# Preliminary Hazard Analysis

Project Address: Agright Poultry Farm, 375 McRaes Road, Goolgowi, NSW 2652

Prepared for: Agright Poultry Pty Ltd

Report Ref: 380601-375McRaesRd-LotePHA-RevB

Date: 04/11/2022

**Commercial in Confidence**

## Conditions of Use

© Copyright Lote Consulting Pty Ltd 2022

The report addressee may only reproduce this report in full for use with respect to the project specified in the report. No organisations or individuals are permitted to reproduce this report or any part thereof for any other purpose without the prior written consent from the Managing Director of Lote Consulting Pty Ltd.

The copyright and intellectual property rights of Lote Consulting Pty Ltd extend to the data, ideas, methodologies, calculation procedures, and conclusions presented in this report and must not be used without authorisation in writing from Lote Consulting Pty Ltd. This report is subject to change and no liability will be accepted in relation to any loss resulting from use of the report pending approval from the authority having jurisdiction.

## Contact Information

**Lote Consulting Pty Ltd**

**Sydney | Newcastle | Albury | Darwin | Melbourne**

**Postal Address**
PO Box W33
Westfield Parramatta, NSW 2150
Australia

T: 1300 761 744
E: info@loteconsulting.com

ABN 75 166 888 544

# Quality Information

**Ref:** 380601-375McRaesRd-LotePHA-RevB

**Revision History:**

| Revision | Revision Date | Details | Document Details | | |
|---|---|---|---|---|---|
| | | | Prepared | Reviewed | Authorised |
| A | 14/10/22 | Draft for design team review only | Jason Costa | Renton Parker NER CPEng<br>Christopher Koch | Dr S A Magrabi Director – Fire & Risk Engineering BDC No: 0240 |
| B | 04/10/2022 | For submission | Jason Costa<br>Renton Parker NER CPEng AIDGC No. 094 | Dr S A Magrabi<br>Christopher Koch | Dr S A Magrabi Director – Fire & Risk Engineering BDC No: 0240 |

# Report Reading Guide

The scope of this Preliminary Hazard Analysis (PHA) is to assess whether the storage and handling of Dangerous Goods (DGs) at the proposed Agright Poultry Farm may result in incidents which have offsite impacts. This PHA is divided into the following sections:

EXECUTIVE SUMMARY

1.0 INTRODUCTION

2.0 METHODOLOGY

3.0 SITE DESCRIPTION

4.0 HAZARD IDENTIFICATION

5.0 CONSEQUENCE ANALYSIS

6.0 FREQUENCY ANALYSIS

7.0 CONCLUSION AND RECOMMENDATIONS

8.0 VALIDITY AND LIMITATIONS

9.0 REFERENCES

The project stakeholders will have varying degrees of involvement in the fire engineering process with an interest in different sections. It is recommended that each stakeholder read the entire document, paying particularly attention to the sections indicated in Table 0.

**Table 0 – Recommended reading guide table for project stakeholders**

| Stakeholder | Executive Summary | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Appendices |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Client | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Architect | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Certifying Authority | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Project Manager | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Services Engineers | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | |
| Fire Brigades | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Managing Contractor | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Sub-Contractor | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |

# Table of Contents

# Executive Summary

## Background

Agright Poultry Pty Ltd (Agright) have proposed to modify an existing State Significant Development (SSD-8036) and develop a poultry farm at 375 McRaes Rd, Goolgowi NSW 2652, Australia. The modified development will consist of two (2) farms (20 sheds each). As part of their operations, Agright will store and handle Class 2.1 flammable gases (Liquefied Petroleum Gas, LPG) in bulk tanks for use in the heating system.

Where Dangerous Goods (DGs) are stored, the site is subject to the State Environmental Planning Policy (Resilience and Hazards) 2021 (SEPP) (1) which aims to assess the risk posed by the site to adjacent land uses. The proposed quantities of flammable gas to be stored at the Agright site would exceed the thresholds of Chapter 3 of the SEPP. Hence, it is necessary to assess the risks posed in the form of a Preliminary Hazard Analysis (PHA) in accordance with the Hazardous Industry Planning Advisory Paper (HIPAP) No. 4 (2) and No. 6 (3) for submission with the modified application.

Agright has commissioned Lote Consulting Pty Ltd (Lote) to prepare a PHA for the facility. This document represents the PHA for the proposed Agright Poultry Farm at 375 McRaes Rd, Goolgowi NSW 2652.

## Conclusions

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

Incidents carried forward for consequence analysis were assessed in detail to estimate the impact distances. Impact distances were modelled in Gexcon 'Effects' (15) software which developed contours for each scenario which were overlaid onto the site layout diagram to determine if an offsite impact would occur. The consequence analysis showed that only the Boiling Liquid Expanding Vapour Explosion (BLEVE) scenarios had the potential to impact offsite. As such, frequency analysis was conducted on these scenarios to determine the probability of a fatality at the site boundary.

The frequency analysis and risk assessment showed that the site would have a fatality risk of $8.12\times10^{-4}$ chances per million per year (PMPY) at the site boundary, with lesser risk at further distances from the boundary. HIPAP No. 4 (2) publishes acceptable risk criteria at the site boundary of $50\times10^{-6}$ chances per year (for industrial sites). Therefore, the probability of a fatality at the site boundary is within the acceptable risk criteria.

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 site would only be classified as potentially hazardous and would be permitted within the current land zoning for the site.

## Recommendations

Based on the analysis, the following outcomes from the assessment are:

a) The Dangerous Goods requirements of the Work Health and Safety Regulation 2017 shall be complied with (i.e. preparation of risk assessments, registers, notifications, etc.)

a) Compliance with LPG Standard AS 1596:2014 for the storage and handling of LP Gas.

b) The following safety measures shall be in place:

    i. Non-return valves on both the tank and LPG tanker;

    ii. Excess flow valves on the LPG tanker;
    iii. Earthing connections; and
    iv. Ignition source control measures.

c) The safeguards outlined in Table A1 in Appendix A – Hazard Identification Table shall be implemented including but not limited to:
    i. LPG facilities to be designed to comply with AS/NZS 1596:2014 (10) and shall be installed by an experienced LPG facility supply company.
    ii. Ignition source control per AS/NZS 60079.14:2017 (9) including earthing to prevent static sparks.
    iii. Hoses shall be tested annually as per AS/NZS 1596:2014 and the ADG (7).

d) Preparation of an Emergency Response Plan and Emergency Services Information Package in accordance with HIPAP No. 1.

e) The LPG storages shall be subject to hazardous area classification in accordance with AS/NZS 60079 series of standards (8).

f) A hazardous area verification dossier shall be prepared in accordance with AS/NZS 60079.14:2017 (9).

# 1.0 Introduction

## 1.1 Background

Agright Poultry Pty Ltd (Agright) have proposed to modify an existing State Significant Development (SSD-8036) and develop a poultry farm at 375 McRaes Rd, Goolgowi NSW 2652, Australia. The modified development will consist of two (2) farms (20 sheds each). As part of their operations, Agright will store and handle Class 2.1 flammable gases (Liquefied Petroleum Gas, LPG) in bulk tanks for use in the heating system.

Where Dangerous Goods (DGs) are stored, the site is subject to the State Environmental Planning Policy (Resilience and Hazards) 2021 (SEPP) (1) which aims to assess the risk posed by the site to adjacent land uses. The proposed quantities of flammable gas to be stored at the Agright site would exceed the thresholds of Chapter 3 of the SEPP. Hence, it is necessary to assess the risks posed in the form of a Preliminary Hazard Analysis (PHA) in accordance with the Hazardous Industry Planning Advisory Paper (HIPAP) No. 4 (2) and No. 6 (3) for submission with the modified application.

Agright has commissioned Lote Consulting Pty Ltd (Lote) to prepare a PHA for the facility. This document represents the PHA for the proposed Agright Poultry Farm at 375 McRaes Rd, Goolgowi NSW 2652.

## 1.2 Objectives

The objectives of the PHA include:

a) Completion of the PHA according to the Hazardous Industry Planning Advisory Paper (HIPAP) No. 6 – Hazard Analysis (3);

b) Assessment of the PHA results using the criteria in HIPAP No. 4 – Risk Criteria for Land Use Planning (2); and

c) Demonstration of compliance of the site with the relevant codes, standards and regulations such as NSW Planning and Assessment Regulation 1979 (4) and the Work Health and Safety Regulation 2017 (5).

## 1.3 Scope of Services

The scope of work is to complete a PHA study for the proposed Agright Poultry Farm located at 375 McRaes Rd, Goolgowi NSW 2652 as required by the Planning Regulations. The scope does not include any other assessments at the site, nor any other Agright farms.

## 1.4 Abbreviations

| Abbreviation | Description |
|---|---|
| ADG | Australian Dangerous Goods Code |
| AS | Australian Standard |
| BLEVE | Boiling Liquid Expanding Vapour Explosion |
| CBD | Central Business District |
| DA | Development Application |
| DGs | Dangerous Goods |

| Abbreviation | Description |
|---|---|
| DPIE | Department of Planning, Industry and Environment |
| HIPAP | Hazardous Industry Planning Advisory Paper |
| HSE | Health and Safety Executive |
| LPG | Liquefied Petroleum Gas |
| p.a. | Per annum |
| PFD | Probability of Failure on Demand |
| PHA | Preliminary Hazard Analysis |
| PMPY | Per million per year |
| SEPP | State Environmental Planning Policy |

## 1.5 Relevant Project Stakeholders

The relevant project stakeholders that have been nominated by the Client for purposes of participating in the fire engineering process are outlined in Table 1-1

**Table 1-1 – Project Stakeholders**

| Name | Company | Role |
|---|---|---|
| Daniel Bryant | Agright Poultry Pty Ltd | Client / Owner's Representative |
| TBA | Department of Planning, Industry and Environment | Regulatory Authority |
| David Ireland | PSA Consulting | Planner |
| Renton Parker<br>Jason Costa | Lote Consulting | Dangerous Goods Assessor |
| Dr Amer Magrabi (BDC No: 0240)<br>Christopher Koch | Lote Consulting | Fire Safety Engineer |

# 2.0 Methodology

## 2.1 Multi-Level Risk Assessment

The Multi-Level Risk Assessment approach (6) 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) of the 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.

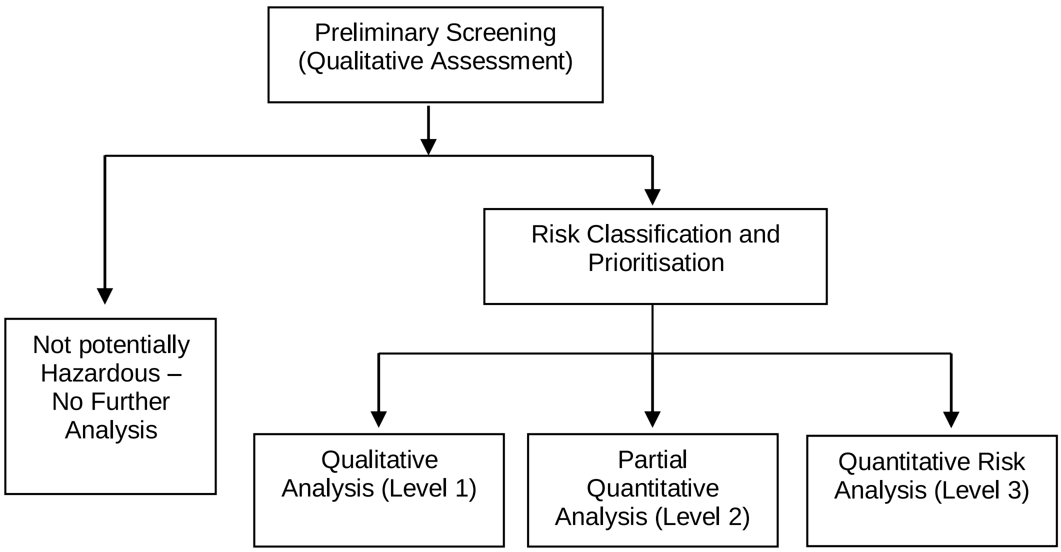


**Figure 2-1: The Multi-Level Risk Assessment Approach**

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 (6).

## 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 (3).

Each postulated hazardous incident was assessed qualitatively in light of proposed safeguards (technical and management controls). Where a potential offsite impact was identified, the incident was carried into the main report for further analysis. Where the qualitative review in the main report determined that the safeguards were adequate to control the hazard, or that the consequence would have no offsite impact, no further analysis was performed. Section 4.1 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 (2). The criteria selected for screening incidents is discussed in Section 4.1.

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 (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 the design team. A final report was then developed, incorporating the comments received from the design team for submission to the Regulatory Authority.

# 3.0 Site Description

## 3.1 Site Location

The proposed site is to be located at 375 McRaes Road, Goolgowi, NSW 2652 which is approximately 24 km west of the Goolgowi town centre. Figure 3-1 shows the regional location of the site in relation to the Goolgowi town centre. The site layout is provided in Figure 3-2.


**Figure 3-1 – Agright farm location (Source Google Maps)**

### *3.1.1 Adjacent Land Use*

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

g) North – Rural farmland;

h) South – Rural farmland;

i) East – Rural farmland; and

j) West – Rural farmland.

## 3.2 General Description

The proposed poultry farm will comprise forty (40) poultry sheds. Each shed will have a maximum of 56,000 birds with a maximum aggregate capacity of 2,240,000 (2.24 million) birds across the property. In addition to the poultry sheds, there will be other ancillary buildings and infrastructure including manager residences, water tanks, access roads and other services. There will be a total of sixteen (16) LPG tanks which each have a volume of 7,500 L resulting in a total storage of 120,000 L of LPG at the site.

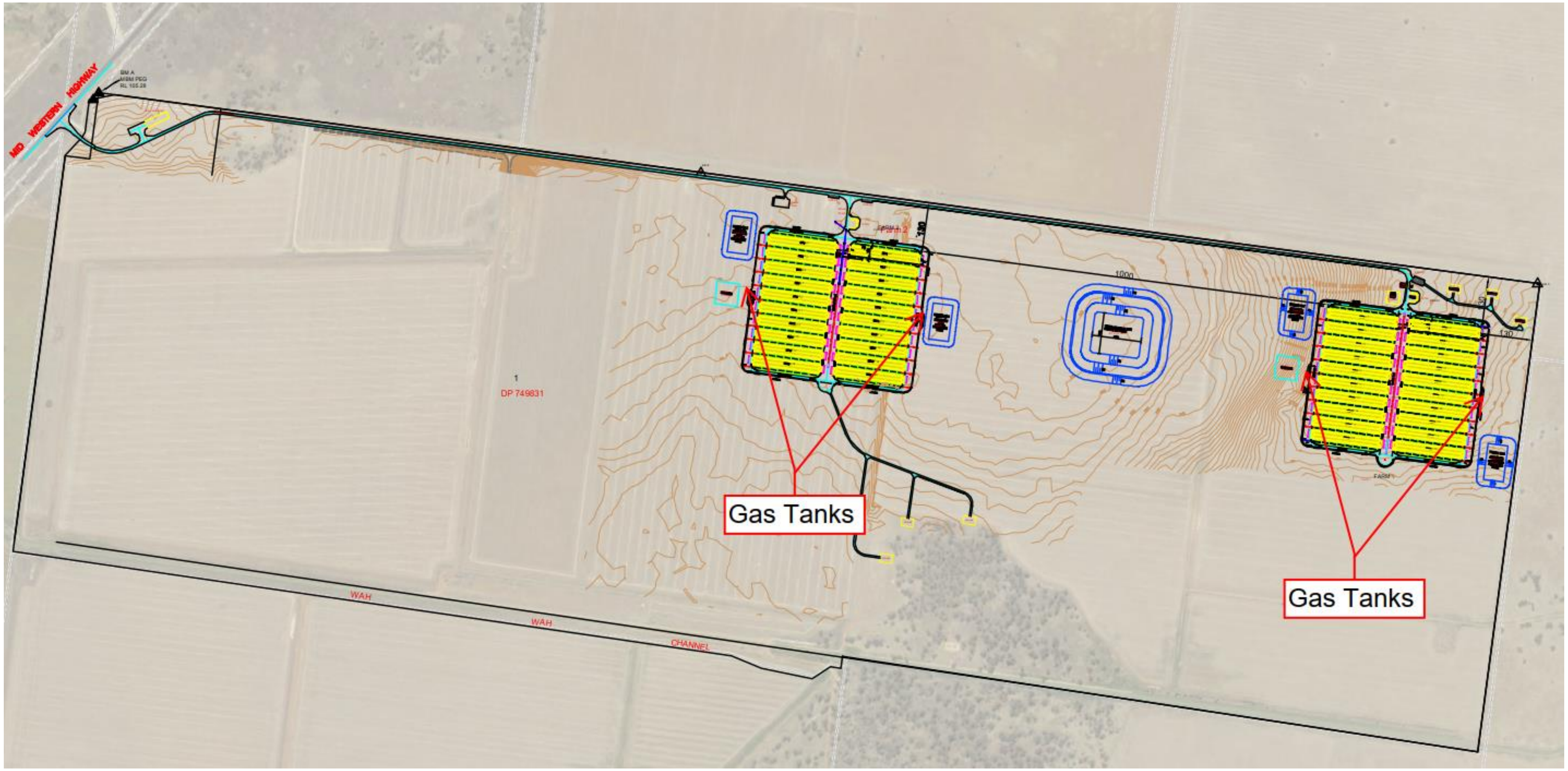


**Figure 3-2 – Farm Layout**

## 3.3 Quantities of Dangerous Goods Stored and Handled

Provided in Table 3-1 is a summary of the DG classes and quantities that will be stored at the site.

**Table 3-1 - Proposed Dangerous Goods to be Stored**

| Storage Area | DG Class | Packing Group | Max Qty (L) |
|---|---|---|---|
| LPG Tanks | 2.1 | n/a | 120,000 |

# 4.0 Hazard Identification

## 4.1 Introduction

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

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

a) *Fire Impacts* - It is noted in Hazardous Industry Planning Advisory Paper (HIPAP) No. 4 (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 (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 3 km from the site. Hence, by selecting 4.7 kW/m$^2$ as the consequence impact criteria (at the adjacent site boundary) the assessment is considered conservative.

b) *Explosion* - It is noted in HIPAP No. 4 (2) that a criterion is provided for the maximum permissible explosion overpressure 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 impacts discussed above, this is conservative as the 7 kPa value listed in HIPAP No. 4 relates to residential areas, which are more than 3 km from the site.

c) *Toxicity* – Toxic substances have not been proposed to be stored at the site. However, toxic products may be formed as a result of incomplete combustion of DGs or other materials stored on site. Hence, toxicity has been included within the assessment.

d) *Property Damage and Accident Propagation* - It is noted in HIPAP No. 4 (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 of incident propagation, for this study, incidents that result in a heat radiation less than 23 kW/m$^2$ and explosion overpressure less than 14 kPa at the site boundary are screened from further assessment. Those incidents exceeding 23 kW/m$^2$ or 14 kPa at the site boundary are carried forward for further assessment with respect to incident propagation (i.e. frequency and risk).

e) *Societal Risk* – HIPAP No. 4 (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 Agright facility, there is currently no significant intensification of population around the proposed site. Therefore, societal risk has not 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 (7)**

| 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 (LFL). 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. |

## 4.3 Hazard Identification

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

a) LPG release, ignition and pool fire.

b) LPG release and ignition causing flash fire or explosion.

c) LPG unloading incident, hose rupture, LPG release, ignition and jet fire.

d) LPG jet fire, impact on LPG delivery tanker and subsequent Boiling Liquid Expanding Vapour Explosion (BLEVE).

e) LPG jet fire, impact on LPG tank and subsequent BLEVE.

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

## 4.4 LPG Release, Ignition and Pool Fire

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

The potential for a leak to occur which is sufficient to cause a release that exceeds the evaporation rate and thus develop a pool large enough to ignite is low. The area shall be zoned per the requirements of AS/NZS 60079.10.1:2009 (8), with ignition sources controlled per AS/NZS 60079.14:2017 (9), which reduces the potential for ignition. The low likelihood of this scenario eventuating is substantiated by numerous similar sized LPG tanks installed throughout Australia with very low incidences of leaks and fires occurring from such installations.

Furthermore, the potential for a pool fire to impact over the site boundary is significant. However all areas surrounding the site are farmland with no industrial or residential buildings and so the risk posed is negligible. Hence, it is considered that this scenario would not feasibly result in an offsite impact. Therefore, this incident has not been carried forward for further analysis.

## 4.5 LPG Release, Ignition and Flashfire or Explosion

As the site LPG tanks are depleted, they will be refilled by a delivery tanker at the site. During loading of the tanks there is the potential for the hose to rupture which may be the result of a puncture of the hosing or deterioration through general wear and tear. It has been assumed that the hoses are inspected monthly, and pressure tested annually in accordance with the Australian Dangerous Goods Code (7).

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

If the operator is incapacitated or unable to stop the transfer, the LPG will continue to flow developing a substantial cloud which may contact an ignition source and ignite which would result in a flash fire or explosion. It is noted the area is unconfined and an explosion is unlikely to occur. Hence, this scenario would likely eventuate as a flash fire.

The potential for a fatality to occur offsite as a result of a flash fire is low. As LPG is a dense gas, any release will spread along at ground level and due to the open nature of the site it will not accumulate to a level where a flash fire would have a significant impact (i.e. fully engulf personnel). Furthermore, the site boundary is a substantial distance from where the tanks are stored allowing adequate time for dispersion of the LPG to below the Lower Explosive Limit (LEL) prior to impacting over the site boundary.

AS/NZS 1596:2014 (10) has been developed with reference to the likely impact scenarios from storage of LPG in various tank sizes. Review of Table 6.1 of AS/NZS 1596:2014 (10) indicates for a 7.5 kL tank the separation distance to a protected place is 6 m. Therefore, the standard would consider that in open air, events resulting from a release from the tank would be unlikely to significantly impact >6 m. However, it is noted that the volume of LPG within the delivery tanker is significantly higher than that of the tank itself and thus, the release volume may exceed that which the standard is based upon and result in greater impact distances.

Therefore, although this scenario is unlikely to eventuate it has been carried froward for further analysis to determine whether any offsite impact may result from a flashfire during LPG transfer.

## 4.6 LPG Unloading Incident, Hose Rupture, LPG Release, Ignition and Jet Fire

As with Section 4.5, there is the potential for a significant LPG release during transfer if the hose were to rupture. If the vapour cloud were ignited, it would burn back to the release point and subsequently form a jet fire. Unlike flash fires, the impacts from a jet fire are likely to be substantial and would potentially impact over the site boundary. Hence, this incident has been carried forward for further analysis.

## 4.7 LPG Jet Fire, Impact on LPG Delivery Tanker and Subsequent Boiling Liquid Expanding Vapour Explosion (BLEVE)

Similarly, to the scenario described in Section 4.6, the hose may rupture during LPG transfer resulting in a jet fire. If this jet fire were aimed at the delivery tanker, the tanker shell would begin to heat, transferring the heat into the LPG within the tank which would begin to vaporise and increase the pressure within the tanker. At the design pressure of the tank, the pressure relief valve will begin to lift to relieve pressure within the tanker.

As the liquid level within the tanker drops, the impact zone of the jet fire may impact the vapour space in the tanker. The vapour will absorb less energy than the liquid which will result in localised heating of the tanker shell at the point of the jet fire impact. This may compromise the structural integrity of the tanker shell which may rupture resulting in a blast overpressure as the vessel fails and formation of an LPG vapour cloud which may also ignite resulting in a vapour cloud explosion known as a Boiling Liquid

Expanding Vapour Explosion (BLEVE). BLEVEs can have significant consequences. Hence, this incident has been carried forward for further analysis to assess the potential impact zone.

## 4.8 LPG Jet Fire, Impact on LPG Tank and Subsequent BLEVE

Similarly, to the scenario described in Section 4.6, the hose may rupture during LPG transfer resulting in a jet fire. If this jet fire were aimed at the LPG tank, the tank shell would begin to heat, transferring the heat into the LPG within the tank which would begin to vaporise and increase the pressure within the tank which may result in a BLEVE, as discussed in Section 4.7. Hence, this incident has been carried forward for further analysis to assess the potential impact zone.

# 5.0 Consequence Analysis

## 5.1 Incidents Carried Forward for Consequence Analysis

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

a) LPG release, ignition and flash fire

b) LPG unloading incident, hose rupture, LPG release, ignition and jet fire.

c) LPG jet fire, impact on LPG delivery tanker and subsequent Boiling Liquid Expanding Vapour Explosion (BLEVE).

d) LPG jet fire, impact on LPG tank and subsequent BLEVE.

Each incident has been assessed in the following sections.

## 5.2 LPG Release, Ignition and Flash Fire

There is the potential for a hose to rupture and release high pressure LPG if the excess flow valve on the tanker fails and operator intervention does not occur. This LPG would disperse and potentially result in a flash fire if the gas cloud were to contact an ignition source. A detailed analysis has been conducted in Appendix B3 based on the worst-case release scenario being from the tanker as the volume contained within the tanker far exceeds that of the tank itself. The analysis indicated that a flash fire would have an impact length of 177 m and an impact width of 124 m, as summarised in Table 5-1. The impact contours are depicted in Figure 5-1.

**Table 5-1: Flash Fire Impact Distances**

| Item | Distance (m) |
|---|---|
| Length of Flammable Cloud | 177 |
| Width of Flammable Cloud | 124 |

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

The boundary of the site is shared with a rural property which contains no inhabitable buildings, agricultural areas or other activities where people would be expected to gather. There are no sensitive land uses or protected places on the adjacent property which may be affected by the 4.7 $kW/m^2$ heat contour. Additionally, for a flash fire to occur over the site boundary, the flammable vapour cloud would also need to be travelling in the direction of the boundary whilst maintaining a concentration above LEL, significantly reducing the likelihood of this scenario occurring.

Therefore, even though there are slight impacts over the site boundary it is considered that the LPG tank (and thus the tanker transfer operations) is located in an acceptable position on site. This scenario has not been carried forward for further analysis. However due to the additional overpressure impacts of BLEVE incidents, the BLEVE scenarios discussed in the following sections have been assessed further. It is noted that the frequency analysis conducted for BLEVE scenarios would largely apply to a flash fire scenario which also requires a release and ignition to occur.

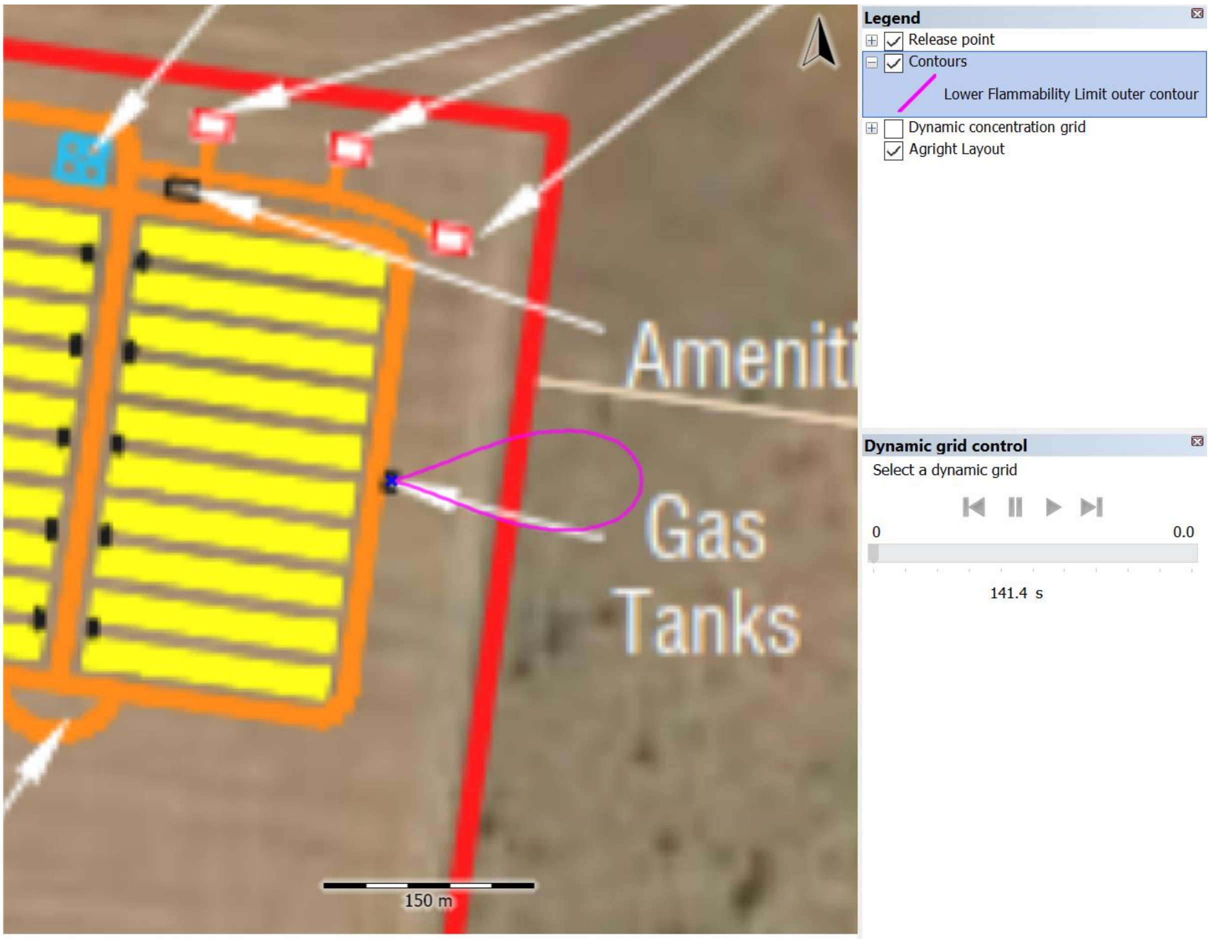


**Figure 5-1: Tanker Flash Fire Impact Distance**

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

There is the potential for a hose to rupture and release high pressure LPG if the excess flow valve on the tanker fails and operator intervention does not occur. If this stream ignited, a jet fire could occur. A detailed analysis has been conducted in Appendix B4 for this scenario which indicates the jet fire would have a flame length of 33 m. The radiant heat impact distances for this incident are summarised in Table 5-2, with the contours depicted in Figure 5-2.

**Table 5-2: Jet Fire Heat Radiation Impact Distances**

| Radiant Heat (kW/m$^2$) | Distance (m) |
|---|---|
| 35 | 39 |
| 23 | 46 |
| 12.6 | 59 |
| 4.7 | 91 |

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

The heat radiation contours from this incident impact just to the site boundary and there are no areas where people may congregate within the impact contours. Therefore, this incident has not been carried forward for further assessment.

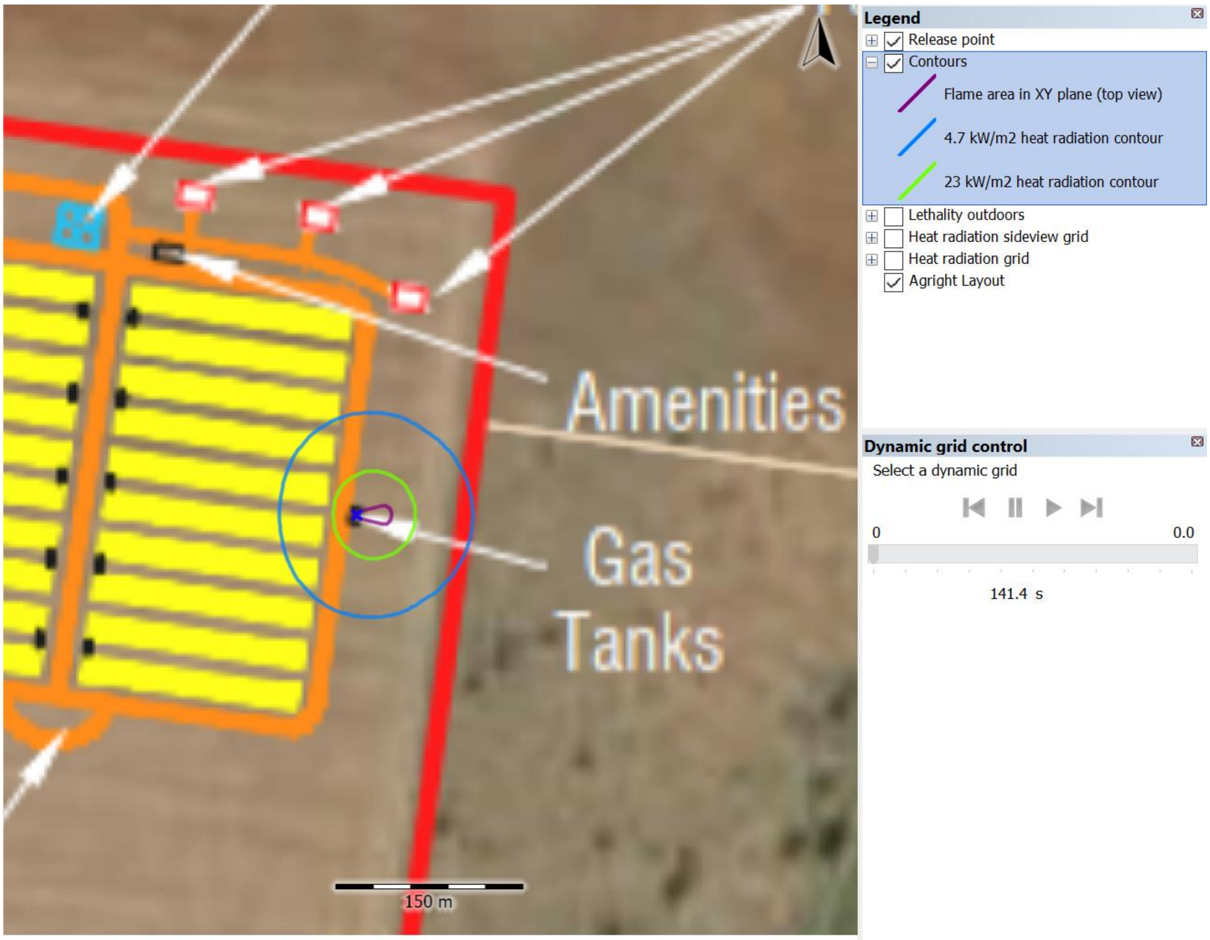


**Figure 5-2: LPG Jet Fire Impact Distances**

## 5.4 LPG Tank Jet Fire and Tanker BLEVE

In the event of a jet fire and impingement on the delivery tanker there is potential for the LPG in the tanker to boil escalating to a BLEVE if intervention measures fail. A detailed analysis has been conducted in Appendix B5, and the overpressure impact distances summarised in Table 5-3 and the contours depicted in Figure 5-3.

**Table 5-3: LPG Tanker BLEVE Overpressure Impact Distances**

| Overpressure (kPa) | Distance (m) |
|---|---|
| 70 | 13 |
| 35 | 26 |
| 21 | 41 |
| 14 | 58 |
| 7 | 104 |

A secondary analysis was conducted to determine the heat radiation contours which would result from the BLEVE fireball. These impact contours have a significantly larger reach than the overpressure contours, as depicted in Table 5-4 and Figure 5-4.

**Table 5-4: LPG Tanker BLEVE Heat Radiation Impact Distances**

| Radiant Heat ($kW/m^2$) | Distance (m) |
|---|---|
| 35 | 206 |
| 23 | 255 |
| 12.6 | 342 |
| 4.7 | 545 |

Similarly, to the jet fire scenario, several layers of protection are required to fail before the initiating event could occur. In addition, the jet fire would need to be impinged on the tanker before it could lead to a BLEVE which takes considerable time as the LPG must boil off such that the liquid level is below the impact point. The explosion overpressure contours minorly impact over the site boundary; however, the heat radiation impact contours impact significantly over the boundary.

The boundary of the site is shared with a rural property which contains no inhabitable buildings, agricultural areas or other activities where people would be expected to gather. There are no sensitive land uses or protected places on the adjacent property which may be affected by the 4.7 $kW/m^2$ heat contour. Furthermore, the model was conducted based on 100% fill level within the tanker. However, it is noted that this is physically impossible as there must be some vapour space within the tanker in order for a BLEVE to occur. Thus, the model results in extremely conservative impact distances. Therefore, even though there are impacts over the site boundary it is considered that the LPG tank (and thus the tanker transfer operations) is located in an acceptable position on site. Nonetheless, this scenario has been carried forward for further analysis to determine the frequency of it occurring.

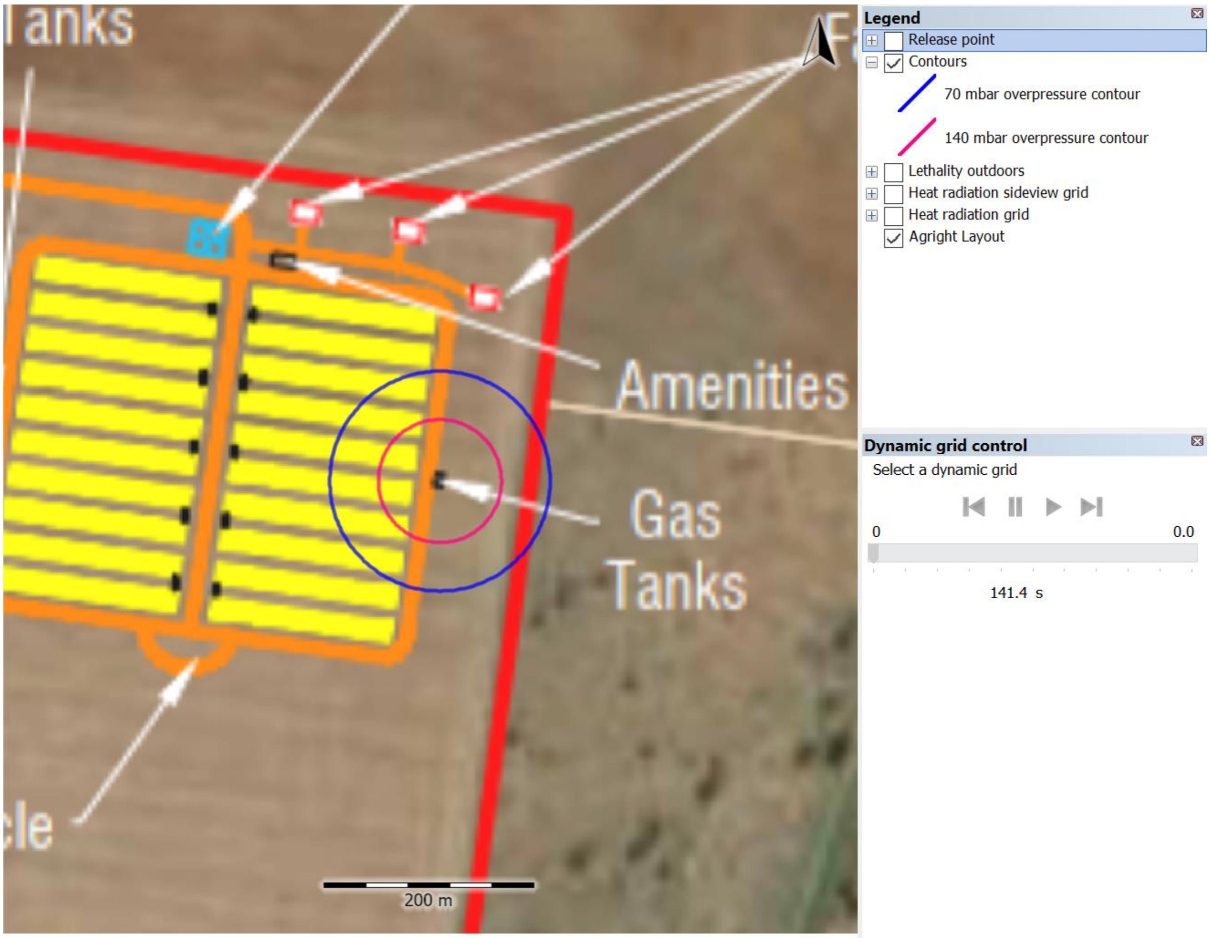


**Figure 5-3: LPG Tanker BLEVE Overpressure Impact Distances**

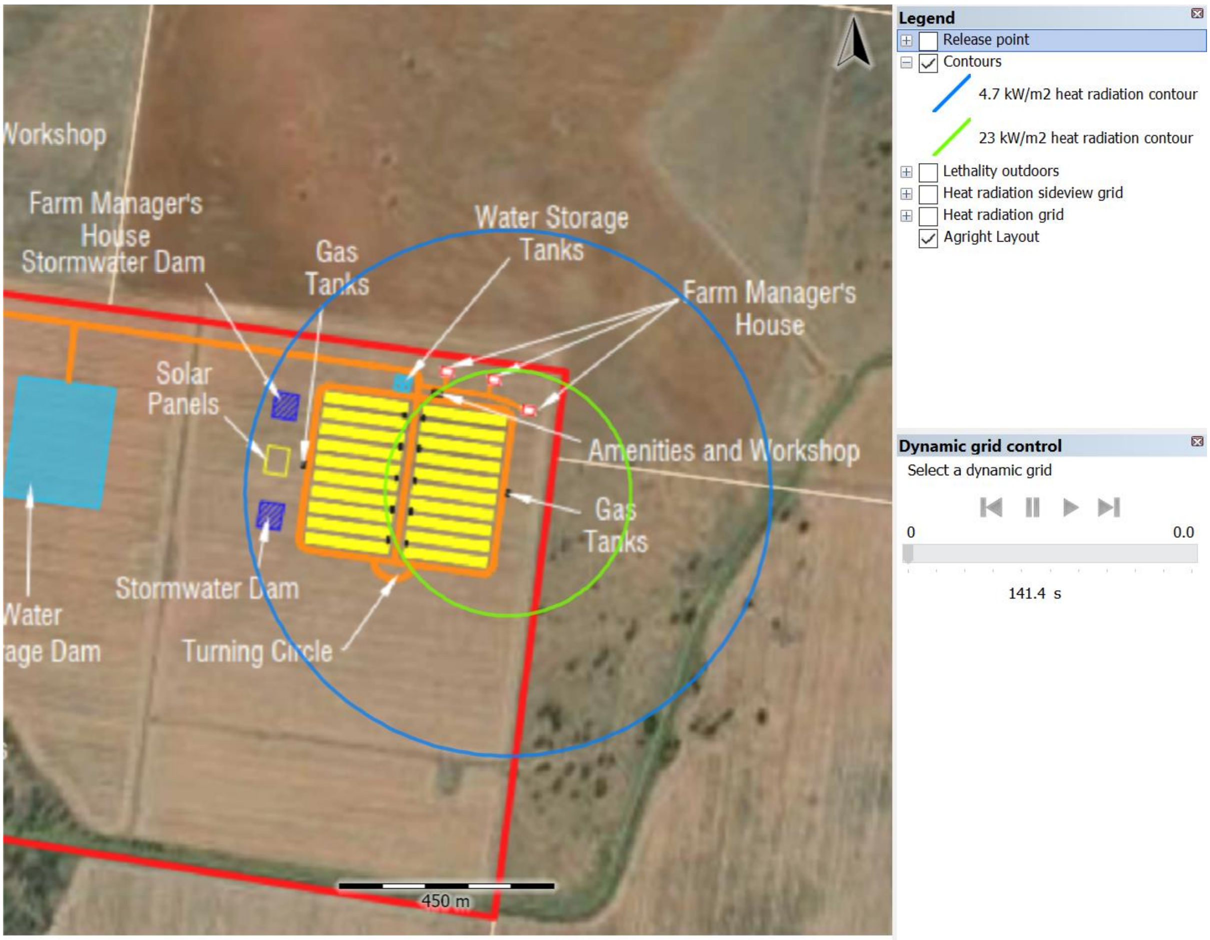


**Figure 5-4: LPG Tanker BLEVE Heat Radiation Impact Distances**

## 5.5 LPG Tank Jet Fire and Tank Shell BLEVE

In the event of a jet fire and impingement on the LPG tank there is potential for the LPG in the tank to boil escalating to a BLEVE if intervention measures fail. A detailed analysis has been conducted in Appendix B6, and the overpressure impact distances summarised in Table 5-5 and the contours depicted in Figure 5-5.

**Table 5-5: LPG Tank BLEVE Overpressure Impact Distances**

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

A secondary analysis was conducted to determine the heat radiation contours which would result from the BLEVE fireball. These impact contours have a significantly larger reach than the overpressure contours, as depicted in Table 5-6 and Figure 5-6.

**Table 5-6: LPG Tank BLEVE Heat Radiation Impact Distances**

| Radiant Heat (kW/m²) | Distance (m) |
|---|---|
| 35 | 119 |
| 23 | 148 |
| 12.6 | 199 |
| 4.7 | 317 |

Similar to the jet fire scenario, several layers of protection are required to fail before the initiating event could occur. In addition, the jet fire would need to be impinged on the LPG tank before it could result in a BLEVE, which takes considerable time as the LPG must boil off such that the liquid level is below the impact point. Nonetheless, as discussed in Section 5.4, there are slight heat radiation impacts extending over the site boundary. As such, this scenario has been carried forward for frequency analysis.

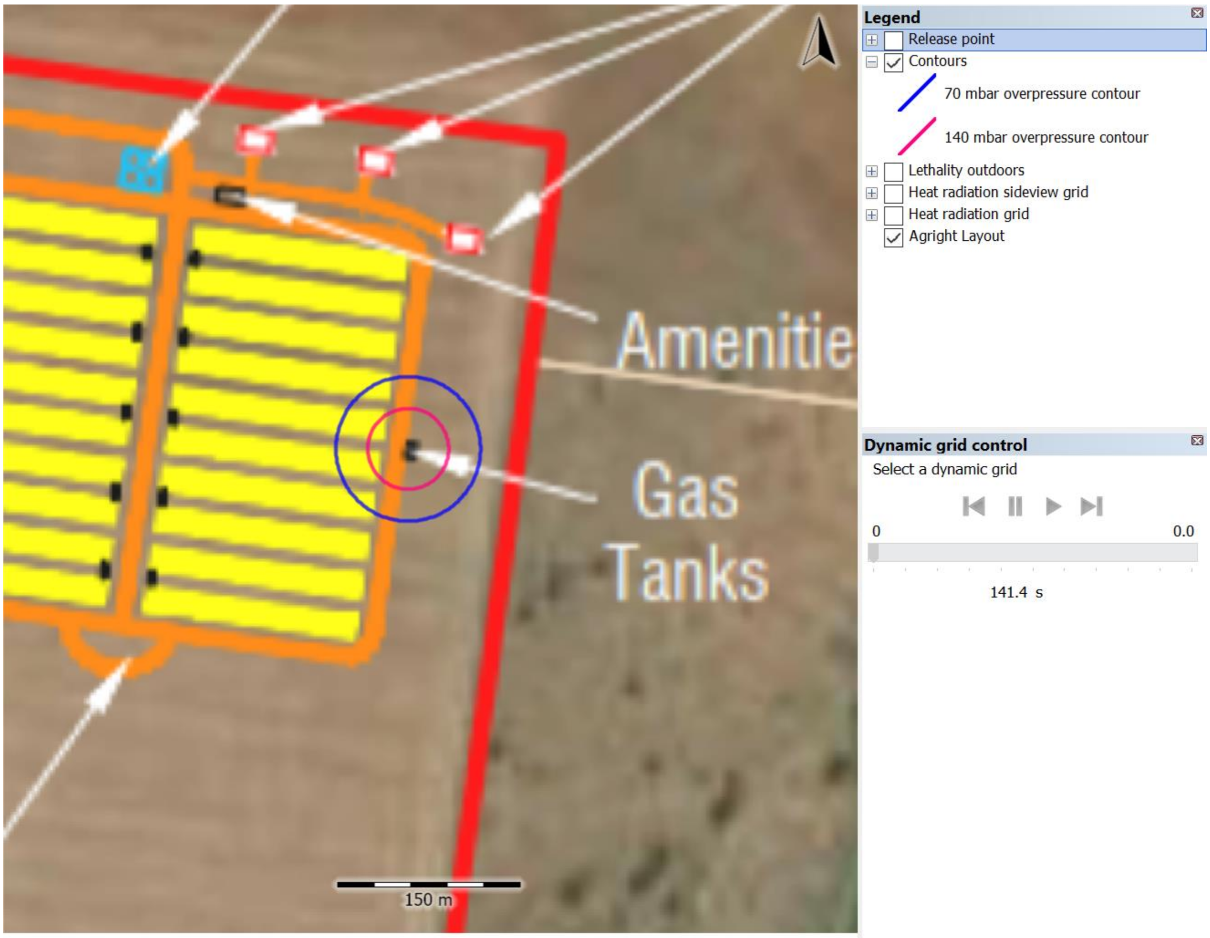


Figure 5-5: LPG Tank BLEVE Impact Distances

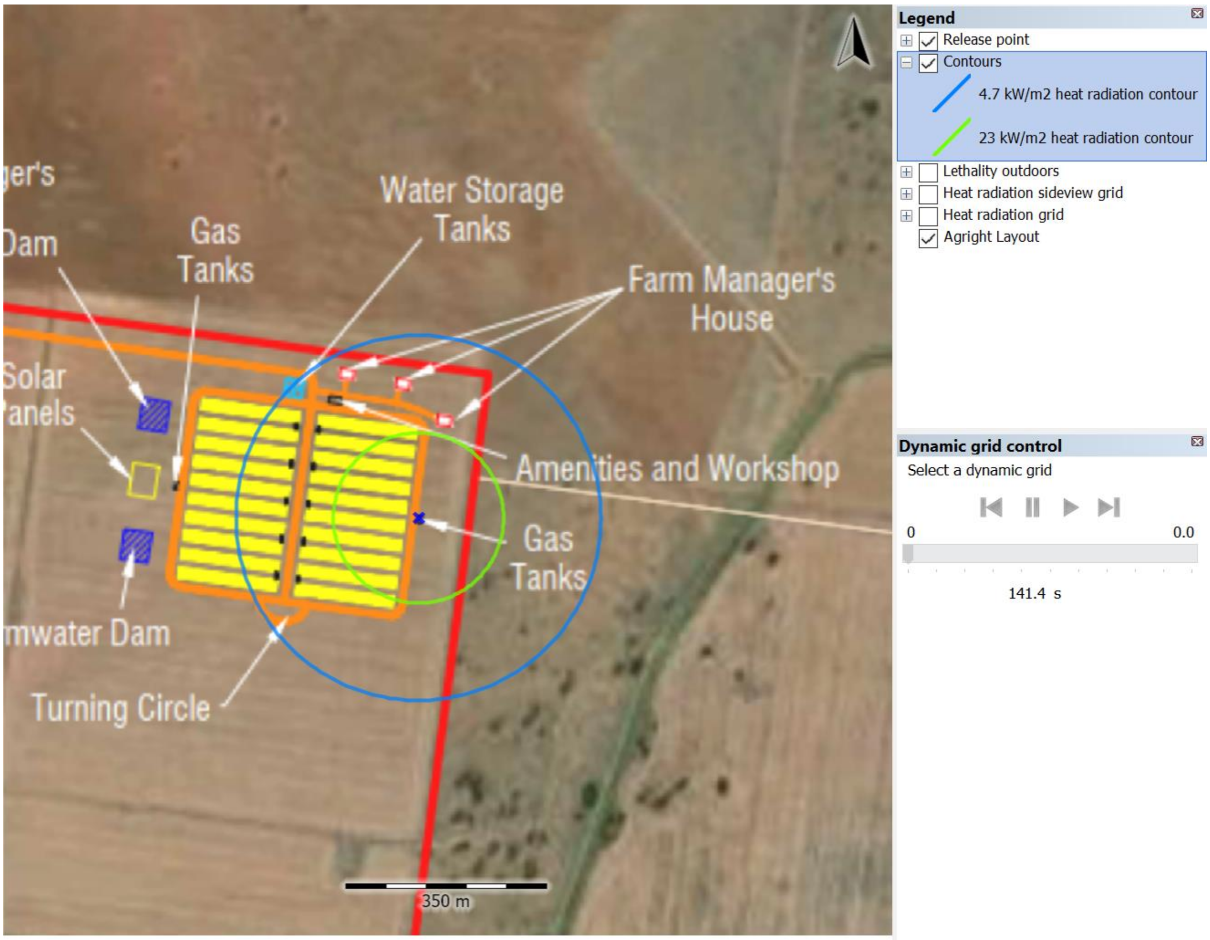


**Figure 5-6: LPG Tank BLEVE Heat Radiation Impact Distances**

# 6.0 Frequency Analysis

The following items have been carried forward for frequency analysis:

a) LPG jet fire, impact on LPG tanker and subsequent BLEVE.

b) LPG jet fire, impact on LPG tank and subsequent BLEVE.

These incidents have been assessed in the following sections.

## 6.1 Probability of Failure on Demand

The failure rates for each component identified in the safety systems which protect against the BLEVE scenario in the following section were sourced from 3rd party databases such as OREDA, Exida, and UK Health and Safety Executive (HSE). A summary of the failure rate information has been included 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:

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

## 6.2 LPG Jet Fire, Impact on LPG Tanker and Subsequent BLEVE

For a tanker BLEVE to occur, a jet fire must impinge on the delivery tanker for a prolonged period causing stress to the tanker shell, pressure build-up and subsequent explosion. For a jet fire to occur, it is necessary for several of the layers of protection to fail such that a high-pressure LPG release is present prior to ignition and jet fire. A review of the safety systems at the site indicates the following items must fail for a jet fire to occur:

a) Rupture of the hose,

b) Failure of the excess flow valve,

c) Failure of the non-return valve,

d) Failure of the emergency stop button to activate the isolation valves, and

e) Failure of the isolation valves.

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

**Table 6-1: Failure Rate Data**

| Component | PFD |
|---|---|
| Hose | $1.04 \times 10^{-5}$ (frequency) (11) |
| Excess flow valve | $6.5 \times 10^{-3}$ (11) |
| Non-return valve | $6.5 \times 10^{-3}$ (11) |
| Emergency Stop | $2.71 \times 10^{-5}$ (12) |
| Isolation Valves | $5 \times 10^{-3}$ (11) |

In addition to the components of the safety system failing, it is necessary for the operator to fail to initiate an emergency stop and the release also needs to ignite. HEART human error probabilities (11) and Human Factors in QRA (13) provide failure rates of operators for tasks similar to that required by an operator to initiate an emergency stop. These are:

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

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

Ignition probabilities were sourced from Lees - Loss Prevention in the Process Industries (14) which provides ignition probabilities based on the number of ignition sources at the site. The site contains very few ignition sources; hence, from Lees, a conservative probability of ignition is estimated as 0.2.

The PFD for each piece of equipment, operation failure and ignition were input into a fault tree to determine the overall probability of a failure resulting in a jet fire. The fault tree is shown in Figure 6-1. The analysis indicates a jet fire will occur with a frequency of $4.06 \times 10^{-10}$ chances per annum (p.a.). The very low frequency indicates that there are many layers of protection at the site, minimising the potential for incident.

Furthermore, this is the frequency of a jet fire occurring, not a BLEVE. Nonetheless, a tanker BLEVE event frequency of $4.06 \times 10^{-10}$ chances p.a. has been maintained as it is difficult to predict whether a jet fire will result in a BLEVE or not. This is conservative as it does not take into account fire brigade intervention which may prevent the event from escalating. Hence, lowering the event frequency.

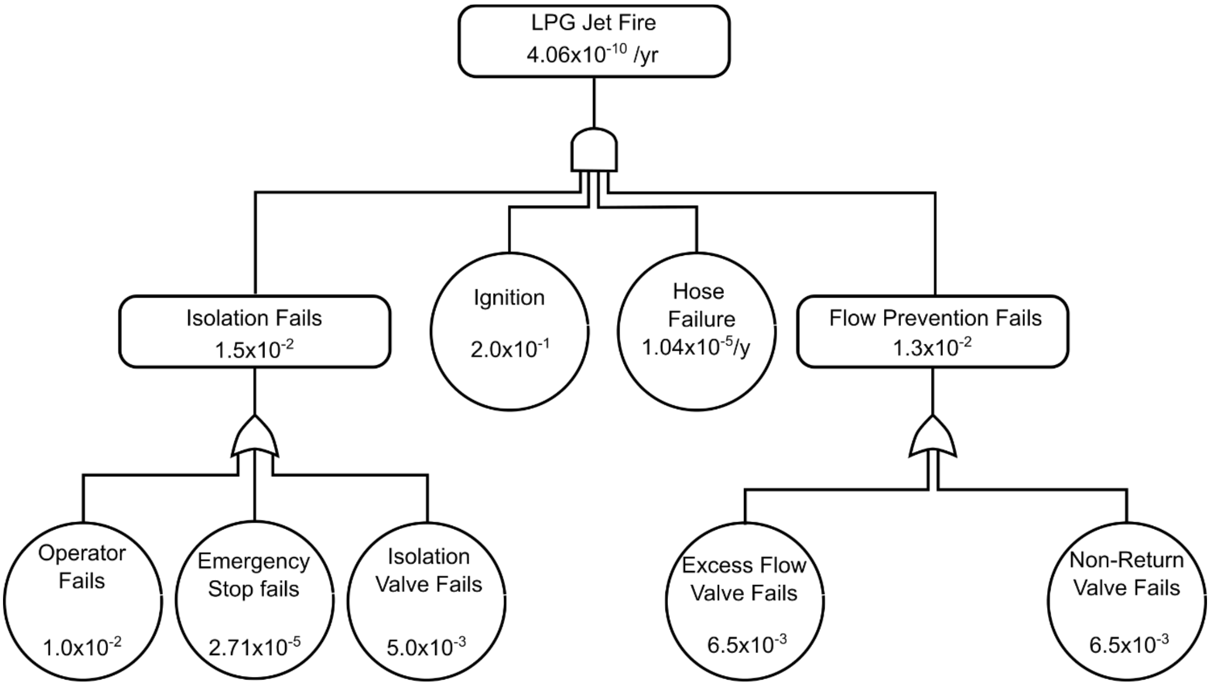


**Figure 6-1: Jet Fire Frequency**

## 6.3 LPG Jet Fire, Impact on LPG Tanker and Subsequent BLEVE

The initiating event for a tank BLEVE is an incident involving a jet fire impinging on the tank shell, as discussed in Section 6.2. Hence, for conservatism, a tank BLEVE event frequency of $4.06 \times 10^{-10}$ chances p.a. has been selected. This is conservative as it does not take into account fire brigade intervention which may prevent the event from escalating; hence, lowering the event frequency.

## 6.4 Total Fatality Risk

Provided in Table 6-2 is a summary of the incidents which may result in a fatality at the site boundary. The total fatality risk at the site boundary was calculated to be $8.12 \times 10^{-4}$ chances per million per year (PMPY)

**Table 6-2: Total Fatality Risk**

| Incident | Fatality Risk |
|---|---|
| Tanker BLEVE | $4.06 \times 10^{-10}$ |
| Tank BLEVE | $4.06 \times 10^{-10}$ |
| **Total** | $\mathbf{8.12 \times 10^{-10}}$ |

## 6.5 Comparison Against Risk Criteria

The NSW Department of Planning and Environment has issued a guideline on acceptable risk criteria (2). The acceptable risk criteria published in the guideline relates to injury, fatality and property damage. The values in the guideline present the maximum levels of risk that are permissible at the land use under assessment.

The adjacent land uses are classified as rural land as it is remote from any residential housing, towns, etc and primarily used for agricultural purposes. For the purposes of this assessment, the land is assessed as 'industrial' as this reflects the lowest sensitivity land use category. For industrial facilities, the maximum permissible fatality risk is $50 \times 10^{-6}$ per year. The assessed highest fatality risk is $8.12 \times 10^{-10}$ PMPY at the closest site boundary (eastern boundary). Hence, the highest risk is well 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, which is over 3 km from the site, are not considered to be exceeded.

## 6.6 Cumulative Assessment

A review of the surrounding area indicates that all adjacent properties within the vicinity are remote agricultural properties. Hence, cumulative risks are not considered to be a risk at this stage as the identified contours would not overlap resulting in a cumulative impact.

# 7.0 Conclusions and Recommendations

## 7.1 Conclusions

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

Incidents carried forward for consequence analysis were assessed in detail to estimate the impact distances. Impact distances were modelled in Gexcon 'Effects' (15) software which developed contours for each scenario which were overlaid onto the site layout diagram to determine if an offsite impact would occur. The consequence analysis showed that only the Boiling Liquid Expanding Vapour Explosion (BLEVE) scenarios had the potential to impact offsite. As such, frequency analysis was conducted on these scenarios to determine the probability of a fatality at the site boundary.

The frequency analysis and risk assessment showed that the site would have a fatality risk of $8.12 \times 10^{-4}$ chances per million per year (PMPY) at the site boundary, with lesser risk at further distances from the boundary. HIPAP No. 4 (2) publishes acceptable risk criteria at the site boundary of $50 \times 10^{-6}$ chances per year (for industrial sites). Therefore, the probability of a fatality at the site boundary is within the acceptable risk criteria.

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 site would only be classified as potentially hazardous and would be permitted within the current land zoning for the site.

## 7.2 Scope of Works Arising

Based on the analysis, the following outcomes from the assessment are:

f) The Dangerous Goods requirements of the Work Health and Safety Regulation 2017 shall be complied with (i.e. preparation of risk assessments, registers, notifications, etc.)

g) Compliance with LPG Standard AS 1596:2014 for the storage and handling of LP Gas.

h) The following safety measures shall be in place:

    i. Non-return valves on both the tank and LPG tanker;

    ii. Excess flow valves on the LPG tanker;

    iii. Earthing connections; and

    iv. Ignition source control measures.

i) The safeguards outlined in Table A1 in Appendix A – Hazard Identification Table shall be implemented including but not limited to:

    i. LPG facilities to be designed to comply with AS/NZS 1596:2014 (10) and shall be installed by an experienced LPG facility supply company.

    ii. Ignition source control per AS/NZS 60079.14:2017 (9) including earthing to prevent static sparks.

    iii. Hoses shall be tested annually as per AS/NZS 1596:2014 and the ADG (7).

j) Preparation of an Emergency Response Plan and Emergency Services Information Package in accordance with HIPAP No. 1.

k) The LPG storages shall be subject to hazardous area classification in accordance with AS/NZS 60079 series of standards (8).

l) A hazardous area verification dossier shall be prepared in accordance with AS/NZS 60079.14:2017 (9).

# 8.0 Validity and Limitations

The reader's attention is drawn to the following limitations with respect to the PHA undertaken in this report:

a) This report has been prepared in accordance with the scope of services described in the contract or agreement between Lote Consulting and the Client.

b) The report relies upon data, surveys, measurements and results taken at or under the particular times and conditions specified herein.

c) Changes to circumstances or facts after certain information or material has been submitted may impact on the accuracy, completeness or currency of the information or material.

d) This report has been prepared solely for use by the Client. Lote Consulting accepts no responsibility for its use by other parties without the specific authorization of Lote Consulting.

e) Lote Consulting reserves the right to alter, amend, discontinue, vary or otherwise change any information, material or service at any time without subsequent notification.

f) Reports marked 'Draft' are subject to change and Lote accepts no liability pending release of the final version of the report.

g) All access to, or use of, the information or material is at the user's risk and Lote Consulting accepts no responsibility for the results of any actions taken on the basis of information or material provided, nor for its accuracy, completeness or currency.

h) Any change in building, occupant or fuel conditions from those considered in this report, or any deviation from the implementation of the fire safety strategy outlined in this report, may result in outcomes not anticipated by the proposed strategy and should be reviewed.

i) It is considered that the scope of works arising from this report and limitations of this report are read, understood and implemented. Lote shall be contacted in relation to any queries on the report content and takes no responsibility for misinterpretation of the report content by others.

j) The architectural and engineering drawings referenced or listed in this report have been utilised for purposes of formulating and assessing the site as nominated in this Report. Lote have not reviewed the drawings for compliance with the BCA, Australian Standards or the Dangerous Goods Guidelines.

# 9.0 References


1. NSW Government. State Environmental Planning Policy (Resilience & Hazards) 2021 [Internet]. NSW Legislation. 2022. Available from: https://legislation.nsw.gov.au/view/html/inforce/current/epi-2021-0730#sec.1.1
2. Department of Planning. Hazardous Industry Planning Advisory Paper No. 4 - Risk Criteria for Land Use Safety Planning. Department of Planning, Sydney; 2011.
3. Department of Planning. Hazardous Industry Planning Advisory Paper No. 6 - Guidelines for Hazard Analysis. Department of Planning, Sydney; 2011.
4. NSW Government. Environmental Planning and Assessment Act 1979 [Internet]. 1979. Available from: https://legislation.nsw.gov.au/view/html/inforce/current/act-1979-203
5. SafeWork NSW. Work Health and Safety Regulation. SafeWork NSW; 2017.
6. Department of Planning. Multi-Level Risk Assessment. Sydney: Department of Planning; 2011.
7. Road Safety Council. Australian Code for the Transport of Dangerous Goods by Road & Rail, 7.4 Edition. Canberra: Road Safety Council; 2016.
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. Standards Australia. AS/NZS 1596:2014 - The Storage and Handling of LP Gas. Sydney: Standards Australia; 2014.
11. Health and Safety Executive. Health Failure Rate and Event Data for use within Risk Assessments. United Kingdom: Health and Safety Executive; 2012.
12. Rockwell Automation. Functional Safety Data Sheet - SAFETY-SR001B-EN P. Rockwell Automation; 2010.
13. Williams JC. A Data Based Method for Assessing and Reducing Human Error. In: Proceedings of IEEE. Monteray, California; 1988.
14. Lees FP. Loss Prevention in the Process Industries. Butterworth-Heinemann, London; 2005.
15. Gexcon. EFFECTS | Gexcon AS - Fire & Explosion Consultants [Internet]. Gexcon; Available from: https://www.gexcon.com/au/software/effects/

# Appendix A – Hazard Identification Table

## A1. Hazard Identification Table

| Area/ Operation | Hazard Cause | Hazard Consequence | Safeguards | Potential for offsite impacts? | Carried forward for further analysis? |
|---|---|---|---|---|---|
| LPG Tank | • Releases from pipework due to corrosion, flange leaks, hose/pump leaks, weld failure, operator error, maintenance error, mechanical damage (e.g. tanker impact on fill point) etc.<br>• Overfilling of tank due to operator error (incorrect tank reading)<br>• Overfilling of tank due to equipment fault or procedures not followed (e.g. leaving operation unattended).<br>• Hose failure, coupling failure or coupling not properly engaged during transfers due to mechanical damage, | • Minor leak (5 mm hole)<br>• Major leak (50 mm hole)<br>If ignition then:<br>• Flash fire, jet fire, pool fire<br>• VCE or BLEVE - potentially hazardous heat radiation and/or overpressure. | • LPG facilities to be designed to comply with AS/NZS 1596:2014 (10) and will be installed by an experienced LPG facility supply company.<br>• Tank and associated pipework/fitting will be pressure tested in accordance with the requirements of the pressure vessels code.<br>• Ignition source control per AS/NZS 60079.14:2017 (9) including earthing to prevent static sparks.<br>• Hoses tested annually as per AS/NZS 1596:2014 and the ADG (7).<br>• Excess flow valves installed in pipework.<br>• Valves to fill point closed until air connected to truck.<br>• Valves shut on breaking of air connection to truck.<br>• All staff including contract drivers will be trained in the specific transfer operations at the site.<br>• Tanker fitted with Emergency Shut Down<br>• Excess flow valve on tanker | Yes | Yes |

| Area/ Operation | Hazard Cause | Hazard Consequence | Safeguards | Potential for offsite impacts? | Carried forward for further analysis? |
|---|---|---|---|---|---|
| | undetected wear and tear or operator error.<br>• Drive away with hoses attached. | | • Manual shutdown valve<br>• Non-return valve on delivery line<br>• Emergency Shutdown on delivery line<br>• Manual valve on delivery line<br>• Overfill protection device<br>• Fusible link on tanker and vessel | | |

# Appendix B – Consequence Analysis

## B1. Incidents Assessed in Detailed Consequence Analysis

The following incidents are assessed for consequence impacts:

a) LPG unloading incident, hose rupture, LPG release, ignition and flash fire.

b) LPG unloading incident, hose rupture, LPG release, ignition and jet fire.

c) LPG jet fire, impact on LPG delivery tanker and subsequent Boiling Liquid Expanding Vapour Explosion (BLEVE).

d) LPG jet fire, impact on LPG tank and subsequent BLEVE.

Each incident has been assessed in the sections below.

## B2. Gexcon – Effects

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

### 9.1 Radiant Heat Physical Impacts

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

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

| Heat Radiation ($kW/m^2$) | Impact |
|---|---|
| 35 | • Cellulosic material will pilot ignite within one minute's exposure<br>• Significant chance of a fatality for people exposed instantaneously |
| 23 | • Likely fatality for extended exposure and chance of a fatality for instantaneous exposure<br>• Spontaneous ignition of wood after long exposure<br>• Unprotected steel will reach thermal stress temperatures which can cause failure<br>• Pressure vessel needs to be relieved or failure would occur |
| 12.6 | • Significant chance of a fatality for extended exposure. High chance of injury<br>• Causes the temperature of wood to rise to a point where it can be ignited by a naked flame after long exposure<br>• 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) |

## B3. LPG Unloading Incident, Hose Rupture, LPG Release, Ignition and Flash Fire

A hose rupture could occur and disperse LPG which, if ignited, could result in a flash fire (noting that there is no confinement on site, so an explosion is not a feasible scenario). The flash fire was modelled based on the worst-case scenario being LPG escaping from a 21-tonne delivery tanker during transfer. The input parameters used in the model are outlined in Appendix Figure B-1.

| **Parameters** | |
|---|---|
| **Inputs** | |
| **Process Conditions** | |
| Chemical name | LPG Sample (Sample mixtures) |
| **Calculation Method** | |
| Type of heavy gas release | Horizontal Jet release |
| **Source Definition** | |
| Mass flow rate of the source (kg/s) | 32.268 |
| Duration of the release (s) | 640 |
| Initial liquid mass fraction (-) | 0.45273 |
| Diameter of expanded jet (m) | 0.35017 |
| Temperature after release (°C) | -42.25 |
| **Process Dimensions** | |
| Height of release (Z-coordinate) (m) | 1 |
| Offset X direction (distance) start dispersion (m) | 0 |
| Offset Z direction (height) start dispersion (m) | 0 |
| **Meteo Definition** | |
| Meteorological data | Pasquill |
| Pasquill stability class | F (Very Stable) |
| Wind speed at 10 m height (m/s) | 2 |
| Predefined wind direction | W |
| **Environment** | |
| Ambient temperature (°C) | 20 |
| Ambient pressure (bar) | 1.0151 |
| Ambient relative humidity (%) | 60 |
| Roughness length description | Open flat terrain; grass, few isolated objects. |

**Appendix Figure B-1: Flash Fire Modelling Inputs**

The impact distances of a flash fire are outlined in Appendix Table B-2.

**Appendix Table B-2: Impact Distance from Flash Fire**

| Item | Distance (m) |
|---|---|
| Length of Flammable Cloud | 177 |
| Width of Flammable Cloud | 124 |

## B4. LPG Unloading Incident, Hose Rupture, LPG Release, Ignition and Jet Fire

A hose rupture could occur and ignite which would result in a jet fire. The jet fire was modelled using the input parameters in Appendix Figure B-2.

| **Parameters** | |
|---|---|
| **Inputs** | |
| **Process Conditions** | |
| Chemical name | LPG Sample (Sample mixtures) |
| Exit temperature (°C) | 20 |
| Exit pressure (bar) | 7.9576 |
| **Calculation Method** | |
| Fraction of the flame covered by soot (-) | 0 |
| **Source Definition** | |
| (Calculated) Mass flow rate (kg/s) | 32.268 |
| **Process Dimensions** | |
| Hole diameter (mm) | 50 |
| Hole rounding | Sharp edges |
| Outflow angle in XZ plane (0°=horizontal; 90°=vertical) (deg) | 90 |
| Release height (stack height) (m) | 1 |
| **Meteo Definition** | |
| Meteorological data | Pasquill |
| Pasquill stability class | F (Very Stable) |
| Wind speed at 10 m height (m/s) | 2 |
| Predefined wind direction | W |
| **Environment** | |
| Ambient temperature (°C) | 20 |
| Ambient pressure (bar) | 1.0151 |
| Ambient relative humidity (%) | 60 |
| Roughness length description | Open flat terrain; grass, few isolated objects. |
| Amount of $CO_2$ in atmosphere (-) | 0.0004 |

**Appendix Figure B-2: Jet Fire Modelling Inputs**

The model calculated a jet flame length of 34 m. The radiant heat emitted from the flame is shown in Appendix Table B-3.

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

| Radiant Heat (kW/m$^2$) | Distance (m) |
|---|---|
| 35 | 39 |
| 23 | 46 |
| 12.6 | 59 |
| 4.7 | 91 |

## B5. LPG Jet Fire, Impact on LPG Delivery Tanker and Subsequent Boiling Liquid Expanding Vapour Explosion (BLEVE)

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

It is noted that it is physically impossible to have a BLEVE and a 100% full tank; however, the DPIE has indicated a preference for modelling BLEVEs with 100% tank volume; hence, the BLEVE has been modelled as a 100% full 21 tonne tanker (41 m$^3$ using a density of 510 kg/m$^3$). The input parameters for the BLEVE modelling are shown in Appendix Figure B-3.

| Parameters | |
|---|---|
| **Inputs** | |
| **Process Conditions** | |
| Chemical name | LPG Sample (Sample mixtures) |
| Initial temperature in vessel (°C) | 20 |
| Burst pressure vessel (bar) | 25 |
| **Calculation Method** | |
| Type of BLEVE calculation | Dynamic BLEVE model |
| Include BLEVE overpressure effects | No |
| **Process Dimensions** | |
| Vessel volume (m3) | 41 |
| Filling degree (%) | 100 |
| Height of the vessel (fireball offset Z) (m) | 0 |
| **Environment** | |
| Ambient temperature (°C) | 20 |
| Ambient relative humidity (%) | 60 |
| Ambient pressure (bar) | 1.0151 |

**Appendix Figure B-3: LPG Tanker BLEVE Input Parameters**

The overpressure impacts calculated from the model have been summarised in Appendix Table B-4.

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

| Overpressure (kPa) | Distance (m) |
|---|---|
| 70 | 13 |
| 35 | 26 |
| 21 | 41 |

| | |
|---|---|
| 14 | 58 |
| 7 | 104 |

Using the same input parameters as for the BLEVE blast, the heat radiation which results from the BLEVE fireball associated with the explosion was also calculated. The results have been summarised in Appendix Table B-5.

**Appendix Table B-5: Heat Radiation from an LPG Tanker BLEVE**

| Radiant Heat (kW/m$^2$) | Distance (m) |
|---|---|
| 35 | 206 |
| 23 | 255 |
| 12.6 | 342 |
| 4.7 | 545 |

## B6. LPG Jet Fire, Impact on LPG Tank and Subsequent BLEVE

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

The input parameters for the BLEVE modelling are shown in Appendix Figure B-4.

| **Parameters** | |
|---|---|
| **Inputs** | |
| **Process Conditions** | |
| Chemical name | LPG Sample (Sample mixtures) |
| Initial temperature in vessel (°C) | 20 |
| Burst pressure vessel (bar) | 26 |
| **Process Dimensions** | |
| Vessel volume (m3) | 7.5 |
| Filling degree (%) | 100 |
| **Environment** | |
| Ambient temperature (°C) | 20 |
| Ambient pressure (bar) | 1.0151 |

**Appendix Figure B-4: LPG Tank BLEVE Input Parameters**

The overpressure impacts calculated from the model have been summarised in Appendix Table B-6.

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

| Overpressure (kPa) | Distance (m) |
|---|---|
| 70 | 8 |
| 35 | 15 |
| 21 | 24 |
| 14 | 34 |
| 7 | 61 |

Using the same input parameters as for the BLEVE blast, the heat radiation which results from the BLEVE fireball associated with the explosion was also calculated. The results have been summarised in Appendix Table B-7.

**Appendix Table B-7: Heat Radiation from an LPG Tank BLEVE**

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

# Appendix C – Frequency Data

## C1. Summary of LPG Tank/Tanker Failure Rate Data

| Component | Failure Rate | Reference | Modifier | PFD |
|---|---|---|---|---|
| Hose | $2x10^{-7}$ per operation | HSE FR1.2.3 (11) | = $2x10^{-7}$ x 52 | =$1.04x10^{-5}$ |
| Excess flow valve | $1.3x10^{-2}$ per demand | HSE FR1.2.1 (11) | Not modified | =0.5 x $1.3x10^{-2}$ = $6.5x10^{-3}$ |
| Non-return valve | $1.3x10^{-2}$ per demand | HSE FR1.2.1 (11) | Not modified | =0.5 x $1.3x10^{-2}$ = $6.5x10^{-3}$ |
| Emergency stop | $1.03x10^{9}$ hours | Rockwell Automation (12) | $1.03x8760/10^{9}$ = 0.009 | =$(\lambda^{2}$ x $t^{2})/3$<br>($0.009^{2}$ x $1^{2}$)/3 = $2.7x10^{-5}$ |
| Isolation valves | $1x10^{-2}$ per demand | HSE FR1.2.1 (11) | Not modified | = 0.5 x $1x10^{-2}$ = $5x10^{-3}$ |