ltd (Riskcon) to prepare a PHA for the facility. This document represents the PHA study for the Charter Hall Compass 2 Warehouse and Distribution at Eastern Creek.

1.2 Objectives

The objectives of the PHA project, for the proposed facility at Lot 1 DP 1274322 Eastern Creek Drive, Eastern Creek, NSW, include:

- Complete the PHA according to the Hazardous Industry Planning Advisory Paper (HIPAP) No. 6 – Hazard Analysis (Ref. [3]);
- Assess the PHA results using the criteria in HIPAP No. 4 – Risk Criteria for Land Use Planning (Ref. [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 Lot 1 DP 1274322 Eastern Creek Drive, Eastern Creek, required by the Planning Regulations for the proposed development. 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. [3]), although 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**.

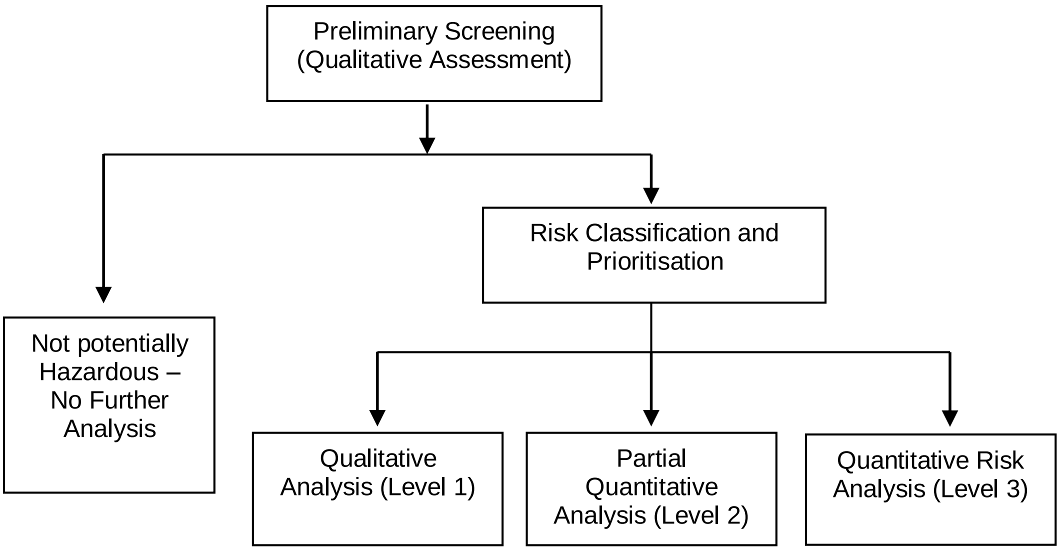


Figure 2-1: The Multi-Level Risk Assessment Approach

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. [4]).

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 Charter Hall. A final report was then developed, incorporating the comments received by Charter Hall for submission to the regulatory authority.

3.0 Site Description

3.1 Site Location

The site is located at Lot 1 DP 1274322 Eastern Creek Drive in Eastern Creek 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 Eastern Creek.

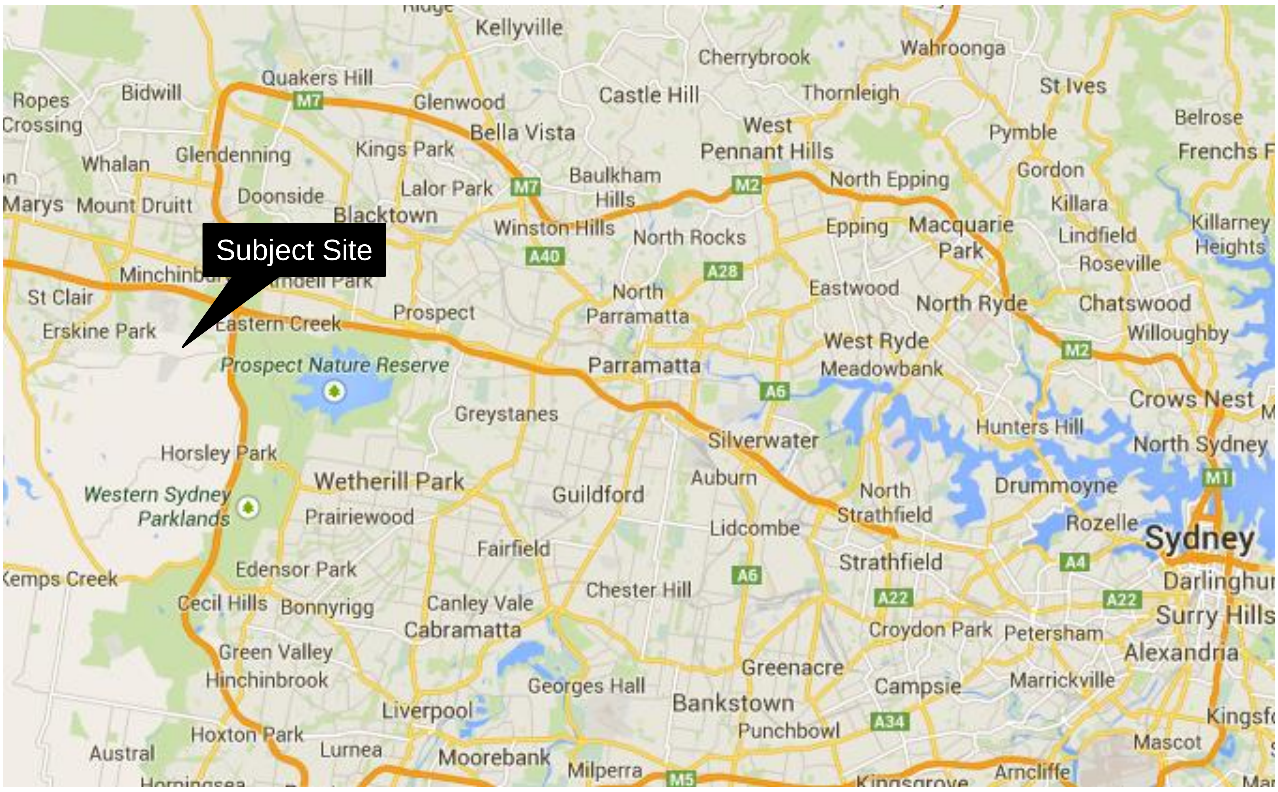


Figure 3-1: Site Location

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 – Industrial warehousing
- South – Industrial warehousing
- East – Industrial warehousing
- West – Industrial warehousing

3.3 Warehouse Detailed Description

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 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 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.

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**. The proposed DG storage locations are shown in **Figure 3-2.**

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

Class	Description	Packing Group	Quantity (kg)
2.1	Flammable gas (aerosols)	n/a	224,000 kg / 56,000*
2.1	Hydrofluorocarbon (HFC) refrigerant gases	n/a	630 kg
2.2	Non-flammable, non-toxic gas (aerosols)	n/a	76,000 / 19,000*
3	Flammable liquids	II & III	420,000

*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 quantities 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 2.2, 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	56.63
2.2	n/a	Not subject to MHF	n/a
3	II & III	50,000	420

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

$$AQR = \frac{56.63}{200} + \frac{420}{50000} = 0.2916$$

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

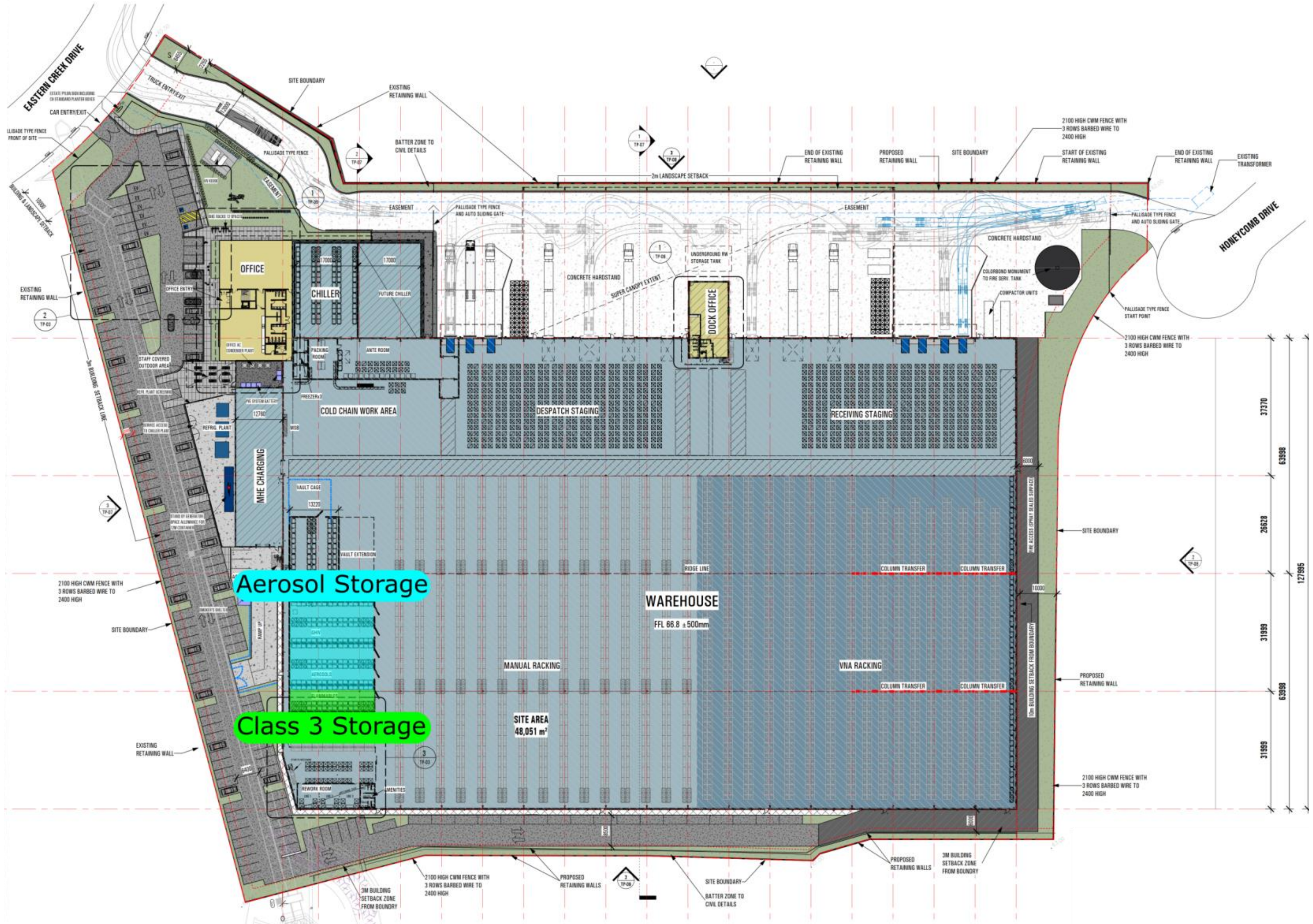


Figure 3-2: Site Layout

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. [4]). 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 have been proposed to be stored at the site; hence, toxicity has been assessed.

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

- _Societal Risk_ – HIPAP No. 4 (Ref. [2]) discusses the application of societal risk to populations surrounding the proposed potentially hazardous facility. It is noted that HIPAP No. 4 indicates that where a development proposal involves a significant intensification of population, in the vicinity of such a facility, the change in societal risk needs to be taken into account. In the case of the facility, there is currently no significant intensification of population around the proposed site; however, the adjacent land has been rezoned residential; hence, there will be housing located approximately 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).
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 60ºC closed-cup test or not more than 65.6ºC 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.

* The Australian Code for the Transport of Dangerous Goods by Road and Rail (Ref. [11])

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.
- HFC gas release, ignition and flash fire, explosion or jet fire.

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. 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.

Notwithstanding the above, the following recommendation has been made:

- The flammable liquid storage shall be subject to hazardous area classification in accordance with AS/NZS 60079.10.1:2009.
- Where a hazardous area is identified around the flammable liquid storage, any electrical equipment installed within the hazardous area shall be installed in accordance with AS/NZS 60079.14:2017.

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).
- Aerosol storage shall be subject to hazardous area classification in accordance with AS/NZS 60079.10.1:2009.
- Where a hazardous area is identified around the aerosol storage, any electrical equipment installed within the hazardous area shall be installed in accordance with AS/NZS 60079.14:2017.

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 4.4** 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) 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 5 m^3/min of water which, if operated for a long period, may result in overflow of site bunding and potential release. The facility has been designed to be able to contain all DG spills and liquid effluent resulting from the management of an incident (i.e. fire) within the premises.

The site will hold 60 minutes of water storage on site as required by FM Global standards; hence, to allow for additional conservatism, following a risk assessment methodology as outlined by the Department of Planning document "*Best Practice Guidelines for Potentially Contaminated Water Retention and Treatment Systems"* (Ref. [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.
- Where a penstock isolation valve is incorporated into the design, it shall be able to isolate automatically upon fire detection.
- Where a penstock isolation valve is incorporated into the design, it shall be capable to manually operate the isolation valve.

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 HFC Gas Release, Ignition and Flash Fire, Explosion or Jet Fire

HFC gases are used within the existing refrigeration system and also proposed as part of a chiller in the expansion. HFC gases are classified as Class 2.1 flammable gases and are used under pressure; hence, in the event of loss of containment there is the potential for a flammable atmosphere to form which if ignited can result in a range of outcomes depending upon the environment and whether immediate or delayed ignition occurs.

Where a high-pressure release occurs with immediate ignition, a jet fire can occur which can result in jet flame extending substantial distance depending upon the pressure and the size of release. A review of burning speeds indicated HFC gases are low burning speeds which results in insufficient heat being released to maintain ignition of a jet flame without a continued ignition source. Furthermore, based upon the location of the refrigeration system, a jet fire would be unlikely to impact over the site boundary.

In the event of delayed ignition, an explosion can occur provided there is sufficient confinement to allow for pressure to build within the flammable atmosphere resulting in a detonation of the vapour cloud. As noted, the low flame speeds within HFC gases may result in insufficient heat generation to sustain the flame through the atmosphere preventing high turbulence from occurring and thus eliminating the accelerating expansion of the vapour cloud which escalates into an explosion. Therefore, an explosion is not considered to be a credible scenario.

If there is insufficient confinement, delayed ignition will result in a flash fire. If the vapour cloud migrates over the site boundary, ignition can result in a flame traversing through the vapour cloud which if someone is exposed within the atmosphere, they are likely to die due to involuntary inhalation of hot air following combustion. Based upon the refrigeration systems it is unlikely that a sufficient atmosphere of gas at flammable concentrations would impact over the site boundary; hence, a fatality from a flash fire is not considered credible.

In addition to the above discussions, refrigeration systems are typically composed of fully-welded systems minimising the potential sources of failure and resulting in only small leaks around valves, fittings, etc. further reducing the size of loss of containment. HFC refrigeration systems have become ubiquitous throughout the country with minimal observable incidents; hence, the potential for loss of containment and high consequence incidents to occur are considered low.

Finally, as flammable gases are stored, it is necessary to assess the potential for a hazardous atmosphere to exist as required by the Work Health and Safety Regulations 2017 (Ref. [10]) and hazardous area rated equipment installed per AS/NZS 60079.14:2017 (Ref. [9]). Notwithstanding this, to ensure it is captured, the following recommendation has been made:

- The HFC refrigeration systems shall be subject to a hazardous area classification in accordance with AS/NZS 60079.10.1:2009.
- Where a hazardous area is identified around the HFC refrigeration system, any electrical equipment installed within the hazardous area shall be installed in accordance with AS/NZS 60079.14:2017.

Based upon the low flame speeds, the design of refrigeration system, the ubiquitous nature of such systems, it is considered that the potential for an offsite impact is unlikely to occur; hence, HFC gas related incidents have not been carried forward for further analysis.

5.0 Consequence Analysis

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

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.

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**.

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

Heat Radiation (kW/m^2)	Distance (m)	
	Base Case	Sensitivity
35	4.6	8.5
23	5.6	10.3
12.6	7.5	13.7
4.7	12.0	22.2

A review of the contours illustrated in **Figure 5-1**indicates there would be no offsite impact at the 4.7 kW/m^2 nor the 23 kW/m^2 contour. As no offsite impact was identified, this incident has not been carried forward for further analysis.

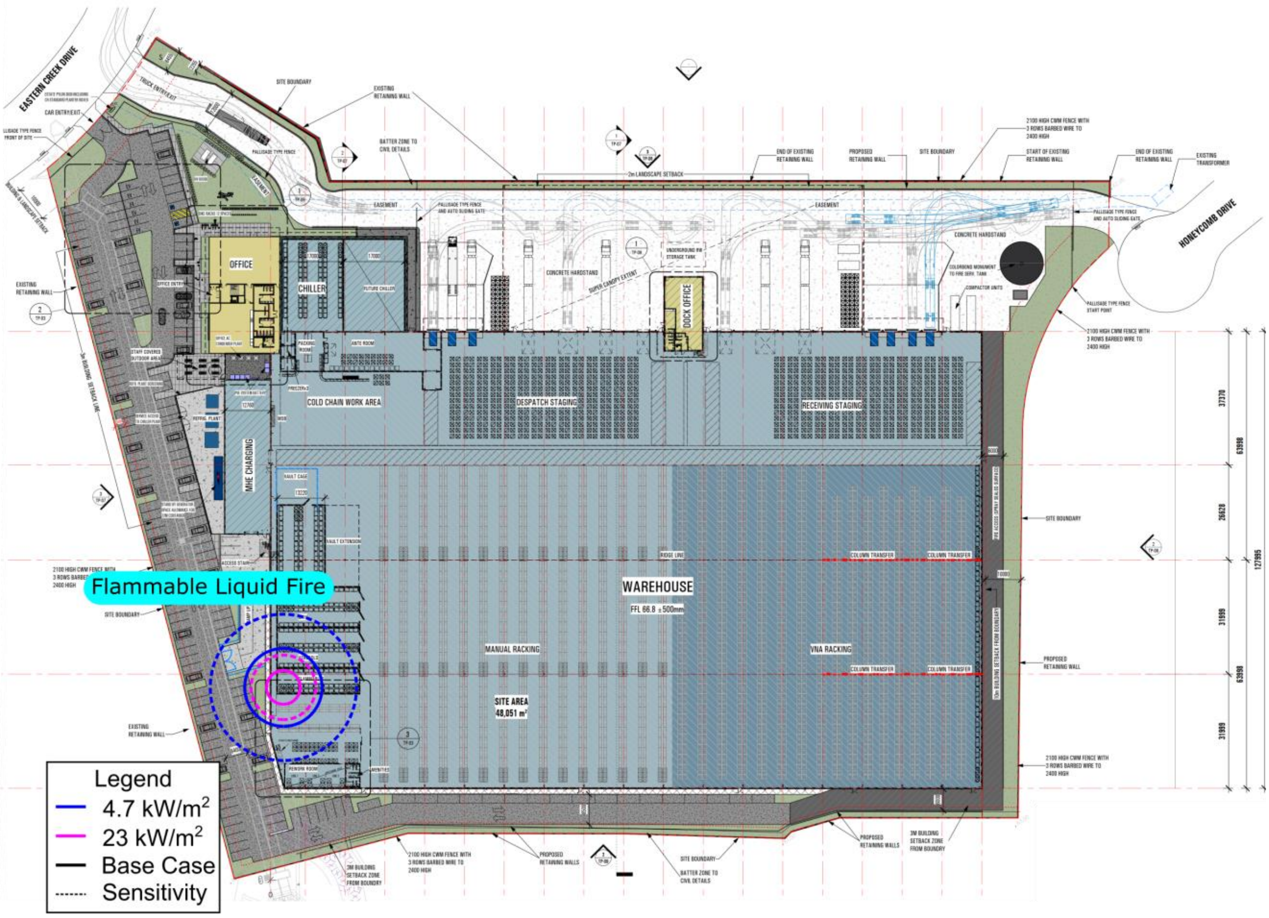


Figure 5-1: Sprinkler Controlled Flammable Material Fire Radiant Heat Contours

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/m^2)	Distance (m)	
	Base Case	Sensitivity
35	5.4	10.1
23	6.5	12.1
12.6	8.6	15.9
4.7	13.7	25.5

A review of the contours illustrated in **Figure 5-2** indicates there would be no offsite impact at the 4.7 kW/m^2 nor the 23 kW/m^2 contour. As no offsite impact was identified, this incident has not been carried forward for further analysis.

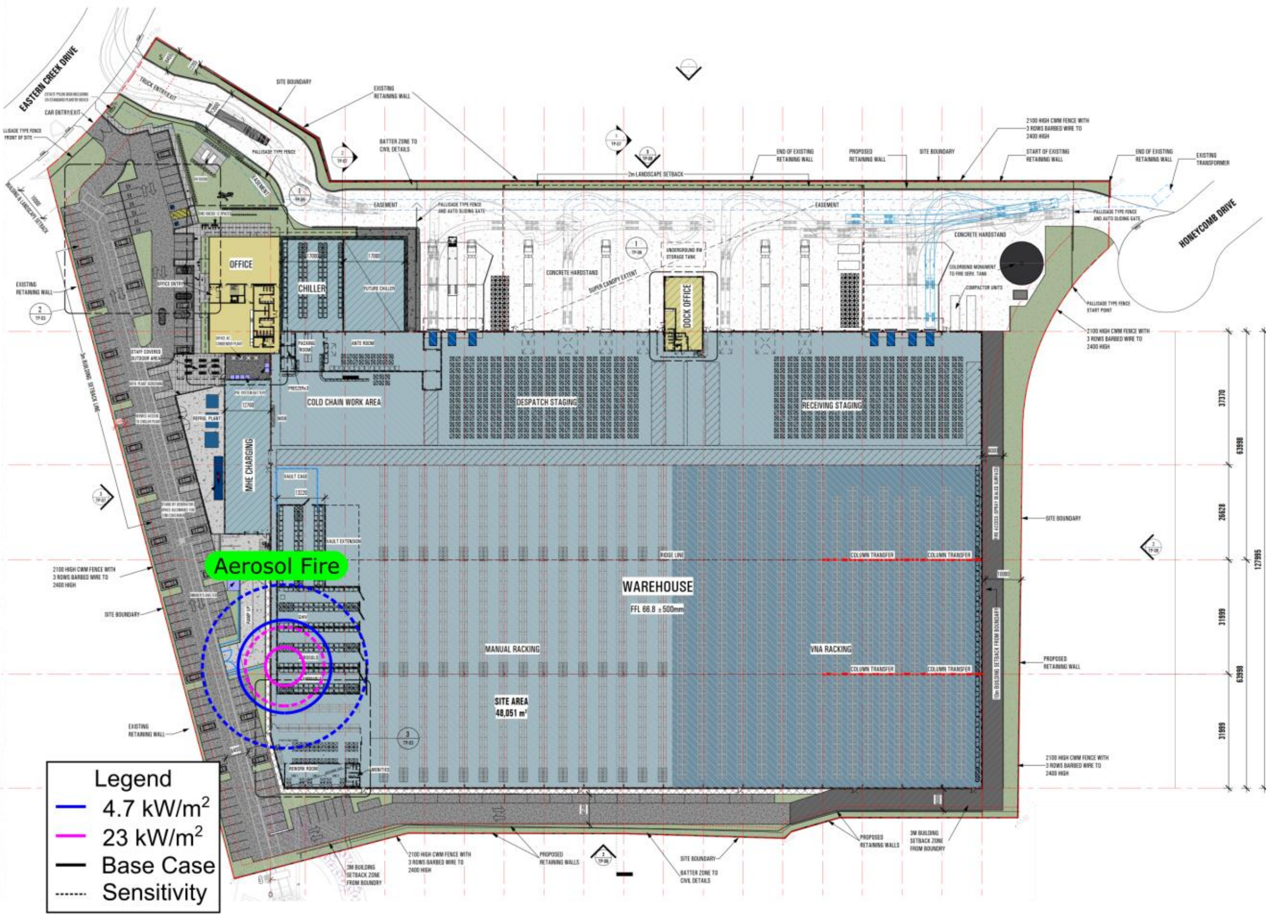


Figure 5-2: Sprinkler Controlled Aerosol Fire Radiant Heat Contours

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 **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/m^2)	Distance (m)
35	Maximum heat flux is 20*
23	Maximum heat flux is 20*
12.6	43.9
4.7	98.6
3.0	133.7

*Based on the research by Mudan & Croche reported in Lees (Ref. [12]) & Cameron/Raman (Ref. [13])

As shown in **Figure 5-3**, the radiant heat impacts at 4.7 kW/m^2 extend over the site boundary; hence, there is the potential for a fatality at the site boundary to occur. Therefore, this incident has been carried forward for further analysis.

It is noted that due to the fire size there will be considerable smoke emitted which would obscure the flame surface reducing the average surface emissive power (SEP) and subsequently it would not exceed 23 kW/m^2. In addition, the distance to the closest buildings is 23 m which would allow attenuation of radiant heat from of luminous spots and would not result in sustained radiant heat such that propagation to adjacent facilities would not occur.

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	73.4
Sulphur Dioxide	127
Hydrogen Chloride	64.5
Soot (Carbon)	146

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 in the most stable F1.5 conditions. 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.

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.

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. [14]). 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**.

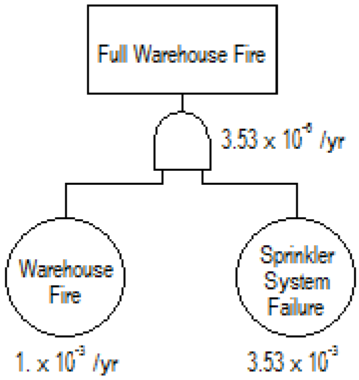


Figure 6-1: Full Warehouse Fire Fault Tree

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 Total Fatality Risk

Provided in **Table 6-1** 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 6-1: Total Fatality Risk

Incident	Fatality Risk
Full warehouse fire	3.53×10^{-6}
Smoke emission	3.53×10^{-6}
Total	$\mathbf{7.06 \times 10^{-6}}$

6.6 Comparison Against Risk Criteria

The NSW Department of Planning and Environment has issued a guideline on the acceptable risk criteria (Ref. [2]). The acceptable risk criteria published in the guideline relates to injury, fatality and property damage. The values in the guideline present the maximum levels of risk that are permissible at the land use under assessment. The adjacent land use would be classified as an industrial site as it is restricted access and only industrial operations are permitted to occur in this area. For industrial facilities, the maximum permissible fatality risk is 50 pmpy. The assessed highest fatality risk is 7.06 pmpy at the closest site boundary (eastern boundary); hence, the highest risk is within the permissible criteria and therefore all other risk points beyond the boundary would be within the acceptable criteria.

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.

6.7 Cumulative Assessment

A review of the surrounding area indicates there are several warehouses within the vicinity; however, a review of the Development Applications (DAs) for these warehouse indicates none of these warehouses exceed the SEPP 33 thresholds. Specific warehouses within the vicinity are:

1. Data centre which was identified to be below SEPP 33 thresholds
2. Jaycar warehouse which stores a range of DGs all below SEPP 33 thresholds.

As the premise of SEPP 33 is that where storage is below the thresholds, offsite impact is not expected to occur, these warehouses are not considered to result in an increase to the cumulative impacts within area. Therefore, the only contributor to the area would be the warehouse subject to assessment within this PHA; hence, cumulative risk are not considered any further.

7.0 Conclusion and Recommendations

7.1 Conclusions

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

Incidents carried forward for consequence analysis were assessed in detail to estimate the impact distances. Impact distances were developed into scenario contours and overlaid onto the site layout diagram to determine if an offsite impact would occur. The consequence analysis showed that one of the scenarios (full warehouse fire) would impact over the site boundary and into the adjacent land use; hence, this incident was 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.

In addition, the only incident which may result in impacts to adjacent structures was a full warehouse fire. Due to the fire size there will be considerable smoke emitted which would obscure the flame surface reducing the average surface emissive power (SEP) and subsequently it would not exceed 23 kW/m^2. In addition, the distance to the closest buildings is 23 m which would allow attenuation of radiant heat from of luminous spots and would not result in sustained radiant heat such that propagation to adjacent facilities would occur.

Review of the estate proposal indicates this development is the only contributor to the risk profile as other entities involving the storage of DGs are below the SEPP 33 thresholds; hence, cumulative risk has not been considered any further. 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 of the Compass 2 Warehouse and Distribution Centre 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:

- 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.
- Where a penstock isolation valve is incorporated into the design, it shall be able to isolate automatically upon fire detection.
- Where a penstock isolation valve is incorporated into the design, it shall be capable to manually operate the isolation valve.
- 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.
- The flammable liquid storage shall be subject to hazardous area classification in accordance with AS/NZS 60079.10.1:2009.
- Where a hazardous area is identified around the flammable liquid storage, any electrical equipment installed within the hazardous area shall be installed in accordance with AS/NZS 60079.14:2017.
- 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).
- Aerosol storage shall be subject to hazardous area classification in accordance with AS/NZS 60079.10.1:2009.
- Where a hazardous area is identified around the aerosol storage, any electrical equipment installed within the hazardous area shall be installed in accordance with AS/NZS 60079.14:2017.
- The HFC refrigeration systems shall be subject to a hazardous area classification in accordance with AS/NZS 60079.10.1:2009.
- Where a hazardous area is identified around the HFC refrigeration system, any electrical equipment installed within the hazardous area shall be installed in accordance with AS/NZS 60079.14:2017.

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

[4] Department of Planning, "Hazardous Industry Planning Advisory Paper No. 6 - Guidelines for Hazard Analysis," Department of Planning, Sydney, 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] National Transport Commission (NTC), "Australian Code for the Transport of Dangerous Goods by Road & Rail, 7th Edition," 2011.

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

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

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

[15] FM Global, "FM Global Data Sheet 7-31: Storage of Aerosol Products," 2016.

Appendix A

Hazard Identification Table

Appendix A

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 3 products 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) • 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	• Aerosols stored in 240/240/240 FRL bunker • In-rack sprinklers according to FM Global Data Sheet 7-31 (Ref. [15]) • Automatic fire protection system
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	Refrigeration system	• Flammable hydrocarbon refrigeration gases	• Release of gases, ignition and flash fire, explosion, or jet fire	• Hydrocarbon refrigeration gases have low flame speeds minimising potential for an explosion, jet fire, flash fire as ignition may not be sustained • Hazardous area classification per AS/NZS 60079.10.1:2009 (Ref. [8]) • Hazardous area rate equipment in accordance with AS/NZS 60079.14:2017 (Ref. [9]) • Fully welded pipework

Appendix B

Consequence Analysis

Appendix B

B1. Incidents Assessed in Detailed Consequence Analysis

The following incidents are assessed for consequence impacts.

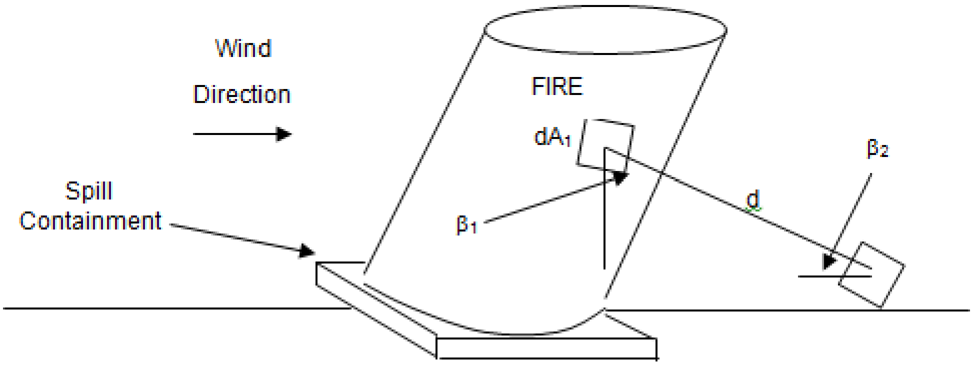
- Flammable material spill, ignition and racking fire.
- LPG release (from aerosol), ignition and racking fire.
- Full warehouse fire and radiant heat.
- Full warehouse fire and toxic smoke emission.

Each incident has been assessed in the sections below.

B2. Spreadsheet Calculator (SSC)

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

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



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

A fire in a bund or at a tank roof will act as a cylinder with the heat from the cylindrical flame radiating to the surrounding area. A number of mathematical models may be used for estimating the heat radiation impacts at various distances from the fire. The point source method is adequate for assessing impacts in the far field; however, a more effective approach is the view factor method, which uses the flame shape to determine the fraction of heat radiated from the flame to a target. The radiated heat is also reduced by the presence of water vapour and the amount of carbon dioxide in air. The formula for estimating the heat radiation impact at a set distance is shown in **Equation B-1** (Ref. [13]).

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

Where:

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

The calculation of the view factor (F) in **Equation B-1** depends upon the shape of the flame and the location of the flame to the receiver. F is calculated using an integral over the surface of the flame, S (Ref. [13]). The formula can be shown as:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The SEP is calculated using the work by Mudan & Croche (Ref. [12] & Ref. [13]) which uses a weighted value based on the luminous and non-luminous parts of the flame. The weighting is based on the diameter and uses the flame optical thickness ratio where the flame has a propensity to extinguish the radiation within the flame itself. The formula is shown in **Equation B-5**.

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

Where;

E_{max} = 140

S = 0.12

E_s = 20

D = pool diameter

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

The flame height is estimated using the Thomas Correlation (Ref. [13]) which is shown in **Equation B-6**.

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

Where;

d_p = pool diameter (m)

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

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

g = 9.81 m/s^2

The transmissivity is estimated using **Equation B-7** (Ref. [13]).

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

Where:

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

and

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

B3. Radiant Heat Physical Impacts

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

Appendix Figure B-2: 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)

Heat Radiation (kW/m^2)	Impact
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 worst credible (WC) 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: WC – 3 m, Sensitivity - 9 m
- Burning rate – 0.0667 $kg/m^2.s$ (this value encompasses a large range of flammable liquid burning rates and is considered conservative due to the nature of the flammable liquids stored, Ref. [12])

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

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

The results for flame height and SEP for each scenario are summarised in **Appendix Figure B-3**.

Appendix Figure B-3: Flame Height and SEP for a Flammable Material Sprinkler Controlled Fire

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

The inputs summarised in **Appendix Figure B-3** were input into the SSC with the results for each scenario shown in **Appendix Figure B-4**.

Appendix Figure B-4: Heat Radiation from a Flammable Material Sprinkler Controlled Fire

Heat Radiation (kW/m^2)	Distance (m)	
	Base Case	Sensitivity
35	4.6	8.5
23	5.6	10.3
12.6	7.5	13.7
4.7	12.0	22.2

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 worst credible (WC) 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: WC – 3 m, Sensitivity - 9 m
- Burning rate – 0.099 $kg/m^2.s$ (the burning rate for LPG, Ref. [12]).

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-5**.

Appendix Figure B-5: Flame Height and SEP for Class 2.1 Sprinkler Controlled Scenarios

Output	Base Case	Sensitivity
Flame Height (m)	7.7	21.0
SEP (kW/m^2)	103.7	60.8

The inputs summarised in **Appendix Figure B-5** were input into the SSC with the results for each scenario shown in **Appendix Figure B-6**.

Appendix Figure B-6: Heat Radiation from Class 2.1 Sprinkler Controlled Scenarios

Heat Radiation (kW/m²)	Distance (m)	
	Base Case	Sensitivity
35	5.4	10.1
23	6.5	12.1
12.6	8.6	15.9
4.7	13.7	25.5

B6. Full Warehouse Fire

The warehouse has a floor area of 25,400 m² which is the area that is assumed to participate in the fire. The equivalent diameter for the fire can be calculated by:

$$D = \sqrt{\frac{4 \times 25{,}400}{\pi}} = 180\ m$$

Provided in **Appendix Figure B-7** is a summary of the classes of materials stored within the facility, the applicable burning rates based on commodities stored and the contribution of each product to the total burning rate

Appendix Figure B-7: Estimation of Average Burning Rate

Class	Quantity (L)*	% of Total Quantity	Burning Rate (kg/m².s)	Burning Rate Based on %
2.1	56,000	11.3	0.099	0.0112
2.2	19,000	3.8	0.022	0.0001
3	420,000	84.9	0.0667	0.0566
Total	**105,000**	**100**	**-**	**0.0686**

*Assumed density of 1,000 kg/m³

The following information was input into the models:

- Equivalent fire diameter – 180 m
- Burning rate – 0.0686 kg/m².s
- Fire wall height: no fire wall

The models provided the following information for the warehouse fire;

- SEP – 20 kW/m²
- Flame Height – 134 m

Provided in **Appendix Figure B-8** are the results generated by the SSC.

Appendix Figure B-8: Heat Radiation Impacts from a Full Warehouse Fire

Heat Radiation (kW/m²)	Distance (m)
35	Maximum heat flux is 20*

Heat Radiation (kW/m²)	Distance (m)
23	Maximum heat flux is 20*
12.6	44.3
4.7	99.5
3.0	134.9

* Research conducted in relation to large fires (Ref. [13]) indicates that where a large fire occurs, it is difficult for complete combustion to occur towards the centre of the fire due to the lack of air being unable to reach the centre of the flames. Hence, combustion tends to occur effectively at the fire surface, but poorly towards the centre of the fire. This generates large quantities of black smoke, which shields the flame surface as the smoke from the centre of the fire escapes towards the outer fire surface. The research presented in Lees (Ref. [12]) indicates that fires will generate a SEP within a range of between 20 kW/m^2 for larger fires and 130 kW/m^2 for smaller fires. Hence, a full warehouse fire would be of significant dimensions, generating large quantities of black smoke, shielding the flames at the fire surface. Hence, for the analysis of a full warehouse fire in this study, an SEP value of 20 kW/m^2 has been used.

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.

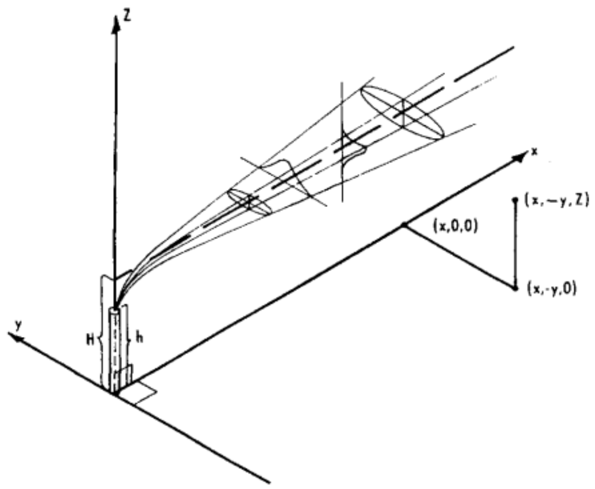
The atmospheric conditions are classified as Pasquill Guifford's Stability categories which are summarised in **Appendix Figure B-9** (Ref. [13]).

Appendix Figure B-9: 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-10** (Ref. [13]).



Appendix Figure B-10: 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-11** with the associated value input as part of this modelling exercise. As noted, the more onerous conditions occur during stable air conditions which allow far reaching effects with reduced dispersion due to low air velocities and vertical mixing. D3 conditions have been used to model the plume dispersion.

Appendix Figure B-11: Input Data for Plume Gaussian Dispersion

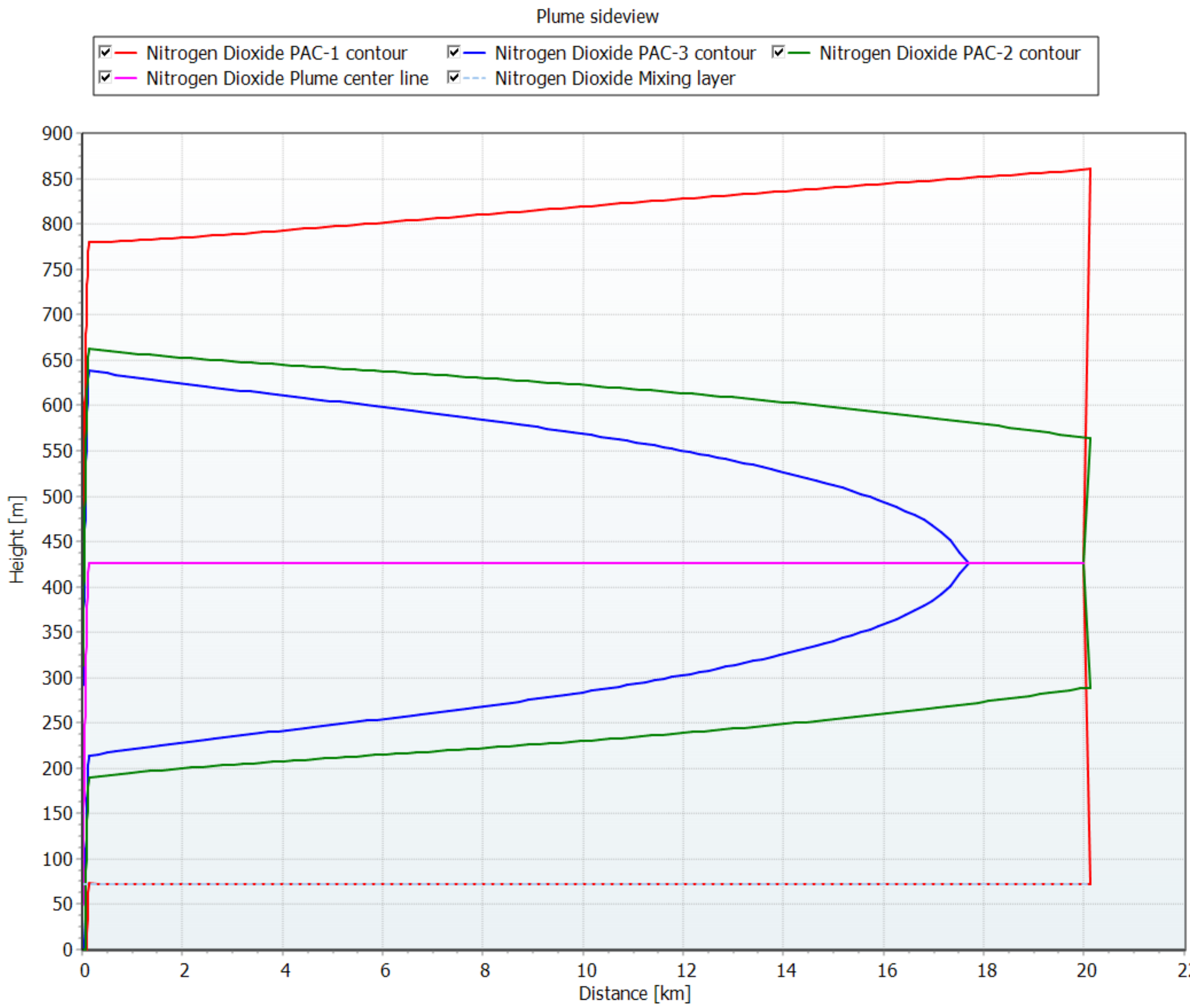
The warehouse was modelled based upon solid product stored within the warehouse and the default settings for solid product within the warehouse was adopted which is based upon typical warehouse configurations within the Netherlands which would be expected to be similar to those expected in Australia. 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-12** is a summary of the pollutant release rates generated by the model.

Appendix Figure B-12: Pollutant Release Rates

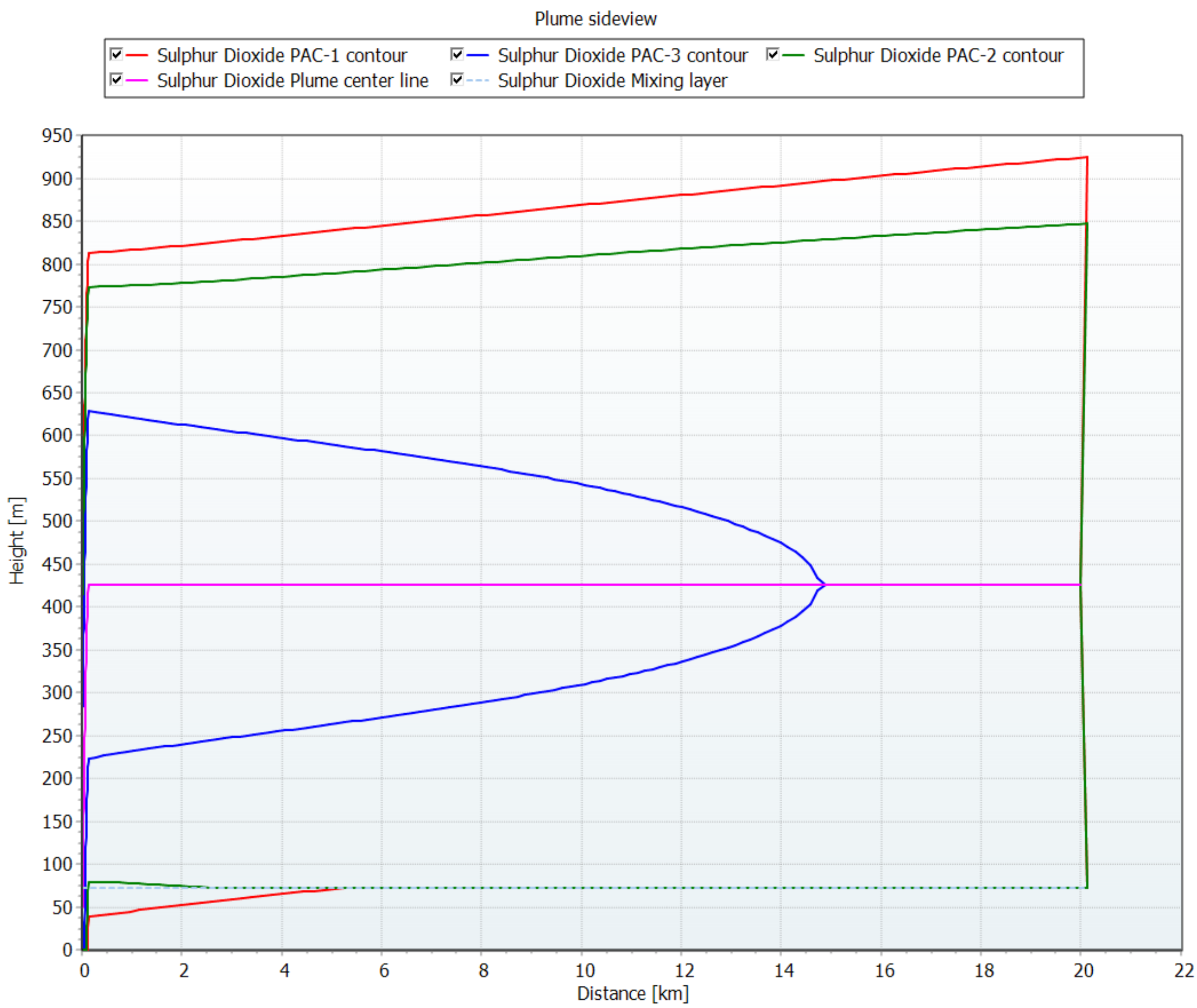
Material	Release Rate (kg/s)
Nitrogen Dioxide	11.6
Sulphur Dioxide	20.0

Material	Release Rate (kg/s)
Hydrogen Chloride	10.2
Soot (Carbon)	23

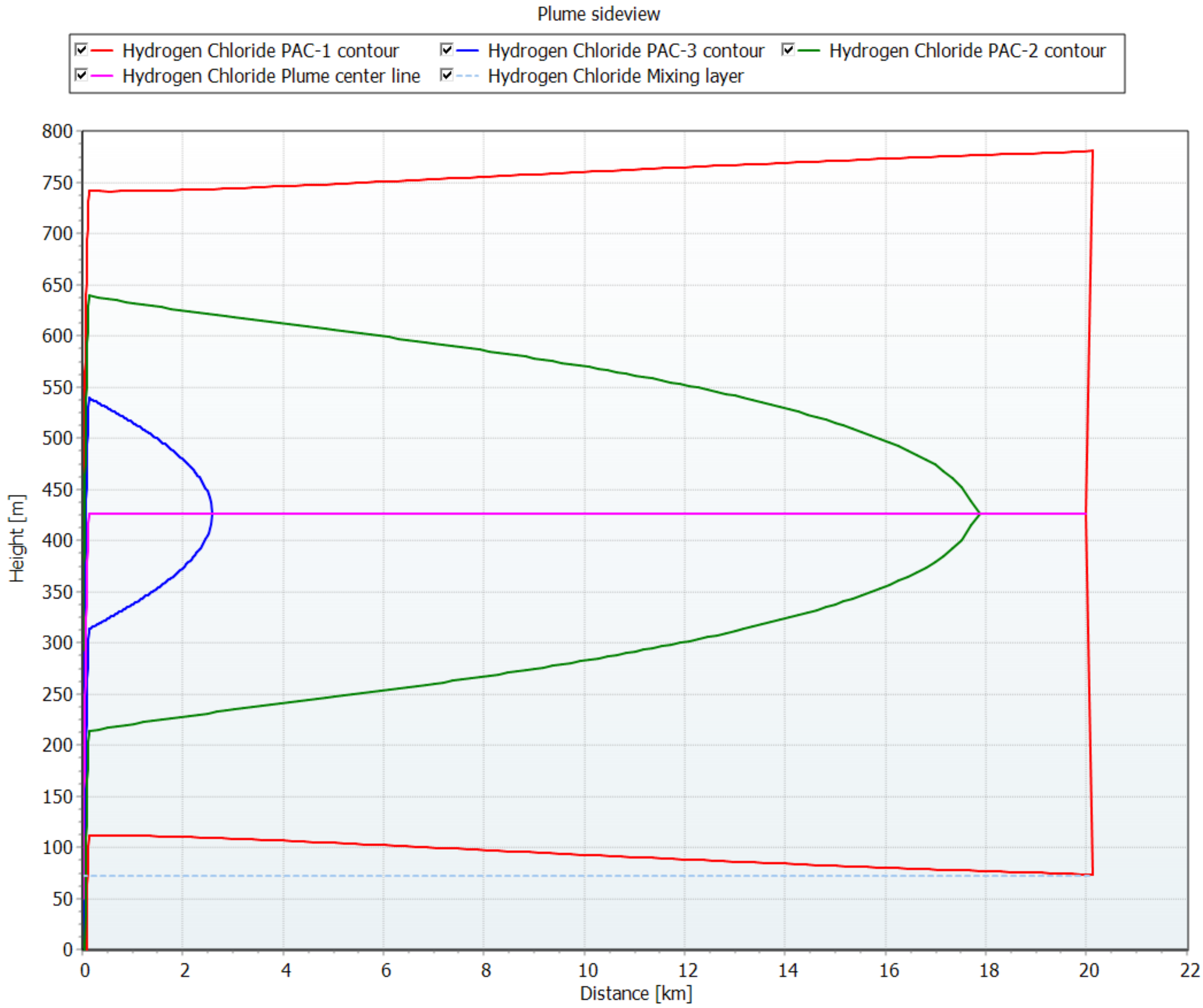
Each of the pollutants were modelled to determine their plume shape and determine whether the plume would puncture through an inversion layer and what the downwind dispersion would look like as the plume cools and settles in the atmosphere. The plume shapes are shown in **Appendix Figure B-13** to **Appendix Figure B-16**.



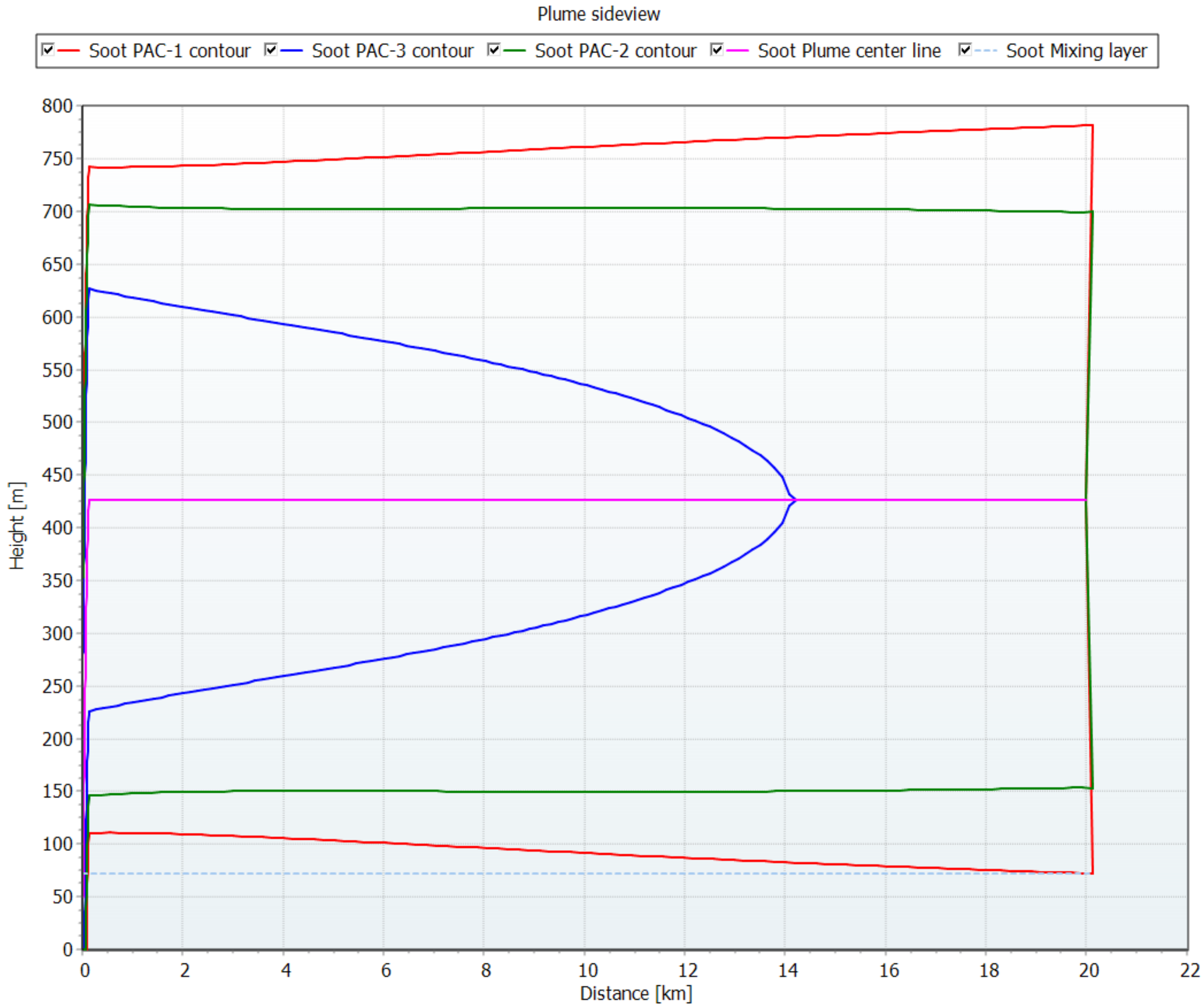
Appendix Figure B-13: Nitrogen Dioxide Downwind Plume Dispersion



Appendix Figure B-14: Sulphur Dioxide Downwind Plume Dispersion



Appendix Figure B-15: Hydrogen Chloride Downwind Plume Dispersion



Appendix Figure B-16: Soot (Carbon) Downwind Plume Dispersion

Appendix C

Warehouse Fire Frequency Estimation

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.