PROJECT DONE ON BEHALF OF
HYPERION SOLAR DEVELOPMENT (PTY) LTD

QUANTITATIVE RISK ASSESSMENT OF THE PROPOSED 75 MW THERMAL DUAL FUEL FACILITY NEAR KATHU, NORTHERN CAPE

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RISCOM (PTY) LTD

RISCOM (PTY) LTD is a consulting company that specialises in process safety. Further to this, RISCOM* is an approved inspection authority (AIA) for conducting Major Hazard Installation (MHI) risk assessments in accordance with the OHS Act 85 of 1993 and its Major Hazard Installation regulations (July 2001). In order to maintain the status of approved inspection authority, RISCOM is accredited by the South African National Accreditation System (SANAS) in accordance with the IEC/ISO 17020:2012 standard.

The accreditation consists of a number of elements, including technical competence and third-party independence.

The independence of RISCOM is demonstrated by the following:

- RISCOM does not sell or repair equipment that can be used in the process industry;
- RISCOM does not have any shareholding in processing companies nor companies performing risk assessment functions;
- RISCOM does not design equipment or processes.

Mike Oberholzer is a professional engineer, holds a Bachelor of Science in Chemical Engineering and is an approved signatory for MHI risk assessments, thereby meeting the competency requirements of SANAS for assessment of the risks of hazardous components, including fires, explosions and toxic releases.

Opinions and interpretations expressed herein this report are outside the scope of SANAS accreditation.

M P Oberholzer Pr. Eng. BSc (Chem. Eng.) MIChemE MSAIChE

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EXECUTIVE SUMMARY

1 INTRODUCTION

Hyperion Solar Development (Pty) Ltd (hereinafter referred to Hyperion is proposing the development of a hybrid generation facility consisting of a dispatchable, dual fuel (liquid or gas) thermal generation plant that will work in combination with the authorised Hyperion 1 & 2 Solar PV Energy Facilities, located approximately 22km north of Kathu within in the Gamagara Local Municipality, which falls within jurisdiction of the John Taolo Gaetsewe District Municipality in the Northern Cape Province.

The 75 MW thermal generation plant, combined with the already authorised solar PV facilities project, will be known as the Hyperion Hybrid Facility.

This application is being submitted in order to enable a compliant bid to be submitted into the Department of Energy's (DoE) Risk Mitigation Independent Power Producer (IPP) Procurement Program (2020).

The development footprint for the thermal facility is located within the area considered for the Hyperion 1 & 2 PV facilities and is anticipated to be approximately 5 ha in extent.
Infrastructure associated with the proposed project will include:

- Gas engines;
- Access road;
- Truck entrance and parking facility;
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- Dry cooling system for operating oils/chemicals;
- Fuel off-loading facility;
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- Water demineralisation plant;
- Authorised substation for PV facility will be utilised;
- Office, maintenance and warehouse building.

Since off-site incidents may result due to hazards of some of the chemical components to be stored on, produced at or delivered to site, RISCOM (PTY) LTD was commissioned to conduct a quantitative risk assessment (QRA), the impacts onto surrounding properties and communities as part of an environmental impact assessment (EIA).

1.1 Terms of Reference

The main aim of the investigation was to quantify the risks to employees, neighbours and the public with regard to the proposed Hyperion facility in Kathu.

This risk assessment was conducted in accordance with the MHI regulations and can be used as notification for the facility. The scope of the risk assessment included:

1. Development of accidental spill and fire scenarios for the facility;
2. Using generic failure rate data (for tanks, pumps, valves, flanges, pipework, gantry, couplings and so forth), determination of the probability of each accident scenario;
3. For each incident developed in Step 2, determination of consequences (such as thermal radiation, domino effects, toxic-cloud formation and so forth);
4. For scenarios with off-site consequences (greater than 1% fatality off-site), calculation of maximum individual risk (MIR), taking into account all generic failure rates, initiating events (such as ignition), meteorological conditions and lethality.

1.2 Purpose and Main Activities

The main activity of the power plant would be the generation of mid-merit power supply to the South African electricity grid/37 updated sentence. The fuel used to generate power would be LPG, delivered to site in road tankers.

1.3 Main Hazards Due to Substance and Process

The main hazards that would occur with a loss of containment of hazardous components at the proposed Hyperion facility in Kathu include exposure to:

- Thermal radiation from fires;
- Overpressure from explosions.

2 ENVIRONMENT

The proposed hybrid thermal power generation plant will be located on Remainder of the Farm Lyndoch 432, approximately 22km north of Kathu within the Gamagara Local Municipality, which falls within jurisdiction of the John Taolo Gaetsewe District Municipality in the Northern Cape Province on the following properties, as shown in Figure 2-1.

The solar facilities PV1 and PV2 are located on either side of the hybrid thermal power facility, with no residential areas or facilities for vulnerable people located within a short distance from the thermal power generation plant.

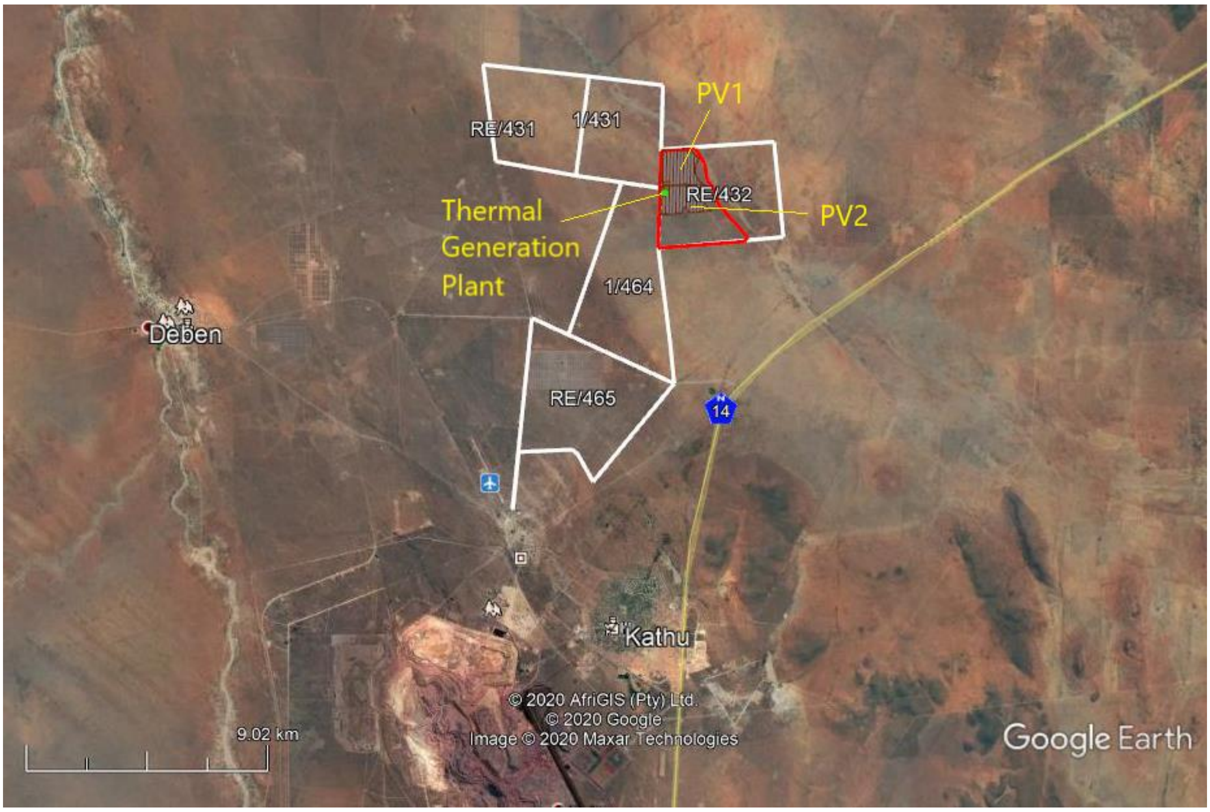


Figure 2-1: Location of the proposed Hyperion facility in Kathu

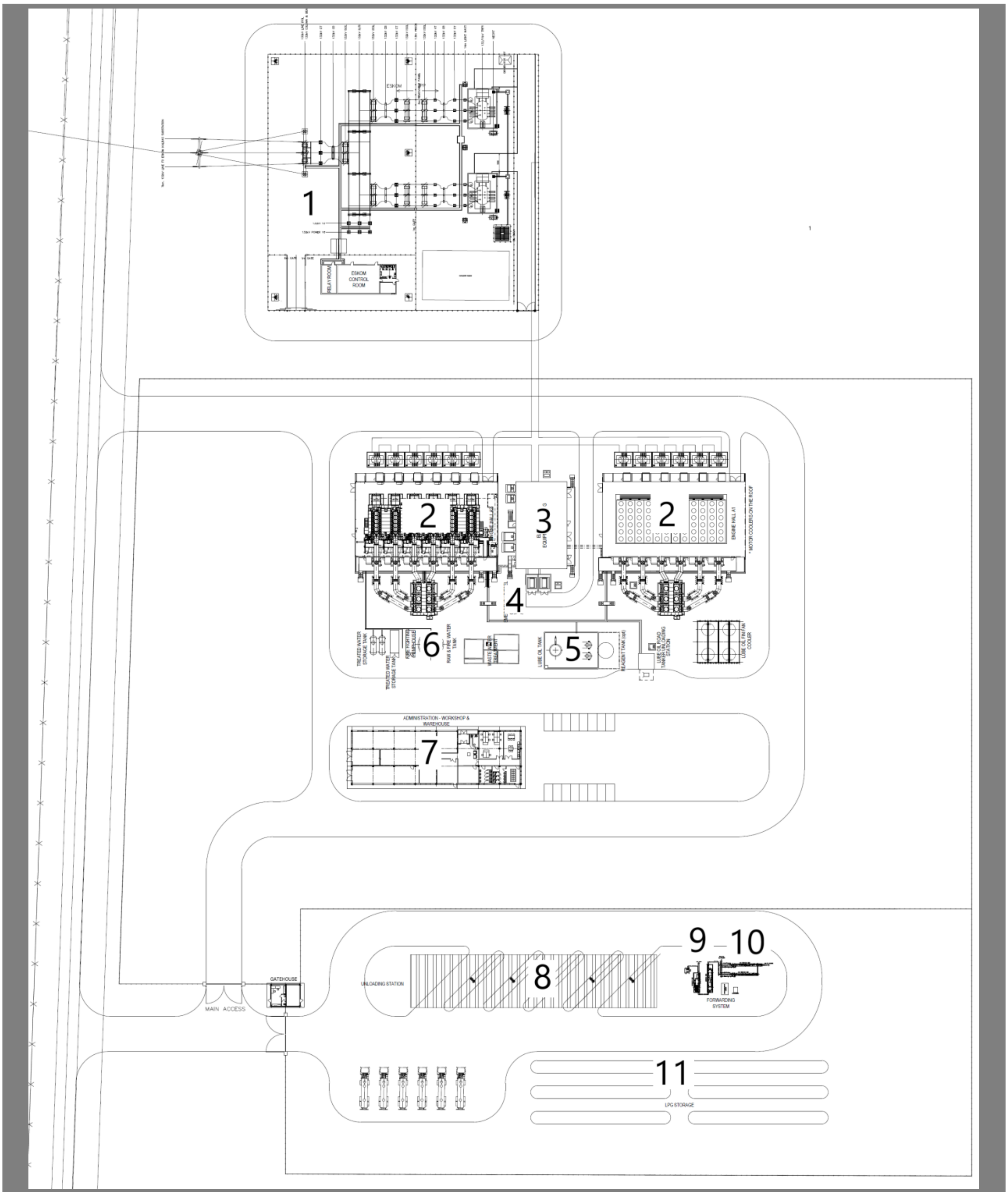
3 PROCESS DESCRIPTION

3.1 Site

The proposed Hyperion facility in Kathu is to consist of bulk LPG storage vessels, offices, workshops and engine rooms, as shown in Figure 3-1.

The facility will consist of a series of gas engines housed in up to two engine rooms, gas exhausts grouped into four stacks of (up to) six exhausts each (maximum stack height of 30 m), admin buildings, control rooms, warehouse and workshop facilities, staff facilities, a guard house, oil tanks, dangerous goods (hydraulic fluid, diesel, lubricant) tanks and sludge tanks, water storage tank(s) or reservoir, LPG storage tank(s) and LPG vaporisation facilities as well as a facility substation and ancillary infrastructure.

The site is located between the solar PV1 and PV2 areas, with easy access from the road for the LPG road tankers.



No.	Description	No.	Description
1	Electrical yard	2	Engine room Electrical equipment
3	Electrical equipment room	4	Emergency diesel generator
5	Lube oil tank	6	Fire water tank
7	Admin building, & workshop	8	LPG offloading gantry
9	Forwarding system	10	Vaporisers
11	LPG Storage	12	

Figure 3-1: Site layout

3.2 Process Description

A simplified process description of the Hyperion thermal power generation power plant is shown in Figure 3-2.

The Hyperion thermal power generation power plant will generate 75 MW of power, when the solar power systems are unavailable. The power generation will use LPG as fuel to generate power. The LPG will be delivered to site in road tankers and stored in bulk pressure tanks before being transported, via pipelines, to the vaporisers and then onto the gensets, located in the engine rooms, that will provide the power that will be exported to Eskom.

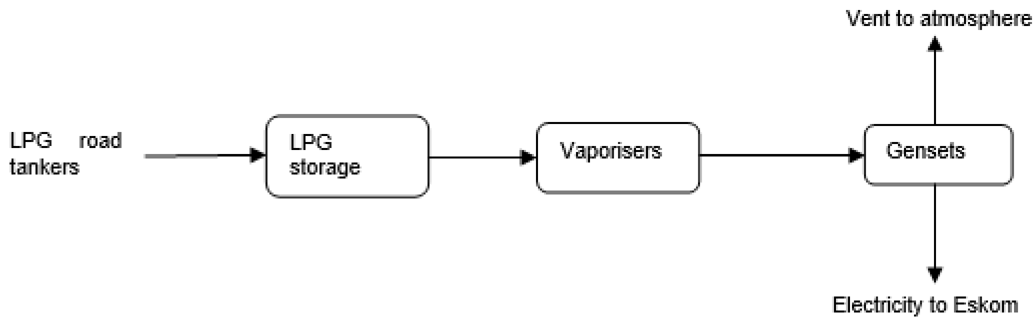


Figure 3-2: Simplified process flow diagram

3.2.1 LPG Installation

The Bulk LPG storage facility comprises of the design, construction and installation of a maximum of 8 x 300 tonne (620 m^3) mounded LPG tanks, compliant with the requirements of South African National standard SANS 10087:3. The position of the mounded tank and associated equipment, is indicated in Figure 3-1.

The LPG tanks will be delivered to site in road tankers of approximately 30 m^3 each and offloaded at the 5-bay road gantry. The offloading will be done by compressing vapours from the LPG storage tank, and forcing the LPG from the road tankers to the storage vessels.

It is estimated that approximately 44 LPG road tankers would be delivered to site every week.

The LPG from the storage tanks would pass through 2 x 100% water bath vaporisers, (operating at about 40ºC) that would heat the LPG from the storage temperature and convert the liquefied gas into vapour. From the vaporisers, the gas will be transported to the engine rooms.

3.3 Summary of Bulk Materials to be Stored on Site

A summary of bulk materials that can give hazardous effects that are to be stored on site, is given in Table 3-1.

Table 3-1: Summary of hazardous components to be stored on site

No.	Component	CAS No.	Inventory
1	LPG (propane)	74-98-6	8 x 6 20 m3

4 METHODOLOGY

The first step in any risk assessment is to identify all hazards. The merit of including a hazard for further investigation is then determined by how significant it is, normally by using a cut-off or threshold value.

Once a hazard has been identified, it is necessary to assess it in terms of the risk it presents to the employees and the neighbouring community. In principle, both probability and consequence should be considered, but there are occasions where, if either the probability or the consequence can be shown to be sufficiently low or sufficiently high, decisions can be made based on just one factor.

During the hazard identification component of the report, the following considerations are taken into account:

- Chemical identities;
- Location of on-site installations that use, produce, process, transport or store hazardous components;
- Type and design of containers, vessels or pipelines;
- Quantity of material that could be involved in an airborne release;
- Nature of the hazard most likely to accompany hazardous materials spills or releases, e.g., airborne toxic vapours or mists, fires or explosions, large quantities to be stored and certain handling conditions of processed components.

The evaluation methodology assumes that the facility will perform as designed in the absence of unintended events such as component and material failures of equipment, human errors, external events and process unknowns.

Risk assessments done in accordance with the MHI regulations are required to be conducted according to SANS 1461. This standard is specific to the MHI risk assessment that is required to be done prior to construction and includes elements that are not usually available at the preparation stage of a project, such as emergency plans and mitigation suggested during the EIA process.

SANS 1461 is based on RIVM (2009) for process plants. The latter standards describe the minimum scenarios to be included in the assessment, as well as the assumptions to be used. As full compliance of SANS 1461 cannot be achieved within the NEMA legislative framework, general compliance of the aforementioned standards at this stage would be applicable and briefly described in the sections below. This general compliance assessment constitutes a quantitative risk assessment (QRA).

The QRA process is summarised with the following steps:

1. Identification of components that are flammable, toxic, reactive or corrosive and that have potential to result in a major incident from fires, explosions or toxic releases;
2. Development of accidental loss of containment (LOC) scenarios for equipment containing hazardous components (including release rate, location and orientation of release);
3. For each incident developed in Step 2, determination of consequences (such as thermal radiation, domino effects, toxic-cloud formation and so forth);
4. For scenarios with off-site consequences (greater than 1% fatality off-site), calculation of maximum individual risk (MIR), taking into account all generic failure rates, initiating events (such as ignition), meteorological conditions and lethality.

Scenarios included in this QRA have impacts external to the establishment. The 1% fatality from acute affects (thermal radiation, blast overpressure and toxic exposure) is determined as the endpoint (RIVM 2009). Thus, a scenario producing a fatality of less than 1% at the establishment boundary under worst-case meteorological conditions would be excluded from the QRA.

5 CONCLUSIONS

Risk calculations are not precise. Accuracy of predictions is determined by the quality of base data and expert judgements.

This risk assessment included the consequences of fires and explosions at the Hyperion facility in Kathu. A number of well-known sources of incident data were consulted and applied to determine the likelihood of an incident to occur.

This risk assessment was performed with the assumption that the site would be maintained to an acceptable level and that all statutory regulations would be applied. It was also assumed that the detailed engineering designs would be done by competent people, and would be correctly specified for the intended duty. For example, it was assumed that tank wall thicknesses have been correctly calculated, that vents have been sized for emergency conditions, that instrumentation and electrical components comply with the specified electrical area classification, that material of construction is compatible with the products, etc.

It is the responsibility of the owners and their contractors to ensure that all engineering designs would have been completed by competent persons and that all pieces of equipment would have been installed correctly. All designs should be in full compliance with (but not limited to) the Occupational Health and Safety Act 85 of 1993 and its regulations, the National Buildings Regulations and the Buildings Standards Act 107 of 1977 as well as local bylaws.

A number of incident scenarios were simulated, taking into account the prevailing meteorological conditions, and described in the report.

5.1 Notifiable Substances

The General Machinery Regulation 8 and its Schedule A on notifiable substances, requires any employer who has a substance equal to or exceeding the quantity listed in the regulation to notify the divisional director. A site is classified as a Major Hazard Installation if it contains one or more notifiable substances, or if the off-site risk is sufficiently high. The latter can only be determined from a quantitative risk assessment.

The notifiable threshold for LPG is listed 25 t in a single vessel. As the proposed installation exceeds the threshold limit, LPG will be classified as a notifiable substance, which would automatically **classify the facility a Major Hazard Installation**.

5.2 LPG Storage and Associated Equipment

LPG would be received from the adjacent facility via a pipeline and stored in a maximum 8 x 300 t storage vessels. The LPG would be vaporised in a vapour phase and sent to the gensets as fuel.

Depending on the physical conditions of the LPG, a large release could result in pool fires, jet fires, flash fires and vapour cloud explosions. The BLEVE consequence was prevented from occurring, because of the mounding of the vessels. All of the aforementioned effects were simulated with the largest downwind distance occurring from a large release from a LPG vessel, extending up to 1.1 km to the 1% fatality from the point of release and could impact surround areas, but would not reach the occupied residential areas.

The risk of $1x10^{-6}$ fatalities per person per year isopleth found to extend beyond the site boundary, and **that alone qualifies the site as a Major Hazard Installation**. The risk was $1x10^{-4}$ fatalities per person per year representing intolerable to the general public, did not reach the site boundary. Thus, the risks to the public would be within the ALARP range and considered tolerable.

5.3 Impacts onto Neighbouring Properties, Residential Areas and MHIs

Most of the surrounding land has not been developed, and thus limited impacts would be experienced from a large release of LPG, within these areas. Impacts into the residential areas, recreational areas, hotels, schools, hospitals and other places of the general would not be expected.

Mitigation must be provided to stop any outflow of LPG from the tanks in the event of pipelines, pumps, etc and exacerbate the impacts from an additional LPG release.

No neighbouring property to Hyperion is classified as a Major Hazardous Installation, thus no knock-on effects from a major incident at the Hyperion power generation facility will be expected.

5.4 Major Hazard Installation

This investigation was done under the National Environmental Management Act (No. 107 of 1998) (NEMA) and its Regulations. This study concluded that under the current design conditions, the proposed Hyperion facility in Kathu **would be considered as a Major Hazard Installation** and would trigger the statutory requirement of completing a MHI risk assessment under the Occupational Health and Safety Act No. 85 of 1993, prior to construction.

The MHI is a regulated process that requires specific information to be included in the study, after completion of the final designs and prior to construction. As such, **this study is not intended to replace the Major Hazard Installation risk assessment which should be completed prior to construction of the terminal**.

6 RECOMMENDATIONS

As a result of the risk assessment study conducted for the proposed Hyperion facility in Kathu, a number of events were found to have risks beyond the site boundary. These risks could be mitigated to acceptable levels.

RISCOM did not find any fatal flaws that would prevent the project proceeding to the detailed engineering phase of the project.

RISCOM would support the project with the following conditions:

- Compliance with all statutory requirements, i.e., pressure vessel designs;
- Compliance with applicable SANS codes, i.e., SANS 10087, SANS 10089, SANS 10108, etc.;
- Incorporation of applicable guidelines or equivalent international recognised codes of good design and practice into the designs;
- Completion of a recognised process hazard analysis (such as a HAZOP study, FMEA, etc.) on the proposed facility prior to construction to ensure design and operational hazards have been identified and adequate mitigation put in place;
- Full compliance with IEC 61508 and IEC 61511 (Safety Instrument Systems) standards or equivalent to ensure that adequate protective instrumentation is included in the design and would remain valid for the full life cycle of the tank farm:
  - Including demonstration from the designer that sufficient and reliable instrumentation would be specified and installed at the facility;
- Preparation and issue of a safety document detailing safety and design features reducing the impacts from fires, explosions and flammable atmospheres to the MHI assessment body at the time of the MHI assessment:
  - Including compliance to statutory laws, applicable codes and standards and world's best practice;
  - Including the listing of statutory and non-statutory inspections, giving frequency of inspections;
  - Including the auditing of the built facility against the safety document;
  - Noting that codes such as IEC 61511 can be used to achieve these requirements;
- Demonstration by Hyperion or their contractor that the final designs would reduce the risks posed by the installation to internationally acceptable guidelines;
- Signature of all terminal designs by a professional engineer registered in South Africa in accordance with the Professional Engineers Act, who takes responsibility for suitable designs;
- Completion of an emergency preparedness and response document for on-site and off-site scenarios prior to initiating the MHI risk assessment (with input from local authorities);
- Permission not being granted for increases to the product list or product inventories without redoing part of or the full EIA;
- Final acceptance of the facility risks with an MHI risk assessment that must be completed in accordance to the MHI regulations:
  - Basing such a risk assessment on the final design and including engineering mitigation.

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1 INTRODUCTION

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1.1 Legislation

Legislation discussed in this subsection is limited to the health and safety of employees and the public.

Risk assessments are conducted when required to do so by law or by companies wishing to determine the risks of the facility for other reasons, such as insurance. In South Africa, risk assessments are carried out under the legislation of two separate acts, each with different requirements. These are discussed in the subsections that follow.

1.1.1 National Environmental Management Act (No. 107 of 1998) (NEMA) and its Regulations

The National Environmental Management Act (NEMA) contains South Africa's principal environmental legislation. It has, as its primary objective, to make provision for cooperative governance by establishing principles for decision making on matters affecting the environment, on the formation of institutions that will promote cooperative governance and on establishing procedures for coordinating environmental functions exercised by organs of state, as well as to provide for matters connected therewith (Government Gazette 1998).

Section 30 of the NEMA act deals with the control of emergency incidents where an "*incident*" is defined as an "*unexpected sudden occurrence, including a major emission, fire or explosion leading to serious danger to the public or potentially serious pollution of, or detriment to the environment, whether immediate or delayed*".

The act defines "*pollution"* as *"any change in the environment caused by:*

(i) Substances;
(ii) Radioactive or other waves; or,
(iii) Noise, odours, dust or heat…

Emitted from any activity, including the storage or treatment of waste or substances, construction and the provision of services, whether engaged in by any person or an organ of state, where that change has an adverse effect on human health or wellbeing or on the composition, resilience and productivity of natural or managed ecosystems, or on materials useful to people, or will have such an effect in the future... "

"*Serious*" is not fully defined but would be accepted as having long lasting effects that could pose a risk to the environment or to the health of the public that is not immediately reversible.

This is similar to the definition of a MHI as defined in the Occupational Health and Safety Act (OHS Act) 85 of 1993 and its MHI regulations.

Section 28 of NEMA makes provision for anyone who causes pollution or degradation of the environment being made responsible for the prevention of the occurrence, continuation or reoccurrence of related impacts and for the costs of repair of the environment. In terms of the provisions under Section 28 that are stated as:

" Every person who causes, has caused or may cause significant pollution or degradation of the environment must take reasonable measures to prevent such pollution or degradation from occurring, continuing or recurring, or, in so far as such harm to the environment is authorised by law or cannot reasonably be avoided or stopped… "

1.1.2 The Occupational Health and Safety Act No. 85 of 1993

The Occupation Health and Safety Act 85 (1993) is primarily intended for the health and safety of the employees, whereas its MHI regulations is intended for the health and safety of the public.

The OHS Act shall not apply in respect of:

" a) *A mine, a mining area or any works as defined in the Minerals Act, 1991 (Act No. 50 of 1991), except in so far as that Act provides otherwise;*

b) *Any load line ship (including a ship holding a load line exemption certificate), fishing boat, sealing boat and whaling boat as defined in Section 2 (1) of the Merchant Shipping Act, 1951 (Act No. 57 of 1951), or any floating crane, whether or not such ship, boat or crane is in or out of the water within any harbour in the Republic or within the territorial waters thereof, (date of commencement of paragraph (b) to be proclaimed.), or in respect of any person present on or in any such mine, mining area, works, ship, boat or crane.* "

1.1.2.1 Major Hazard Installation Regulations

The MHI regulations (July 2001) published under Section 43 of the OHS Act require employers, self-employed persons and users who have on their premises, either permanently or temporarily, a major hazard installation or a quantity of a substance which may pose a **risk** (our emphasis) that could affect the health and safety of employees and the public to conduct a risk assessment in accordance with the legislation.

In accordance with legislation, the risk assessment must be done **prior to construction of the facility** by an approved inspection authority (AIA; see Appendix A and Appendix B), registered with the Department of Labour and accredited by the South African Accreditation Systems (SANAS).

Similar to Section 30 of NEMA as it relates to the health and safety of the public, the MHI regulations are applicable to the health and safety of employees and the public in relation to the operation of a facility and specifically in relation to sudden or accidental major incidents involving substances that could pose a risk to the health and safety of employees and the public.

The notification of the MHI is described in the regulations as an advertisement placement and specifies the timing of responses from the advertisement. It should be noted that the regulation does not require public participation.

The regulations, summarised in Appendix C, essentially consists of six parts, namely:

1. The duties for notification of a MHI (existing or proposed), including:
    a. Fixed;
    b. Temporary installations;
2. The minimum requirements for a quantitative risk assessment (QRA);
3. The requirements for an on-site emergency plan;
4. The reporting steps for risk and emergency occurrences;
5. The general duties required of suppliers;
6. The general duties required of local government.

As this is not an MHI risk assessment, the application of the above legislation is not mandatory but the legislation is described to give a background to this report.

1.2 Terms of Reference

The main aim of the investigation was to quantify the risks to employees, neighbours and the public with regard to the proposed Hyperion facility in Kathu.

This risk assessment was conducted in accordance with the MHI regulations and can be used as notification for the facility. The scope of the risk assessment included:

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1.4 Main Hazards Due to Substance and Process

The main hazards that would occur with a loss of containment of hazardous components at the proposed Hyperion facility in Kathu include exposure to:

- Thermal radiation from fires;
- Overpressure from explosions.

1.5 Software

Physical consequences were calculated with TNO's EFFECTS v.9.0.26 and the data derived was entered into TNO's RISKCURVES v. 9.0.23. All calculations were performed by Mr M P Oberholzer.

1.6 Assumptions and Limitations

The risk assessment was based on the conceptual designs of the facility, excluding the details still to be determined from the detailed designs. Furthermore, EIAs are intended to suggest mitigation which may alter the design and layout of the project. It is thus understood that detail designs would be required to complete the project for construction.

RISCOM used the information provided and made engineering assumptions as described in the document. The accuracy of the document would be limited to the available documents presented for the completion of this report. However, the inventory of hazardous goods of the facility is not expected to increase from the amounts stated in this document and despite the potential of an improved site layout, we expect the maximum impacts to be representative.

With detail designs, we expect additional mitigation, which should reduce the risks calculated.

The greatest impact on accuracy would be omissions from the design presented, changes to the process, substitution of hazards goods (typically), as required by the equipment supplier or the increase of hazardous goods inventory. These would be evaluated under the Major Hazardous Installation regulations, prior to construction.

The risk assessment excludes the following:

- Natural events, such as earthquakes and floods;
- Ecological risk assessment;
- An emergency plan.

2 ENVIRONMENT

2.1 General Background

The proposed hybrid thermal power generation plant will be located on Remainder of the Farm Lyndoch 432, approximately 22km north of Kathu within the Gamagara Local Municipality, which falls within jurisdiction of the John Taolo Gaetsewe District Municipality in the Northern Cape Province on the following properties, as shown in Figure 2-1.

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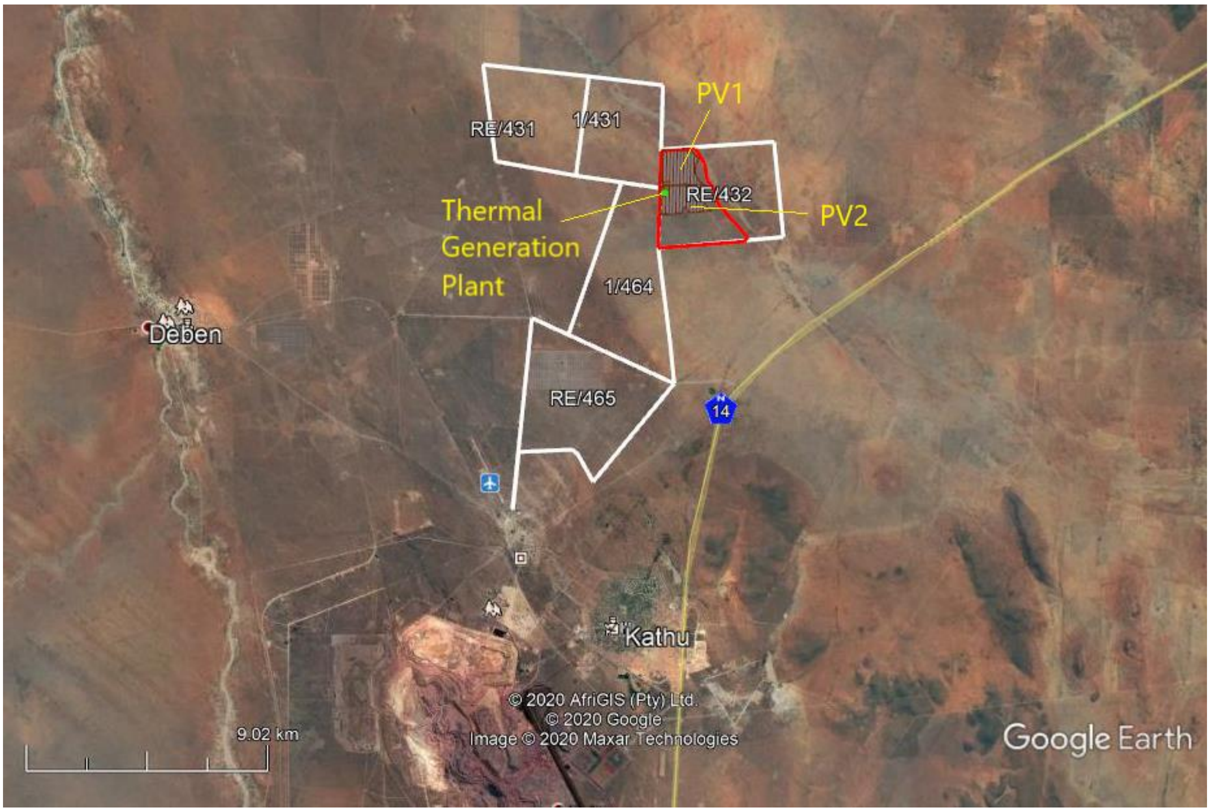


Figure 2-1: Location of the proposed Hyperion facility in Kathu

2.2 Meteorology

Meteorological mechanisms govern the dispersion, transformation and eventual removal of pollutants from the atmosphere. The extent to which pollution will accumulate or disperse in the atmosphere, is dependent on the degree of thermal and mechanical turbulence within the earth's boundary layer. Dispersion comprises vertical and horizontal components of motion.

The stability of the atmosphere and the depth of the surface, i.e., the mixing layer, define the vertical component. The horizontal dispersion of pollution in the boundary layer is primarily a function of the wind field. The wind speed determines both the distance of downwind transport and the rate of dilution as a result of *plume stretching*. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness. The wind directions, and the variability in wind direction, determine the general path pollutants that follow, and the extent of crosswind spreading. Concentration levels of airborne vapours therefore fluctuate in response to changes in atmospheric stability, to concurrent variations in the mixing depth and to shifts in the wind field.

The meteorological conditions at Kathu, as measured by the South African Weather Service, were used as the basis of wind speed, direction and atmospheric stability in this report. The hourly wind analysis was based on the hourly wind speed and direction for the period from the 1st of January 2015 to the 31st of December 2019, while the long-term temperature, rainfall and humidity was based for the period between 1992 and 2019.

2.2.1 Surface Winds

Surface meteorological data, including hourly average wind speed and wind direction recorded at Kathu, was obtained from the South African Weather Service for the period from the 1st of January 2015 to the 31st of December 2019. The wind rose for this period, depicted in Figure 2-2. Kathu experiences a calm period for 2.6% per annum with the predominant wind direction from the south-south east. The windspeed for Kathu is mostly low to medium windspeed, with high windspeeds being rare.

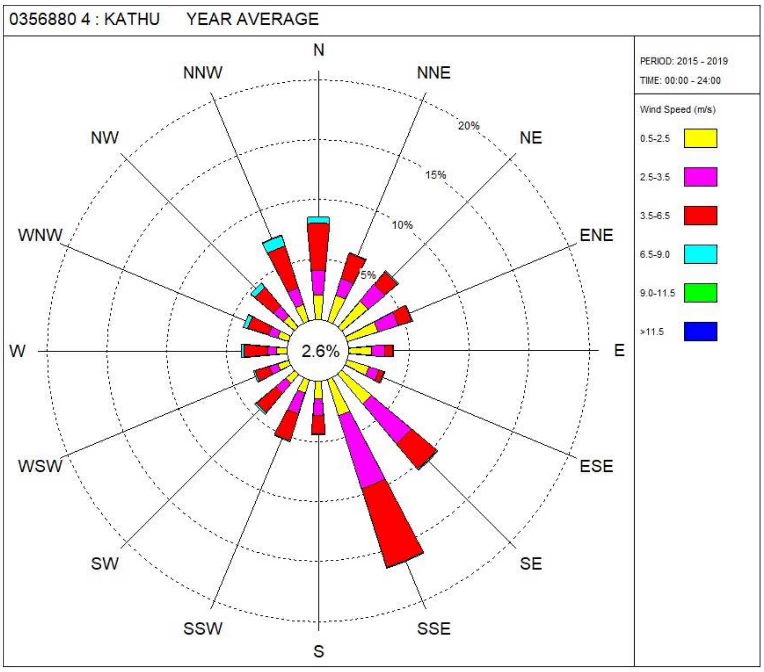


Figure 2-2: Wind speed as a function of wind direction at Kathu for the period from 2015 to 2019

2.2.2 Precipitation, Relative Humidity and Cloud Cover

The long-term rainfall, relative humidity and cloud cover at Kathu, as measured by the South African Weather Service over the period between 1992 and 2019, is given in Table 2-1. Kathu is relatively dry, with an average annual rainfall of 265 mm and the dry seasons ranging from June to September.

The annual average relative humidity is 26% and 55% for day and night respectively, over the yearly average.

Table 2-1: Long-term rainfall at Kathu

Month	Precipitation			Relative Humidity (%)	
	Average Monthly (mm)	Average No. of Days with >= 1 mm	Highest 24-hour Rainfall (mm)	Day	Night
January	59	5.9	57	31	55
February	48	5.1	63	34	61
March	34	4.8	33	34	62
April	30	2.9	46	34	69
May	16	1.6	81	28	67
June	4	0.6	38	27	69
July	1	0.4	9	25	64
August	3	0.3	25	19	50
September	5	0.9	29	17	40
October	22	2.4	62	19	40
November	25	2.9	48	19	39
December	32	4.0	35	24	46
Year	**265**	**31**	**81**	**26**	**55**

2.2.3 Temperature

In Kathu, the summers are long and hot; the winters are short, cold, dry, and windy; and it is mostly clear year-round., with an average daily maximum between 19°C and 30°C. Temperatures very rarely extend below freezing point, with the yearly mean average of daily temperatures being above 10°C.

The long-term temperatures measured at Kathu between 1961 and 1990 by the South African Weather Service, are given in Table 2-2.

Table 2-2: Long-term temperatures measured at Kathu

Month	Temperature (°C)		
	Average Daily Maximum	Average Daily Minimum	Average Daily Mean
January	33	18	25
February	33	17	25
March	31	15	23
April	27	11	19
May	23	6	15
June	21	2	11
July	20	2	11
August	23	4	14
September	28	8	18
October	30	12	21
November	32	14	23
December	34	16	25
Year	**28**	**10**	**19**

2.2.4 Atmospheric Stability

Atmospheric stability is frequently categorised into one of six stability classes. These are briefly described in Table 2-3. The atmospheric stability, in combination with the wind speed, is important in determining the extent of a pollutant from a release. A very stable atmospheric condition, typically at night, would have a low wind speed and produce the greatest endpoint for a dense gas. Conversely, a buoyant gas would have the greatest endpoint distance at a high wind speed.

Table 2-3: Atmospheric stability classification scheme

Stability Class	Stability Classification	Description
A	Very unstable	Calm wind, clear skies, hot daytime conditions.
B	Moderately unstable	Clear skies, daytime conditions.
C	Unstable	Moderate wind, slightly overcast daytime conditions.
D	Neutral	Strong winds or cloudy days and nights.
E	Stable	Moderate wind, slightly overcast night-time conditions.
F	Very stable	Low winds, clear skies, cold night-time conditions.

Risk assessments are calculated on six represented weather classes covering the stability conditions of stable, neutral and unstable as well as low and high wind speeds. In terms of Pasquill classes, the representative conditions are given in Table 2-4.

Table 2-4: Representative weather classes

Stability Class	Wind (m/s)
B	3
D	1.5
D	5
D	9
E	5
F	1.5

As wind velocities are a vector quantity (i.e., have speed and direction) and blow preferentially in certain directions, it is mathematically incorrect to give an average wind speed over the 360°C of wind direction, and will result in incorrect risk calculations. It would also be incorrect to base the risk calculations on one wind category, e.g., 1.5/F.

In order to obtain representative risk calculations, hourly weather data of wind speed and wind direction were analysed over a five-year period and categorised into the six wind classes for day and night time conditions for 16 wind directions. The risk was then determined using the contributions of each wind class in various wind directions.

The allocation of observations into the six weather classes is summarised in Table 2-5, with the representative weather classes for Kathu given in Figure 2-3, and used as input for the risk calculations.

Table 2-5: Allocation of observations into six weather classes

<table>
<tr><th>Wind Speed</th><th>A</th><th>B</th><th>B/C</th><th>C</th><th>C/D</th><th>D</th><th>E</th><th>F</th></tr>
<tr><td>< 2.5 m/s</td><td colspan="3" rowspan="3">B 3 m/s</td><td colspan="3">D 1.5 m/s</td><td colspan="2">F 1.5 m/s</td></tr>
<tr><td>2.5 - 6 m/s</td><td colspan="3">D 5 m/s</td><td colspan="2" rowspan="2">E 5 m/s</td></tr>
<tr><td>> 6 m/s</td><td colspan="3">D 9 m/s</td></tr>
</table>

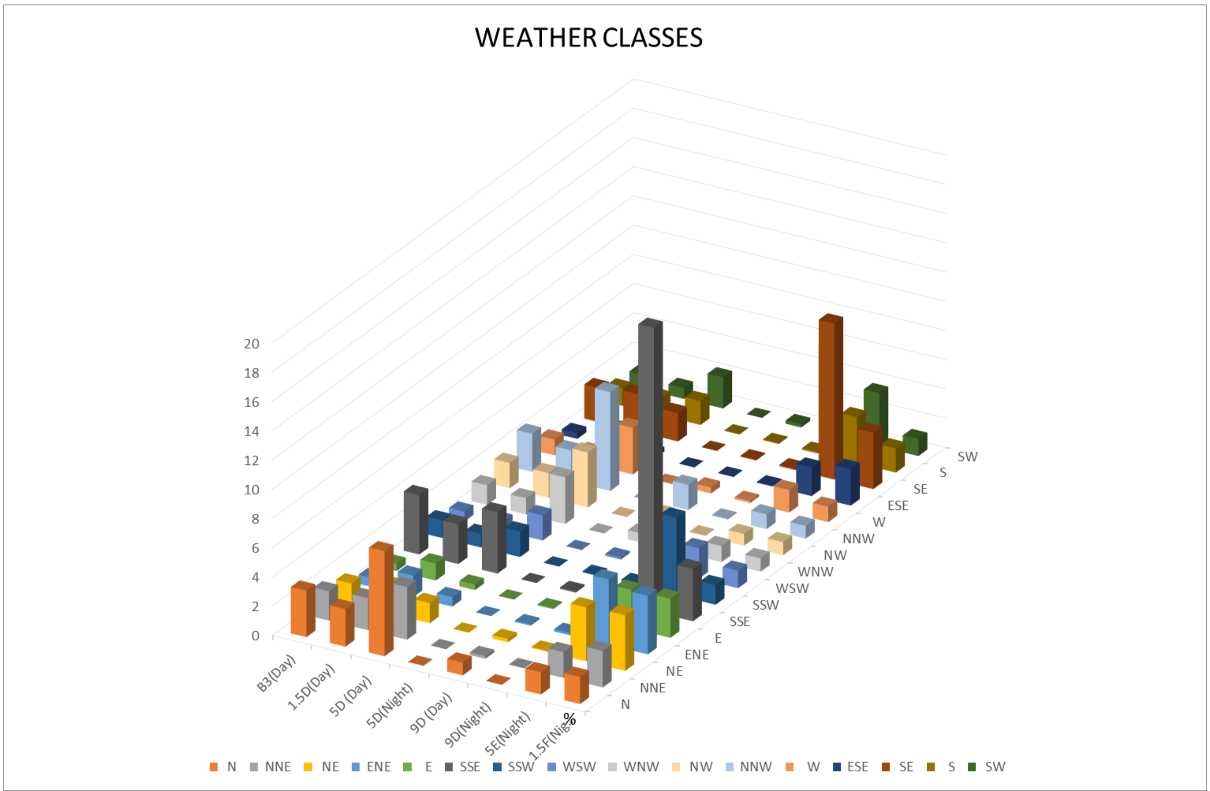


Figure 2-3: Representative weather classes for Kathu (2015-2019)

2.2.5 Default Meteorological Value

The default meteorological values used in the simulations, based on local conditions, values are given below in Table 2-6.

Table 2-6: The default meteorological values used in the simulations, based on local conditions

Parameter	Default Value Daytime	Default Value Night Time
Ambient temperature (°C)	28	10
Substrate/bund temperature (°C)	19	19
Water temperature (°C)	19	19
Air pressure (bar)	0.85	0.85
Humidity (%)	26	55
Fraction of a 24-hour period	0.5	0.5
Mixing height	1	1

1 Mixing height is calculated as part of the software

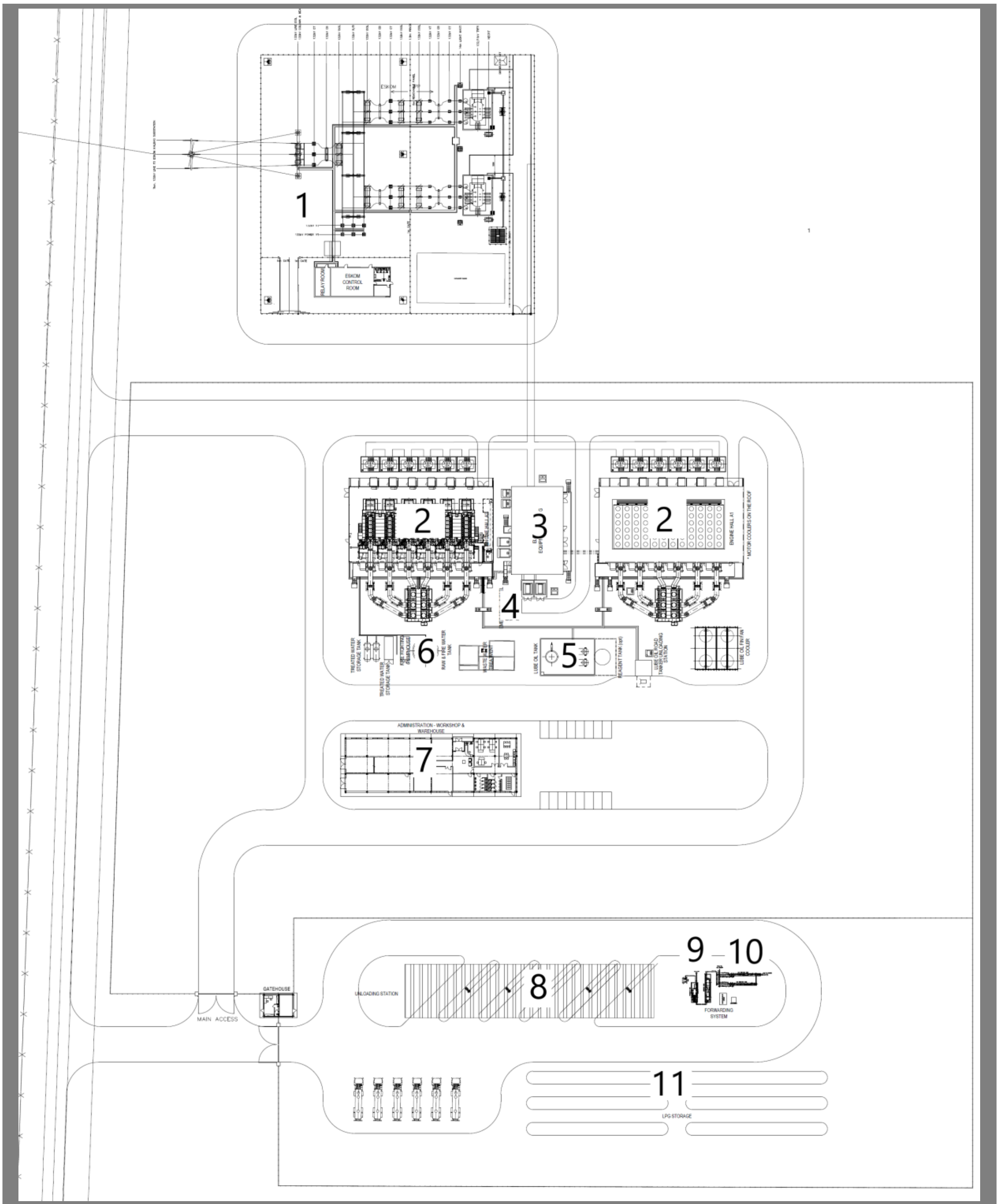
3 PROJECT DESCRIPTION

3.1 Site

The proposed Hyperion facility in Kathu is to consist of bulk LPG storage vessels, offices, workshops and engine rooms, as shown in Figure 3-1.

The facility will consist of a series of gas engines housed in up to two engine rooms, gas exhausts grouped into four stacks of (up to) six exhausts each (maximum stack height of 30 m), admin buildings, control rooms, warehouse and workshop facilities, staff facilities, a guard house, oil tanks, dangerous goods (hydraulic fluid, diesel, lubricant) tanks and sludge tanks, water storage tank(s) or reservoir, LPG storage tank(s) and LPG vaporisation facilities as well as a facility substation and ancillary infrastructure.

The site is located between the solar PV1 and PV2 areas, with easy access from the road for the LPG road tankers.



No.	Description	No.	Description
1	Electrical yard	2	Engine room Electrical equipment
3	Electrical equipment room	4	Emergency diesel generator
5	Lube oil tank	6	Fire water tank
7	Admin building, & workshop	8	LPG offloading gantry
9	Forwarding system	10	Vaporisers
11	LPG Storage	12	

Figure 3-1: Site layout

3.2 Project Description

A simplified process description of the Hyperion thermal power generation power plant is shown in Figure 3-2.

The Hyperion thermal power generation power plant will generate 75 MW of power, when the solar power systems are unavailable. The power generation will use LPG as fuel to generate power. The LPG will be delivered to site in road tankers and stored in bulk pressure tanks before being transported, via pipelines, to the vaporisers and then onto the gensets, located in the engine rooms, that will provide the power that will be exported to Eskom.

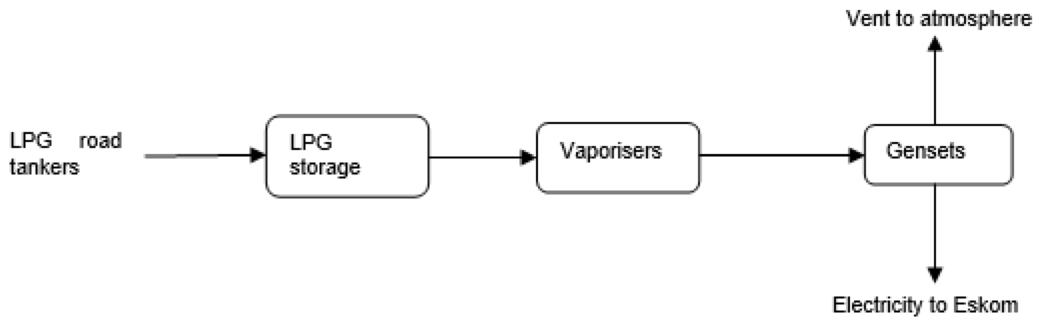


Figure 3-2: Simplified process flow diagram

3.2.1 LPG Installation

The Bulk LPG storage facility comprises of the design, construction and installation of a maximum of 8 x 300 tonne (620 m^3) mounded LPG tanks, compliant with the requirements of South African National standard SANS 10087:3. The position of the mounded tank and associated equipment, is indicated in Figure 3-1.

The LPG tanks will be delivered to site in road tankers of approximately 30 m^3 each and offloaded at the 5-bay road gantry. The offloading will be done by compressing vapours from the LPG storage tank, and forcing the LPG from the road tankers to the storage vessels.

It is estimated that approximately 44 LPG road tankers would be delivered to site every week.

The LPG from the storage tanks would pass through 2 x 100% water bath vaporisers, (operating at about 40ºC) that would heat the LPG from the storage temperature and convert the liquefied gas into vapour. From the vaporisers, the gas will be transported to the engine rooms.

3.3 Summary of Bulk Materials to be Stored on Site

A summary of bulk materials that can give hazardous effects that are to be stored on site, is given in Table 3-1.

Table 3-1: Summary of hazardous components to be stored on site

No.	Component	CAS No.	Inventory
1	LPG (propane)	74-98-6	8 x 6 20 m^3

4 METHODOLOGY

Risk assessment done in accordance with the MHI regulations are required to be conducted according to SANS 1461. This standard is specific to the MHI risk assessment that is required to be done prior to construction and includes elements that is not usually available at the preparation, such as emergency plans and mitigation suggested during the EIA process.

SANS 1461 is based on RIVM (2009) for process plants. The latter standards describe the minimum scenarios to be included in the assessment, as well as the assumptions to be used. As full compliance of SANS 1461 cannot be achieved within the NEMA legislative framework, general compliance of the aforementioned standards would be applicable and briefly described in the sections below.

The QRA process is summarised with the following steps:

1. Identification of components that are flammable, toxic, reactive or corrosive and that have potential to result in a major incident from fires, explosions or toxic releases;
2. Development of accidental loss of containment (LOC) scenarios for equipment containing hazardous components (including release rate, location and orientation of release);
3. For each incident developed in Step 2, determination of consequences (such as thermal radiation, domino effects, toxic-cloud formation and so forth);
4. For scenarios with off-site consequences (greater than 1% fatality off-site), calculation of maximum individual risk (MIR), taking into account all generic failure rates, initiating events (such as ignition), meteorological conditions and lethality.

4.1 Hazard Identification

The first step in any risk assessment is to identify all hazards. The merit of including a hazard for further investigation is then determined by how significant it is, normally by using a cut-off or threshold value.

Once a hazard has been identified, it is necessary to assess it in terms of the risk it presents to the employees and the neighbouring community. In principle, both probability and consequence should be considered but there are occasions where, if either the probability or the consequence can be shown to be sufficiently low or sufficiently high, decisions can be made based on just one factor.

During the hazard identification component of the report, the following considerations are taken into account:

- Chemical identities;
- Location of on-site installations that use, produce, process, transport or store hazardous components;
- Type and design of containers, vessels or pipelines;
- Quantity of material that could be involved in an airborne release;
- Nature of the hazard most likely to accompany hazardous materials spills or releases, e.g., airborne toxic vapours or mists, fires or explosions, large quantities to be stored and certain handling conditions of processed components.

The evaluation methodology assumes that the facility will perform as designed in absence of unintended events, such as component and material failures of equipment, human errors, external events and process unknowns.

4.1.1 Notifiable Substances

The General Machinery Regulation 8 and its Schedule A on notifiable substances, requires any employer who has a substance equal to or exceeding the quantity listed in the regulation to notify the divisional director. A site is classified as a Major Hazard Installation if it contains one or more notifiable substances, or if the off-site risk is sufficiently high. The latter can only be determined from a quantitative risk assessment.

The notifiable threshold for LPG is listed 25 t in a single vessel. As the proposed installation exceeds the threshold limit, LPG will be classified as a notifiable substance, which would automatically **classify the facility a Major Hazard Installation**.

4.1.2 Substance Hazards

All components on site were assessed for potential hazards according to the criteria discussed in this section.

4.1.2.1 Chemical Properties

A short description of bulk hazardous components to be stored on, produced at or delivered to site is given in the following subsections. The material safety data sheets (MSDSs) of the respective materials are attached in Appendix E.

- **Liquid Petroleum Gas (LPG)**

Liquid petroleum gas (LPG) primarily consists of propane with minor impurities such as butane. It is a colourless gas at room temperature with the odour of commercial natural gas. It has a low boiling point of -41.9°C and is often compressed and transported and sold as a liquid, primarily as a fuel.

Propane is a severe fire and explosion hazard with an invisible vapour that spreads easily and can be ignited by many sources such as pilot lights, welding equipment, electrical motors, switches and so forth. It is heavier than air and can travel along the ground for some distance to an ignition source.

It is not compatible with strong oxidants and can react with these, resulting in fires and explosions.

It is not considered a carcinogenic material. The toxicology and the physical and chemical properties suggest that overexposure is unlikely to aggravate existing medical conditions.

Overexposure may cause dizziness and drowsiness. Effects of a single (acute) overexposure may result in asphyxiation, due to lack of oxygen, which could be fatal. Self-contained breathing apparatus may be required by rescue workers. Moderate concentrations may cause headaches, drowsiness, dizziness, excitation, excess salivation, vomiting and unconsciousness. Vapour contact with the skin will not cause any harm. However, contact with the liquid may cause frostbite due to the low temperature of liquid propane.

4.1.2.2 Corrosive Liquids

Corrosive liquids considered under this subsection are those components that have a low or high pH and that may cause burns if they come into contact with people or may attack and cause failure of equipment.

Corrosive material that will be stored on site will include ammonium hydroxide, hydrochloric acid and caustic soda. Of these components, ammonium hydroxide and hydrochloric acid are treated as toxic components, while caustic soda will have impacts in the immediate vicinity, but not expected to extend beyond the site boundary.

4.1.2.3 Reactive Components

Reactive components are components that when mixed or exposed to one another react in a way that may cause a fire, explosion or release a toxic component.

All components to be stored on, produced at or delivered to site are considered thermally stable in atmospheric conditions. The reaction with air is covered under the subsection dealing with ignition probabilities.

4.1.2.4 Flammable and Combustible Components

Flammable and combustible components are those that can ignite and give a number of hazardous effects, depending on the nature of the component and conditions. These effects may include pool fires, jet fires and flash fires as well as explosions and fireballs.

The flammable and combustible components to be stored on, produced at or delivered to site, are listed in Table 4-1. These components have been analysed for fire and explosion risks.

Table 4-1: Flammable and combustible components to be stored on, produced at or delivered to site

Component	Flashpoint (°C)	Boiling Point (°C)	LFL (vol. %)	UFL (vol. %)
LPG	-103.5	-42	2.1	9.5

4.1.3 Physical Properties

For this study, LPG were modelled as a pure component, as given in Table 4-2. The physical properties used in the simulations were based on the DIPPR[1] data base, which are preloaded in the simulation software.

Table 4-2: Representative components

Component	Modelled as
LPG	Propane

4.1.4 Components Excluded from the Study

Components excluded from the study, are listed in Table 4-3.

Table 4-3: Components excluded from the study

Component	Inventory	Reasons for Exclusion
Nitrogen	Portable cylinders	Will only be brought on site when maintenance would be required and would be in cylinders.
Lube oil	Unknown	High flash point >100ºC.

1 Design Institute for Physical Properties

4.2 Physical and Consequence Modelling

In order to establish which impacts follow an accident, it is first necessary to estimate the physical process of the spill (i.e., rate and size), spreading of the spill, evaporation from the spill, subsequent atmospheric dispersion of the airborne cloud and, in the case of ignition, the burning rate and resulting thermal radiation from a fire and the overpressures from an explosion.

The second step is then to estimate the consequences of a release on humans, fauna, flora and structures in terms of the significance and extent of the impact in the event of a release. The consequences could be due to toxic or asphyxiant vapours, thermal radiation or explosion overpressures. They may be described in various formats.

The simplest methodology would show a comparison of predicted concentrations, thermal radiation or overpressures to short-term guideline values.

In a different but more realistic fashion, the consequences may be determined by using a dose-response analysis. Dose-response analysis aims to relate the intensity of the phenomenon that constitutes a hazard to the degree of injury or damage that it can cause. Probit analysis is possibly the method mostly used to estimate probability of death, hospitalisation or structural damage. The probit is a lognormal distribution and represents a measure of the percentage of the vulnerable resource that sustains injury or damage. The probability of injury or death (i.e., the risk level) is in turn estimated from this probit (risk characterisation).

Consequence modelling gives an indication of the extent of the impact for selected events and is used primarily for emergency planning. A consequence that would not cause irreversible injuries would be considered insignificant, and no further analysis would be required. The effects from major incidents are summarised in the following subsections.

4.2.1 Fires

Combustible and flammable components within their flammable limits may ignite and burn if exposed to an ignition source of sufficient energy. On process plants, releases with ignition normally occur as a result of a leakage or spillage. Depending on the physical properties of the component and the operating parameters, combustion may take on a number of forms, such as pool fires, jet fires, flash fires and so forth.

4.2.1.1 Thermal Radiation

The effect of thermal radiation is very dependent on the type of fire and duration of exposure. Certain codes, such as the American Petroleum Institute API 520 and API 2000 codes, suggest values for the maximum heat absorbed by vessels to facilitate adequate relief designs in order to prevent failure of the vessel. Other codes, such as API 510 and the British Standards BS 5980 code, give guidelines for the maximum thermal radiation intensity and act as a guide to equipment layout, as shown in Table 4-4.

The effect of thermal radiation on human health has been widely studied, relating injuries to the time and intensity of exposure.

Table 4-4: Thermal radiation guidelines (BS 5980 of 1990)

Thermal Radiation Intensity (kW/m^2)	Limit
1.5	Will cause no discomfort for long exposure.
2.1	Sufficient to cause pain if unable to reach cover within 40 seconds.
4.5	Sufficient to cause pain if unable to reach cover within 20 seconds.
12.5	Minimum energy required for piloted ignition of wood and melting of plastic tubing.
25	Minimum energy required to ignite wood at indefinitely long exposures.
37.5	Sufficient to cause serious damage to process equipment.

For pool fires, jet fires and flash fires CPR 18E (Purple Book; 1999) suggests the following thermal radiation levels be reported:

- 4 kW/m^2, the level that glass can withstand, preventing the fire entering a building, and that should be used for emergency planning;
- 10 kW/m^2, the level that represents the 1% fatality for 20 seconds of unprotected exposure and at which plastic and wood may start to burn, transferring the fire to other areas;
- 35 kW/m^2, the level at which spontaneous ignition of hair and clothing occurs, with an assumed 100% fatality, and at which initial damage to steel may occur.

4.2.1.2 Bund and Pool Fires

Pool fires, either tank or bund fires, consist of large volumes of a flammable liquid component burning in an open space at atmospheric pressure.

The flammable component will be consumed at the burning rate, depending on factors including prevailing winds. During combustion, heat will be released in the form of thermal radiation. Temperatures close to the flame centre will be high but will reduce rapidly to tolerable temperatures over a relatively short distance. Any building or persons close to the fire or within the intolerable zone will experience burn damage with severity depending on the distance from the fire and time exposed to the heat of the fire.

In the event of a pool fire, the flames will tilt according to the wind speed and direction. The flame length and tilt angle affect the distance of thermal radiation generated.

4.2.1.3 Jet Fires

Jet fires occur when a flammable component is released with a high exit velocity ignites.

In process industries this may be due to design (such as flares) or due to accidental releases. Ejection of a flammable component from a vessel, pipe or pipe flange may give rise to a jet fire and in some instances the jet flame could have substantial ‘reach’.

In modelling jet fires from punctures, the release can be considered to be steady-state. For underground modelling, consequence model considers a vertical jet flame at ground level, with wind tilt created by the current wind velocity. Above ground pipelines are modelled as horizontal releases at the release height.

Depending on wind speed, the flame may tilt and impinge on other pipelines, equipment or structures. The thermal radiation from these fires may cause injury to people or damage equipment some distance away from the source of the flame.

4.2.1.4 Fireball

A fireball occurs with the immediate ignition of a large gas release forming a mushroom-shaped cap that is fed from below by the established part of the fire, lasts typically for up to 30 seconds (depending on pipeline diameter and initial pressure).

4.2.1.5 Flash Fires

A loss of containment of a flammable component may mix with air, forming a flammable mixture. The flammable cloud would be defined by the lower flammable limit (LFL) and the upper flammable limit (UFL). The extent of the flammable cloud would depend on the quantity of the released and mixed component, physical properties of the released component, wind speed and weather stability. An ignition within a flammable cloud can result in an explosion if the front is propagated by pressure. If the front is propagated by heat, then the fire moves across the flammable cloud at the flame velocity and is called a flash fire. Flash fires are characterised by low overpressure, and injuries are caused by thermal radiation. The effects of overpressure due to an exploding cloud are covered in the subsection dealing with vapour cloud explosions (VCEs).

A flash fire would extend to the lower flammable limit; however, due to the formation of pockets, it could extend beyond this limit to the point defined as the ½ LFL. It is assumed that people within the flash fire would experience lethal injuries while people outside of the flash fire would remain unharmed. The ½ LFL is used for emergency planning to evacuate people to a safe distance in the event of a release.

4.2.2 Explosions

The concentration of a flammable component would decrease from the point of release to below the lower explosive limits (LEL), at which concentration the component can no longer ignite. The sudden detonation of an explosive mass would cause overpressures that could result in injury or damage to property.

Such an explosion may give rise to any of the following effects:

- Blast damage;
- Thermal damage;
- Missile damage;
- Ground tremors;
- Crater formation;
- Personal injury.

Obviously, the nature of these effects depends on the pressure waves and the proximity to the actual explosion. Of concern in this investigation are the ‘far distance effects’, such as limited structural damage and the breakage of windows, rather than crater formations.

Table 4-5 and Table 4-6 give a more detailed summary of the damage produced by an explosion due to various overpressures.

CPR 18E (Purple Book; 1999) suggests the following overpressures be determined:

- 0.03 bar overpressure, corresponding to the critical overpressure causing windows to break;
- 0.1 bar overpressure, corresponding to 10% of the houses being severely damaged and a probability of death indoors equal to 0.025:
    - No lethal effects are expected below 0.1 bar overpressure on unprotected people in the open;
- 0.3 bar overpressure, corresponding to structures being severely damaged and 100% fatality for unprotected people in the open;
- 0.7 bar overpressure, corresponding to an almost entire destruction of buildings.

Table 4-5: Summary of consequences of blast overpressure (Clancey 1972)

Pressure (Gauge)		Damage
Psi	**kPa**	
0.02	0.138	Annoying noise (137 dB), if of low frequency (10 – 15 Hz).
0.03	0.207	Occasional breaking of large glass windows already under strain.
0.04	0.276	Loud noise (143 dB); sonic boom glass failure.
0.1	0.69	Breakage of small under strain windows.
0.15	1.035	Typical pressure for glass failure.
0.3	2.07	‘Safe distance’ (probability 0.95; no serious damage beyond this value); missile limit; some damage to house ceilings; 10% window glass broken.
0.4	2.76	Limited minor structural damage.
0.5–1.0	3.45–6.9	Large and small windows usually shattered; occasional damage to window frames.
0.7	4.83	Minor damage to house structures.
1.0	6.9	Partial demolition of houses, made uninhabitable.
1.0–2.0	6.9–13.8	Corrugated asbestos shattered; corrugated steel or aluminium panels, fastenings fail, followed by buckling; wood panels (standard housing) fastenings fail, panels blown in.
1.3	8.97	Steel frame of clad building slightly distorted.
2.0	13.8	Partial collapse of walls and roofs of houses.
2.0–3.0	13.8–20.7	Concrete or cinderblock walls (not reinforced) shattered.
2.3	15.87	Lower limit of serious structural damage.
2.5	17.25	50% destruction of brickwork of house.
3.0	20.7	Heavy machines (1.4 t) in industrial building suffered little damage; steel frame building distorted and pulled away from foundations.
3.0–4.0	20.7–27.6	Frameless, self-framing steel panel building demolished.
4.0	27.6	Cladding of light industrial buildings demolished.
5.0	34.5	Wooden utilities poles (telegraph, etc.) snapped; tall hydraulic press (18 t) in building slightly damaged.
5.0–7.0	34.5–48.3	Nearly complete destruction of houses.
7.0	48.3	Loaded train wagons overturned.
7.0–8.0	48.3–55.2	Brick panels (20 – 30 cm) not reinforced fail by shearing or flexure.
9.0	62.1	Loaded train boxcars completely demolished.
10.0	69.0	Probable total destruction buildings; heavy (3 t) machine tools moved and badly damaged; very heavy (12 000 lb. / 5443 kg) machine tools survived.
300	2070	Limit of crater lip.

Table 4-6: Damage caused by overpressure effects of an explosion (Stephens 1970)

Equipment	Overpressure (psi)																								
	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	12	14	16	18	20
Control house steel roof	A	C	V				N																		
Control house concrete roof	A	E	P	D			N																		
Cooling tower	B			F			O																		
Tank: cone roof		D				K							U												
Instrument cubicle			A			LM						T													
Fire heater				G	I					T															
Reactor: chemical				A				I				P						T							
Filter				H					F									V			T				
Regenerator						I				IP					T										
Tank: floating roof						K							U												D
Reactor: cracking							I							I							T				
Pine supports							P					SO													
Utilities: gas meter									Q																
Utilities: electric transformer									H					I						T					
Electric motor										H								I							V
Blower										Q										T					
Fractionation column											R			T											
Pressure vessel horizontal												PI						T							
Utilities: gas regulator												I								MQ					
Extraction column													I							V	T				
Steam turbine															I						M	S			V
Heat exchanger															I			T							
Tank sphere																I						I	T		
Pressure vessel vertical																					I	T			
Pump																					I		Y		

A	Windows and gauges break
B	Louvers fall at 0.3–0.5 psi
C	Switchgear is damaged from roof collapse
D	Roof collapses
E	Instruments are damaged
F	Inner parts are damaged
G	Bracket cracks
H	Debris-missile damage occurs
I	Unit moves and pipes break
J	Bracing fails
K	Unit uplifts (half filled)
L	Power lines are severed
M	Controls are damaged
N	Block wall fails
O	Frame collapses
P	Frame deforms
Q	Case is damaged
R	Frame cracks
S	Piping breaks
T	Unit overturns or is destroyed
U	Unit uplifts (0.9 filled)
V	Unit moves on foundations

4.2.2.1 Vapour Cloud Explosions (VCEs)

The release of a flammable component into the atmosphere could result in formation of a flash fire, as described in the subsection on flash fires, or a vapour cloud explosion (VCE). In the case of a VCE, an ignited vapour cloud between the higher explosive limits (HEL) and the lower explosive limit (LEL) could form a fireball with overpressures that could result in injury or damage to property.

4.2.2.2 Boiling Liquid Expanding Vapour Explosions (BLEVEs)

A boiling liquid expanding vapour explosion (BLEVE) can occur when a flame impinges on a pressure cylinder, particularly in the vapour space region where cooling by evaporation of the contained material does not occur; the cylinder shell would weaken and rupture with a total loss of the contents, and the issuing mass of material would burn as a massive fireball.

The major consequences of a BLEVE are intense thermal radiation from the fireball, a blast wave and propelled fragments from the shattered vessel. These fragments may be projected to considerable distances. Analyses of the travel range of fragment missiles from a number of BLEVEs suggest that the majority land within 700 m from the incident. A blast wave from a BLEVE is fairly localised but can cause significant damage to immediate equipment.

A BLEVE occurs sometime after the vessel has been engulfed in flames. Should an incident occur that could result in a BLEVE, people should be evacuated to beyond the 1% fatality line.

4.2.3 Scenario Selection

The standard used for the calculation was SANS 1461, which describes that cross-country pipelines must be done to IGEM/TD/2 and PD 8010-3. Furthermore, the SANS 1461 is based on RIVM (2009). The respective event trees represented below were taken from the respective standards. The cross-country pipeline was underground with a vertical release, while the process piping and plant were above ground with a horizontal release.

4.2.3.1 Scenarios for Release of a Pressurised Liquefied Gas

The nature of the release of a liquefied gas from a pressurised vessel is dependent on the position of the hole.

A hole above the liquid level will result in a vapour release only, and the release rate would be related to the size of the hole and internal pressure of the tank. Over a period of time, bulk temperature reduces, with an associated decrease in the vapour release rate.

A hole below the liquid level will result in a release of a liquid stream. In the reduced pressure of the atmosphere, a portion of the liquid will vaporise at the normal boiling point. This phenomenon is called flashing and is shown in Figure 4-1. The pool formed after flashing then evaporates at a rate proportional to the pool area, surrounding temperature and wind velocity.

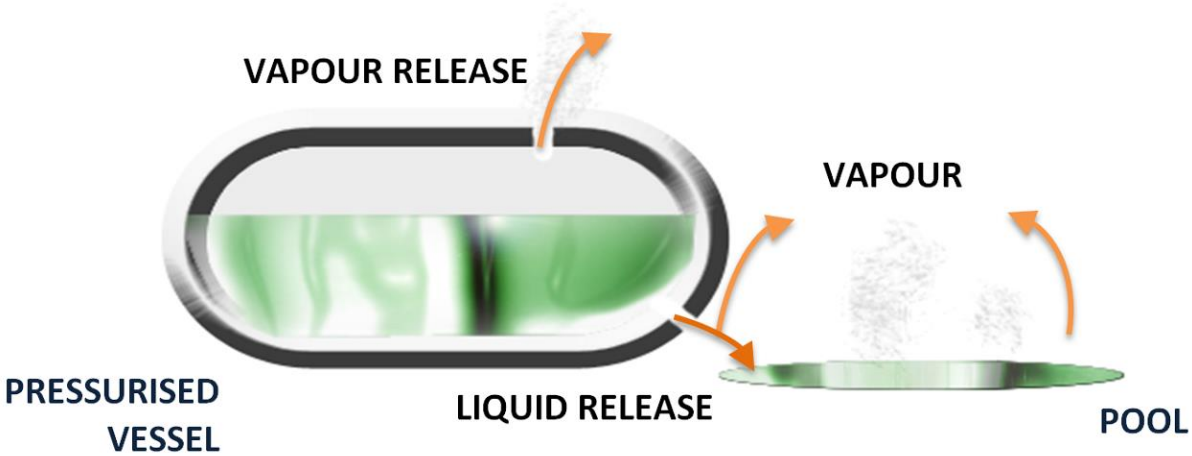


Figure 4-1: Airborne vapours from a loss of containment of liquefied gas stored in a pressurised vessel

4.2.3.2 Instantaneous Release of a Pressured Liquefied Flammable Gas

An instantaneous loss of containment of a liquefied flammable gas could result in the consequences, given in the event tree of Figure 4-2. Probability of the events occurring is dependent on a number of factors and is determined accordingly. All the scenarios shown in the figure are determined separately and reported in relevant subsections of the report.

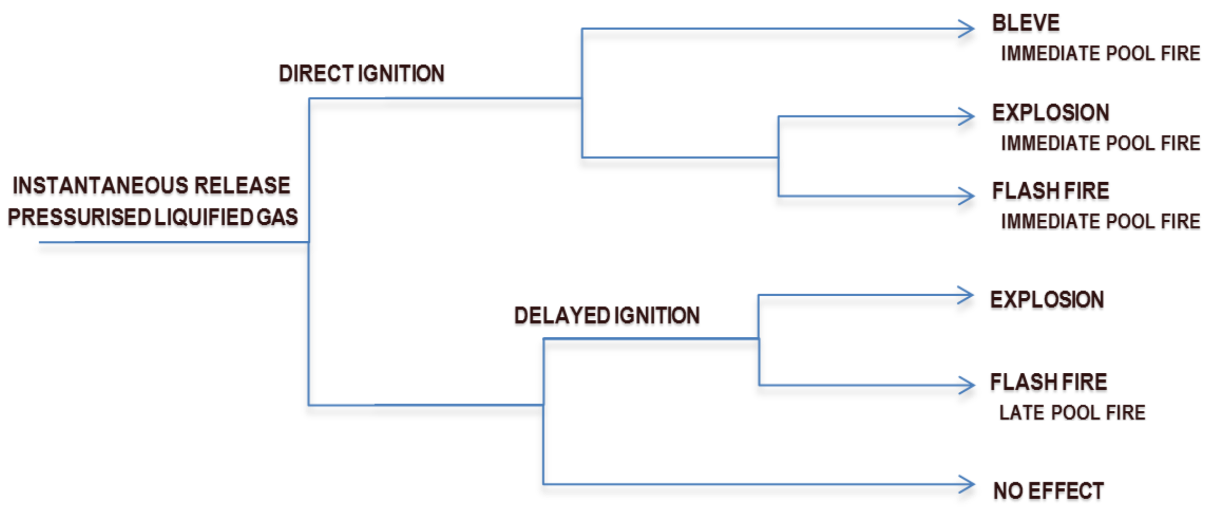


Figure 4-2: Event tree for an instantaneous release of a liquefied flammable gas

4.2.3.3 Continuous Release of a Pressurised Liquefied Flammable Gas

The continuous loss of containment of a liquefied flammable gas could result in the consequences, given in the event tree of Figure 4-3. Probability of the events occurring is dependent on a number of factors and is determined accordingly. All the scenarios shown in the figure are determined separately and reported in relevant subsections of the report.

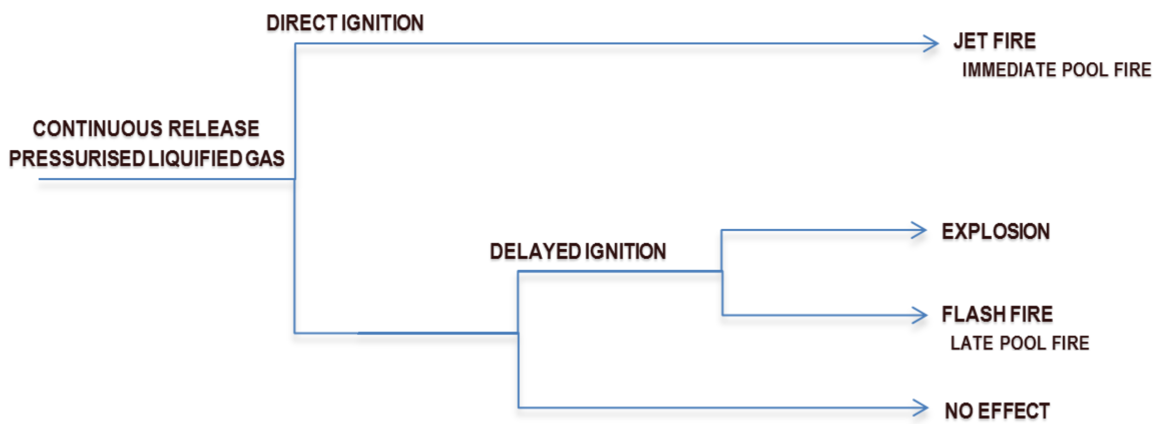


Figure 4-3: Event tree for a continuous release of a liquefied flammable gas

4.2.3.4 Continuous Release of a Flammable Gas

The continuous loss of containment of a flammable gas could result in the consequences, given in the event tree of Figure 4-4. Probability of the events occurring is dependent on a number of factors and is determined accordingly. All the scenarios shown in the figure are determined separately and reported in relevant subsections of the report.

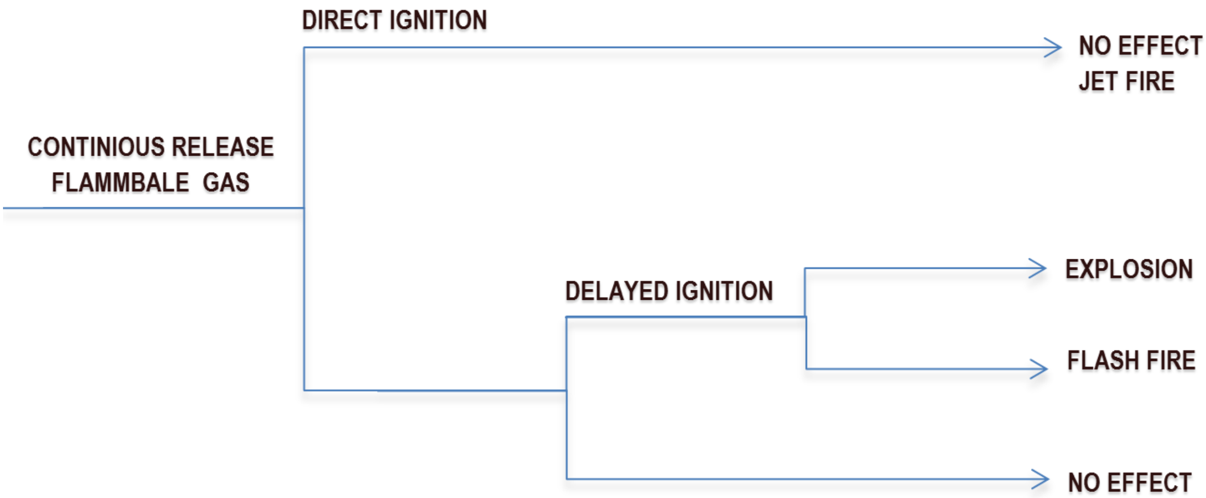


Figure 4-4: Event tree for a continuous release of a flammable gas

4.2.3.5 Continuous Release of a Flammable Liquid

The continuous loss of containment of a flammable liquid could result in the consequences, given in the event tree of Figure 4-5. Probability of the events occurring is dependent on a number of factors and is determined accordingly. All the scenarios shown in the figure are determined separately and reported in relevant subsections of the report.

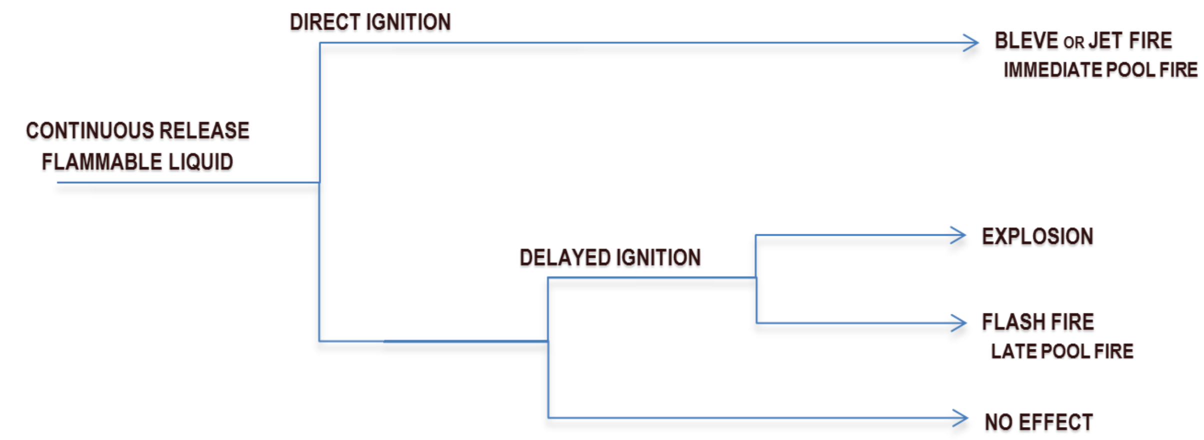


Figure 4-5: Event tree for a continuous release of a flammable liquid

4.3 Risk Analysis

4.3.1 Background

It is important to understand the difference between hazard and risk.

A hazard is anything that has the potential to cause damage to life, property and the environment. Furthermore, it has constant parameters (like those of petrol, chlorine, ammonia, etc.) that pose the same hazard wherever present.

On the other hand, risk is the probability that a hazard will actually cause damage and goes along with how severe that damage will be (consequence). Risk is therefore the probability that a hazard will manifest itself. For instance, the risks of a chemical accident or spill depends upon the amount present, the process the chemical is used in, the design and safety features of its container, the exposure, the prevailing environmental and weather conditions and so on.

Risk analysis consists of a judgement of probability based on local atmospheric conditions, generic failure rates and severity of consequences, based on the best available technological information.

Risks form an inherent part of modern life. Some risks are readily accepted on a day-to-day basis, while certain hazards attract headlines even when the risk is much smaller, particularly in the field of environmental protection and health. For instance, the risk of one-in-ten-thousand chance of death per year associated with driving a car is acceptable to most people, whereas the much lower risks associated with nuclear facilities (one-in-ten-million chance of death per year) are deemed unacceptable.

A report by the British Parliamentary Office of Science and Technology (POST), entitled 'Safety in Numbers? Risk Assessment and Environmental Protection', explains how public perception of risk is influenced by a number of factors in addition to the actual size of the risk. These factors were summarised as follows in Table 4-7.

Table 4-7: Influence of public perception of risk on acceptance of that risk, based on the POST report

Control	People are more willing to accept risks they impose upon themselves or they consider to be 'natural' than to have risks imposed upon them.
Dread and Scale of Impact	Fear is greatest where the consequences of a risk are likely to be catastrophic rather than spread over time.
Familiarity	People appear more willing to accept risks that are familiar rather than new risks.
Timing	Risks seem to be more acceptable if the consequences are immediate or short term, rather than if they are delayed (especially if they might affect future generations).
Social Amplification and Attenuation	Concern can be increased because of media coverage, graphic depiction of events or reduced by economic hardship.
Trust	A key factor is how far the public trusts regulators, policy makers or industry; if these bodies are open and accountable (being honest as well as admitting mistakes and limitations and taking account of differing views without disregarding them as emotive or irrational), then the public is more likely consider them credible.

A risk assessment should be seen as an important component of ongoing preventative action, aimed at minimising or hopefully avoiding accidents. Reassessments of risks should therefore follow at regular intervals and after any changes that could alter the nature of the hazard, so contributing to an overall prevention programme and emergency response plan of the facility. Risks should be ranked with decreasing severity and the top risks reduced to acceptable levels.

Procedures for predictive hazard evaluation have been developed for the analysis of processes when evaluating very low probability accidents with very high consequences (for which there is little or no experience) as well as more likely releases with fewer consequences (for which there may be more information available). These addresses both the probability of an accident as well as the magnitude and nature of undesirable consequences of that accident. Risk is usually defined as some simple function of both the probability and consequence.

4.3.2 Predicted Risk

Physical and consequence modelling addresses the impact of a release of a hazardous component without taking into account probability of occurrence. This merely illustrates the significance and the extent of the impact in the event of a release. Modelling should also analyse cascading or knock-on effects due to incidents in the facility and the surrounding industries and suburbs.

During a risk analysis, the likelihood of various incidents is assessed, the consequences calculated and finally the risk for the facility is determined.

4.3.2.1 Generic Equipment Failure Scenarios

In order to characterise various failure events and assign a failure frequency, fault trees were constructed starting with a final event and working from the top down to define all initiating events and frequencies. Unless otherwise stated, analysis was completed using published failure rate data (RIVM 2009). Equipment failures can occur in tanks, pipelines and other items handling hazardous chemical components. These failures may result in:

- Release of combustible, flammable and explosive components with fires or explosions upon ignition.

4.3.2.2 Storage Vessels

Typical failure frequencies for atmospheric and pressure vessels are listed, respectively, in Table 4-8 and Table 4-9.

Table 4-8: Failure frequencies for atmospheric vessels

Event	Leak Frequency (per item per year)
Small leaks	$1x10^{-4}$
Severe leaks	$3x10^{-5}$
Catastrophic failure	$5x10^{-6}$

Table 4-9: Failure frequencies for pressure vessels

Event	Failure Frequency (per item per year)
Small leaks	$1x10^{-5}$
Severe leaks	$5x10^{-7}$
Catastrophic failure	$5x10^{-7}$

4.3.2.3 Transport and Process Piping

Piping may fail as a result of corrosion, erosion, mechanical impact damage, pressure surge (water hammer) or operation outside the design limitations for pressure and temperature. Failures caused by corrosion and erosion usually result in small leaks, which are easily detected and corrected quickly. For significant failures, the leak duration may be from 10–30 minutes before detection.

Generic data for leak frequency for process piping is generally expressed in terms of the cumulative total failure rate per year for a 10 m section of pipe for each pipe diameter. Furthermore, failure frequency normally decreases with increasing pipe diameter. Scenarios and failure frequencies for a pipeline apply to pipelines with connections, such as flanges, welds and valves.

The failure data given in Table 4-10 represents the total failure rate, incorporating all failures of whatever size and due to all probable causes. These frequencies are based on an assumed environment where no excessive vibration, corrosion, erosion or thermal cyclic stresses are expected. For incidents causing significant leaks (such as corrosion), the failure rate will be increased by a factor of 10.

Table 4-10: Failure frequencies for process pipes

Description	Frequencies of Loss of Containment for Process Pipes (per meter per year)	
	Full Bore Rupture	Leak
Nominal diameter < 75 mm	$1x10^{-6}$	$5x10^{-6}$
75 mm < nominal diameter < 150 mm	$3x10^{-7}$	$2x10^{-6}$
Nominal diameter > 150 mm	$1x10^{-7}$	$5x10^{-7}$

4.3.2.4 Pumps and Compressors

Pumps can be subdivided roughly into two different types, reciprocating pumps and centrifugal pumps. This latter category can be further subdivided into canned pumps (sealless pumps) and gasket (pumps with seals). A canned pump can be defined as an encapsulated pump where the process liquid is located in the space around the rotor (impeller), in which case gaskets are not used.

Compressors can also be subdivided roughly into reciprocating compressors and centrifugal compressors.

Failure rates for pumps and compressors, are given in Table 4-11 and Table 4-12.

Table 4-11: Failure frequency for centrifugal pumps and compressors

Event	Canned (No Gasket) Frequency (per annum)	Gasket Frequency (per annum)
Catastrophic failure	$1.0x10^{-5}$	$1.0x10^{-4}$
Leak (10% diameter)	$5.0x10^{-5}$	$4.4x10^{-3}$

Table 4-12: Failure frequency for reciprocating pumps and compressors

Event	Frequency (per annum)
Catastrophic failure	$1.0x10^{-4}$
Leak (10% diameter)	$4.4x10^{-3}$

4.3.2.5 Loading and Offloading

Loading can take place from a storage vessel to a transport unit (road tanker, tanker wagon or ship) or from a transport unit to a storage vessel. The failure frequencies for loading and offloading arms, are given in Table 4-13.

Table 4-13: Failure frequencies for loading and offloading arms and hoses

Event	Frequency (per hour)	
	Loading and Offloading Arms	Loading and Offloading Hoses
Rupture	$3x10^{-8}$	$4x10^{-6}$
Leak with effective diameter at 10% of nominal diameter to max. 50 mm	$3x10^{-7}$	$4x10^{-5}$

4.3.2.6 Human Failure

Human error and failure can occur during any life cycle or mode of operation of a facility. Human failure can be divided into the following categories:

- Human failure during design, construction and modification of the facility;
- Human failure during operation and maintenance;
- Human failure due to errors of management and administration.

Human failure during design, construction and modification is part of the generic failure given in this subsection. Human failure due to errors of organisation and management are influencing factors. Some of the types of tasks that have been evaluated for their rates of human failure, are given in Table 4-14.

Table 4-14: Human failure rates of specific types of tasks (CPR 12E 2005; Red Book)

Tasks	Human Failure (events per year)
Totally unfamiliar, performed at speed with no real idea of likely consequences.	0.55
Failure to carry out rapid and complex actions to avoid serious incident such as an explosion.	0.5
Complex task requiring high level of comprehension and skill.	0.16
Failure to respond to audible alarm in control room within 10 minutes.	$1.0x10^{-1}$
Failure to respond to audible alarm in quiet control room by some more complex action such as going outside and selecting one correct value among many.	$1.0x10^{-2}$
Failure to respond to audible alarm in quiet control room by pressing a single button.	$1.0x10^{-3}$
Omission or incorrect execution of step in a familiar start-up routine.	$1.0x10^{-3}$
Completing a familiar, well-designed, highly-practiced, routine task occurring several times per hour, performed to highest possible standards by a highly-motivated, highly-trained and experienced person totally aware of implications of failures, with time to correct potential error but without the benefit of significant job aids.	$4.0x10^{-4}$

4.3.2.7 Ignition Probability of Flammable Gases and Liquids

Estimation of probability of an ignition is a key step in assessment of risk for installations where flammable liquids or gases are stored. There is a reasonable amount of data available relating to characteristics of ignition sources and effects of release type and location.

Probability of ignition for stationary installations, is given in Table 4-15 (along with classification of flammable substances in Table 4-16). These can be replaced with ignition probabilities related to surrounding activities. For example, probability of a fire from a flammable release at an open flame would increase to a value of 1.

Table 4-15: Probability of direct ignition for stationary installations (RIVM 2009)

Substance Category	Source-Term Continuous	Source-Term Instantaneous	Probability of Direct Ignition
Category 0 Average to high reactivity	< 10 kg/s 10 – 100 kg/s > 100 kg/s	< 1000 kg 1000 – 10 000 kg > 10 000 kg	0.2 0.5 0.7
Category 0 Low reactivity	< 10 kg/s 10 – 100 kg/s > 100 kg/s	< 1000 kg 1000 – 10 000 kg > 10 000 kg	0.02 0.04 0.09
Category 1	All flow rates	All quantities	0.065
Category 2	All flow rates	All quantities	0.0043[1]
Category 3 Category 4	All flow rates	All quantities	0

Table 4-16: Classification of flammable substances

Substance Category	Description	Limits
Category 0	Extremely flammable	Liquids, substances and preparations that have a flashpoint lower than 0°C and a boiling point (or the start of the boiling range) less than or equal to 35°C Gaseous substances and preparations that may ignite at normal temperature and pressure when exposed to air.
Category 1	Highly flammable	Liquids, substances and preparations that have a flashpoint of below 21°C.
Category 2	Flammable	Liquids, substances and preparations that have a flashpoint equal to 21°C and less than 55°C.
Category 3		Liquids, substances and preparations that have a flashpoint greater than 55°C and less than or equal to 100°C.
Category 4		Liquids, substances and preparations that have a flashpoint greater than 100°C.

1 This value is taken from the CPR 18E (Purple Book; 1999). RIVM (2009) gives the value of delayed ignition as zero. RISCOM (PTY) LTD believes the CPR 18E is more appropriate for warmer climates and is a conservative value.

4.4 Risk Criteria

4.4.1 Maximum Individual Risk Parameter

Standard individual risk parameters include: average individual risk; weighted individual risk; maximum individual risk; and, the fatal accident rate. The lattermost parameter is more applicable to occupational exposures.

Only the maximum individual risk (MIR) parameter will be used in this assessment. For this, parameter frequency of fatality is calculated for an individual who is presumed to be present at a specified location. This parameter (defined as the consequence of an event multiplied by the likelihood of the event) is not dependent on knowledge of populations at risk. So, it is an easier parameter to use in the predictive mode than average individual risk or weighted individual risk. The unit of measure is the risk of fatality per person per year.

4.4.2 Acceptable Risks

The next step, after having characterised a risk and obtained a risk level, is to recommend whether the outcome is acceptable.

In contrast to the employees at a facility, who may be assumed to be healthy, the adopted exposure assessment applies to an average population group that also includes sensitive subpopulations. Sensitive subpopulation groups are those people that for reasons of age or medical condition have a greater than normal response to contaminants. Health guidelines and standards used to establish risk normally incorporate safety factors that address this group.

Among the most difficult tasks of risk characterisation is the definition of acceptable risk. In an attempt to account for risks in a manner similar to those used in everyday life, the UK Health and Safety Executive (HSE) developed the risk ALARP triangle. Applying the triangle involves deciding:

- Whether a risk is so high that something must be done about it;
- Whether the risk is or has been made so small that no further precautions are necessary;
- If a risk falls between these two states so that it has been reduced to levels as low as reasonably practicable (ALARP).

This is illustrated in Figure 4-6.

ALARP stands for ‘as low as reasonably practicable’. As used in the UK, it is the region between that which is intolerable, at $1x10^{-4}$ per year, and that which is broadly acceptable, at $1x10^{-6}$ per year. A further lower level of risk, at $3x10^{-7}$ per year, is applied to either vulnerable or very large populations for land-use planning.

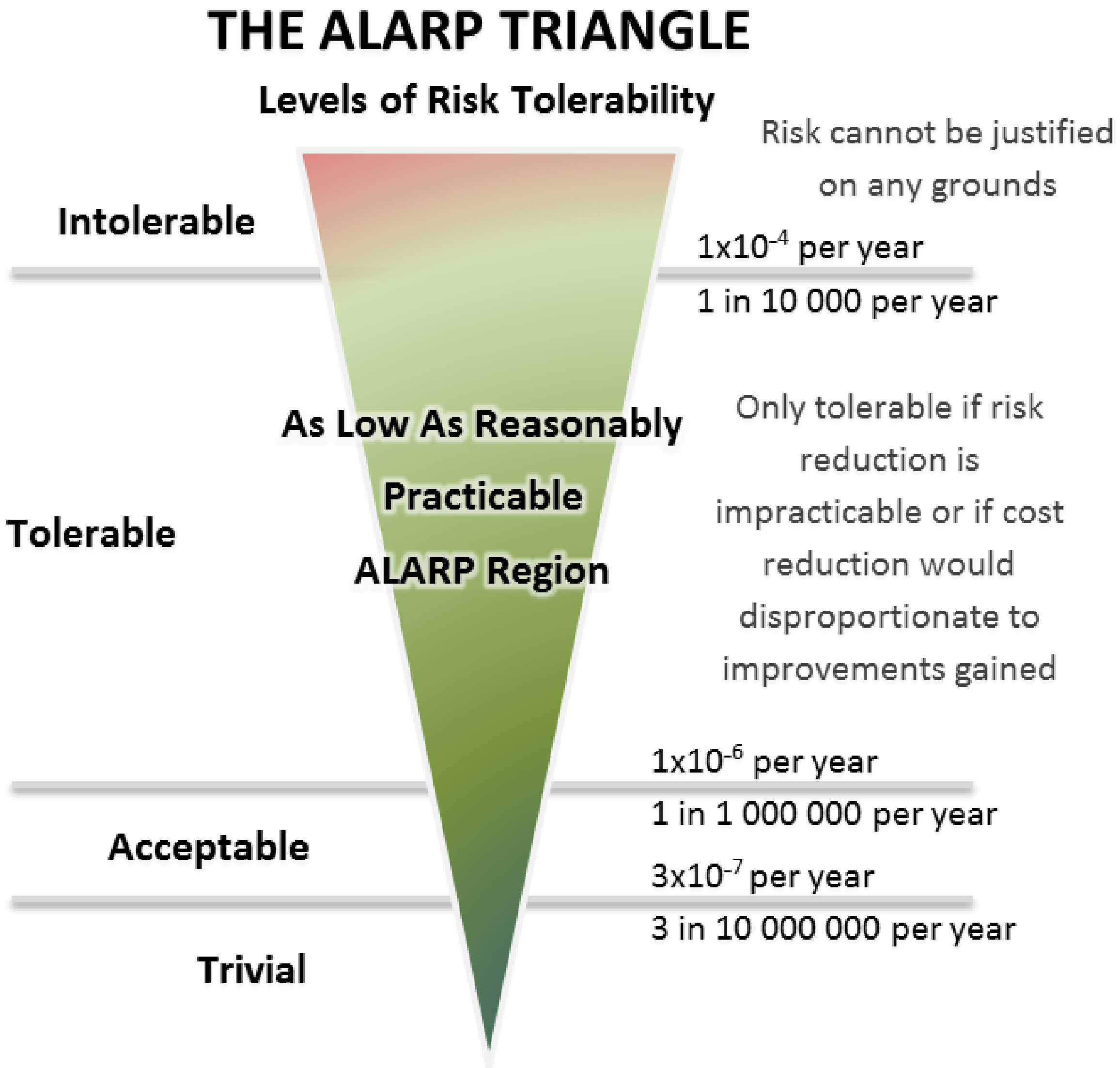


Figure 4-6: UK HSE decision-making framework

It should be emphasised that the risks considered acceptable to employees are different to those considered acceptable to the public. This is due to the fact that employees have personal protection equipment (PPE), are aware of the hazards, are sufficiently mobile to evade or escape the hazards and receive training in preventing injuries.

The HSE (UK) gives more detail on the word practicable in the following statement:

" In essence, making sure a risk has been reduced to ALARP is about weighing the risk against the sacrifice needed to further reduce it. The decision is weighted in favour of health and safety because the presumption is that the duty-holder should implement the risk reduction measure. To avoid having to make this sacrifice, the duty-holder must be able to show that it would be grossly disproportionate to the benefits of risk reduction that would be achieved. Thus, the process is not one of balancing the costs and benefits of measures but, rather, of adopting measures except where they are ruled out because they involve grossly disproportionate sacrifices. Extreme examples might be:

- *To spend £1m to prevent five staff members suffering bruised knees is obviously grossly disproportionate; but,*
- *To spend £1m to prevent a major explosion capable of killing 150 people is obviously proportionate.*

Proving ALARP means that if the risks are lower than $1x10^{-4}$ fatalities per person per year, it can be demonstrated that there would be no more benefit from further mitigation, sometimes using cost benefit analysis. "

4.4.3 Land Planning

SANS 1461 (2018) provides guidelines for land planning criteria This standards is a requirement for completing the MHI risk assessment. Thus, the land planning criteria can only be applied after completion of the MHI risk assessment, under Section 9 of the MHI regulation.

In this study, RISCOM can only suggest land planning approvals, based on the information provided and would require governmental authorities to make final decisions, based on the MHI risk assessment that would be completed after final designs.

Land zoning applied in this study follows the SANS 1461 and HSE (UK) approach of defining the area affected into three zones, consistent to the ALARP approach (HSE 2011).

The three zones are defined as follows:

- The inner zone is enclosed by the risk of $1x10^{-5}$ fatalities per person per year isopleth;
- The middle zone is enclosed by the risk of $1x10^{-5}$ fatalities per person per year and the risk of $1x10^{-6}$ fatalities per person per year isopleths;
- The outer zone is enclosed by the risk $1x10^{-6}$ fatalities per person per year and the risk of $3x10^{-7}$ fatalities per person per year isopleths.

The risks decrease from the inner zone to the outer zone, as shown in Figure 4-7 and Figure 4-8.

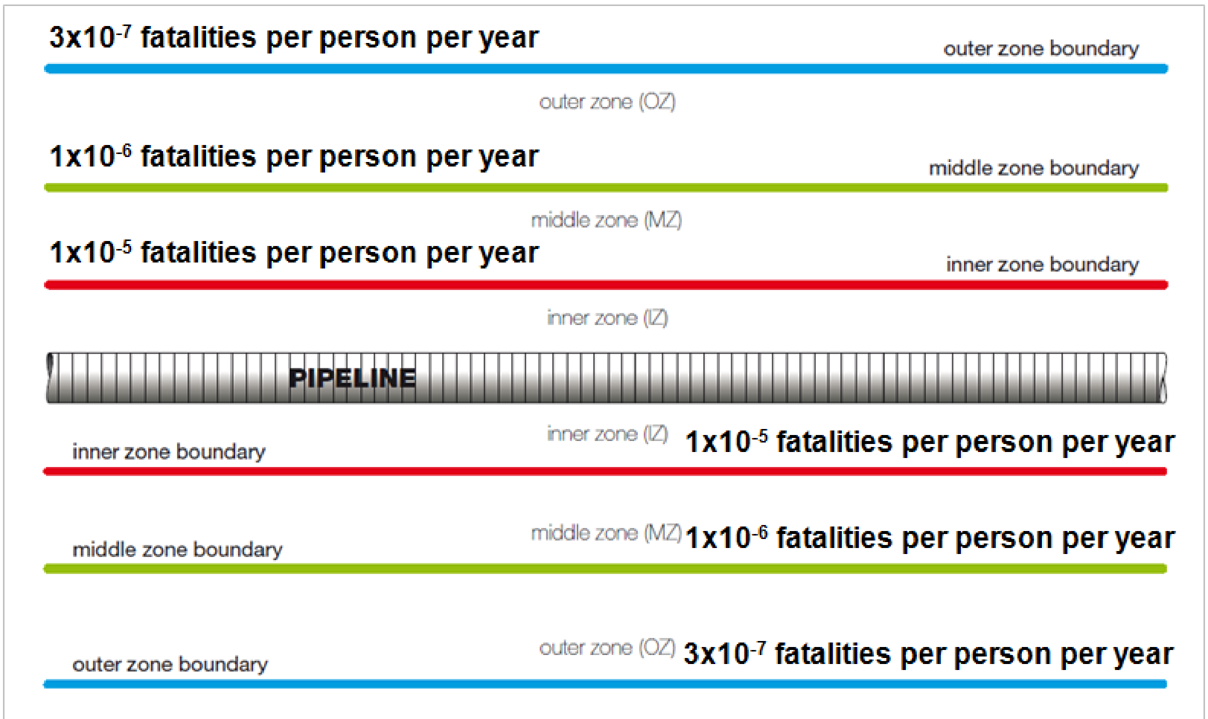


Figure 4-7: Town-planning zones for pipelines

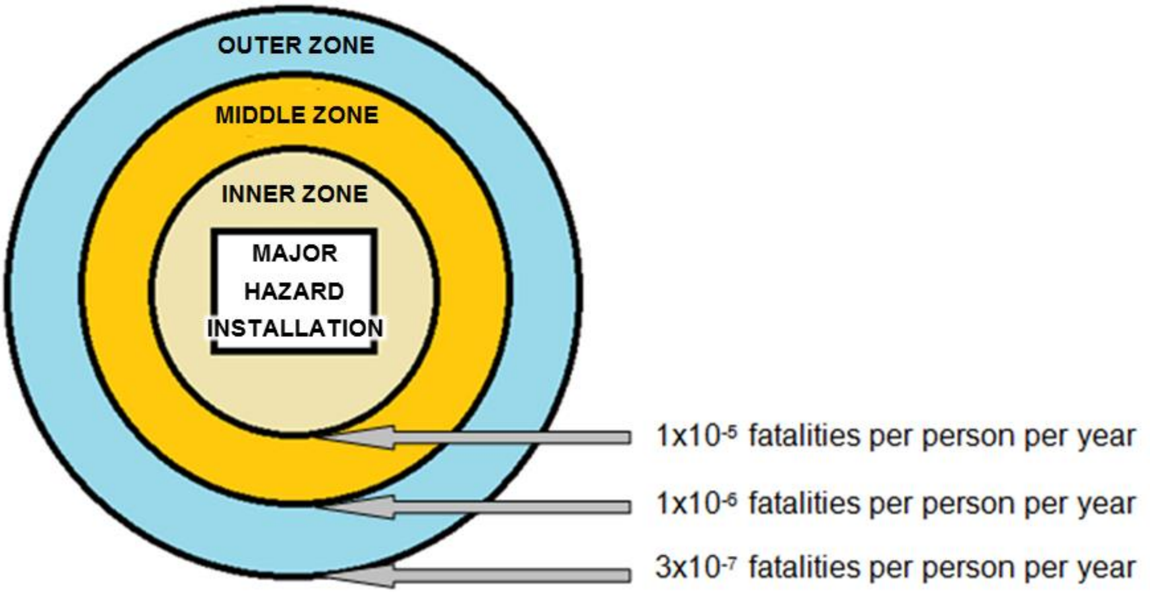


Figure 4-8: Town-planning zones

Once the zones are calculated, the HSE (UK) methodology then determines whether a development in a zone should be categorised as 'advised against' (AA) or as 'don't advise against' (DAA), depending on the sensitivity of the development, as indicated in Table 4-17. There are no land-planning restrictions beyond the outer zone.

Table 4-17: Land-use decision matrix

Level of Sensitivity	Development in Inner Zone	Development in Middle Zone	Development in Outer Zone
1	DAA	DAA	DAA
2	AA	DAA	DAA
3	AA	AA	DAA
4	AA	AA	AA

The sensitivity levels are based on a clear rationale: progressively more severe restrictions are to be imposed as the sensitivity of the proposed development increases.

There are four sensitivity levels, with the sensitivity for housing defined as follows:

- Level 1 is based on workers who have been advised of the hazards and are trained accordingly;
- Level 2 is based on the general public at home and involved in normal activities;
- Level 3 is based on the vulnerability of certain members of the public (e.g., children, those with mobility difficulties or those unable to recognise physical danger);
- Level 4 is based on large examples of Level 2 and of Level 3.

Refer to Appendix D for detailed planning advice for developments near hazardous installations (PADHI) tables. These tables illustrate how the HSE land-use decision matrix, generated using the three zones and the four sensitivity levels, is applied to a variety of development types.

5 RISK ASSESSMENT

Risk assessment was done of each processing unit by firstly selecting a scenario and then completing consequence and outflow modelling. Consequences with possible impacts beyond the site boundary were retained for risk analysis of the unit.

Finally, the risk of the entire facility is determined as a combination of the risk calculated for each unit.

5.1 LPG Installation

5.1.1 The Purpose of the Processing Unit

The LPG installation will consist of a road tanker offloading, for emergency purposes, the LPG storage bullets, LPG vaporisers and pipeline to the respective genset.

The following was assumed in the modelling:

- Maximum of 8 x 620 m^3 LPG storage bullets (Assume length 40 m and diameter 4,5 m) –mounded;
- 3 x 50% product pumps from the LPG bullets to the vaporisers;
- 2 x 100% vaporisers;
- Overfill protection failure rate, 1 in 100 years.

5.1.2 Hazardous Components

LPG is extremely flammable, but not considered toxic. The hazards of LPG are described in more detail in Section 4.1.2.1.

5.1.3 Consequence Modelling

The scenarios modelled for the transport pipeline, are listed in Table 5-1.

Table 5-1: Scenarios modelled

Equipment	Scenarios Modelled	Potential Consequences	Comments
LPG tanker	• Tanker failure • Hose failure • Hose leak	• Jet fire • Flash fires • VCE	• Only on site when delivering LPG • Tanker does not reverse • Safety distances to SANS 10087 • 5 x Offloading bays • Time to offload 1 hour • 44 Tankers per week
Offloading Compressor	• Failure • Leak	• Jet fire • Flash fires • VCE	• Flow rate= 50 m^3/h • Temperature =ambient temperature • Diff head = 4 bar
LPG storage	• Catastrophic failure • Overfill • 10 Minute release • 10 mm Hole	• BLEVE • Pool fire • Jet fire • Flash fires • VCE	• Pressure relief valve • Built to SANS 10087
Product Pump	• Failure • Leak	• Pool fire • Jet fire • Flash fires • VCE	• Flow rate= 30 m^3/h • Temperature =ambient temperature • Diff pressure = 3 bar(g)
Vaporiser	• Catastrophic failure • Single tube failure	• Jet fire • Flash fires • Vapour cloud explosion (VCE)	• Temperature (out) =40ºC • Pressure = 6 bar(g) • Flow rate = same as product pump

5.1.3.1 LPG Offloading Gantry

The LPG tanks will be delivered to site in road tankers of approximately 30 m^3 each and offloaded at the 5-bay road gantry. The offloading will be done by compressing vapours from the LPG storage and forcing the LPG from the road tankers to the storage vessels.

The maximum extent to the 1% fatality will occur from a catastrophic failure of a 30 m^3 road tanker at low wind speeds, as shown in Figure 5-1. The maximum radius for the spilt LPG was calculated at 6 m immediately after the release, but reduced rapidly over time. The coloured lines show the maximum extent of the potential effects from a westerly wind direction, while the orange curve indicates the maximum extent from all wind directions.

In this case, the BLEVE dominates the impacts and determines the maximum extent to the 1% fatality. The VCE overpressure for the 1% fatality is equal to 0.1 bar overpressure, that would result in damage to the engine room, as well of the nearby PV panels and extend beyond the site boundary to the west.

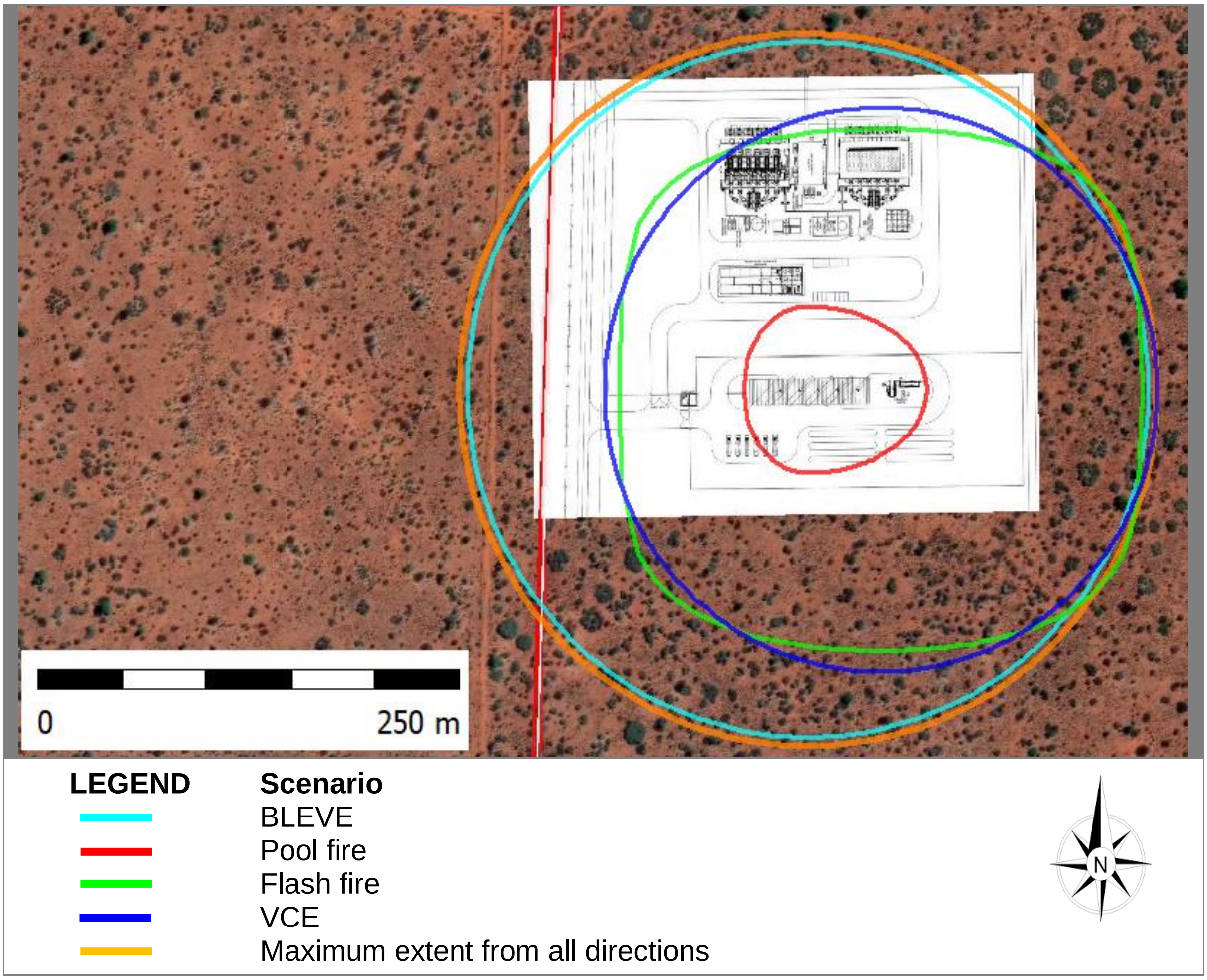


Figure 5-1: The maximum extent to the 1% fatality from a catastrophic failure of a 30 m^3 road tanker

5.1.3.2 LPG Storage

The LPG will be received from the neighbouring property and stored in a maximum of 8 x 620 m^3 mounded bullets as a saturated liquefied gas at ambient temperature.

The maximum extent to the 1% fatality will occur from a release of the entire contents of a 620 m^3 LPG storage tank over 10 minutes, as shown in Figure 5-2. The coloured lines show the maximum extent of the potential effects from a westerly wind direction, while the orange curve indicates the maximum extent from all wind directions.

In this case, the flash fires and vapour cloud explosions dominate the impacts and determines the maximum extent to the 1% fatality. People in the open within the flash fire, are assumed to suffer fatal injuries. The VCE overpressure for the 1% fatality is equal to 0.1 bar overpressure, that would result in mild damage to the neighbouring property, including damage to walls and roof.

The maximum extent of the 1% fatality could extend beyond the site boundary to the west. As the surrounding areas are undeveloped, the impacts from a large loss of containment of an LPG bullet would not reach the residential areas.

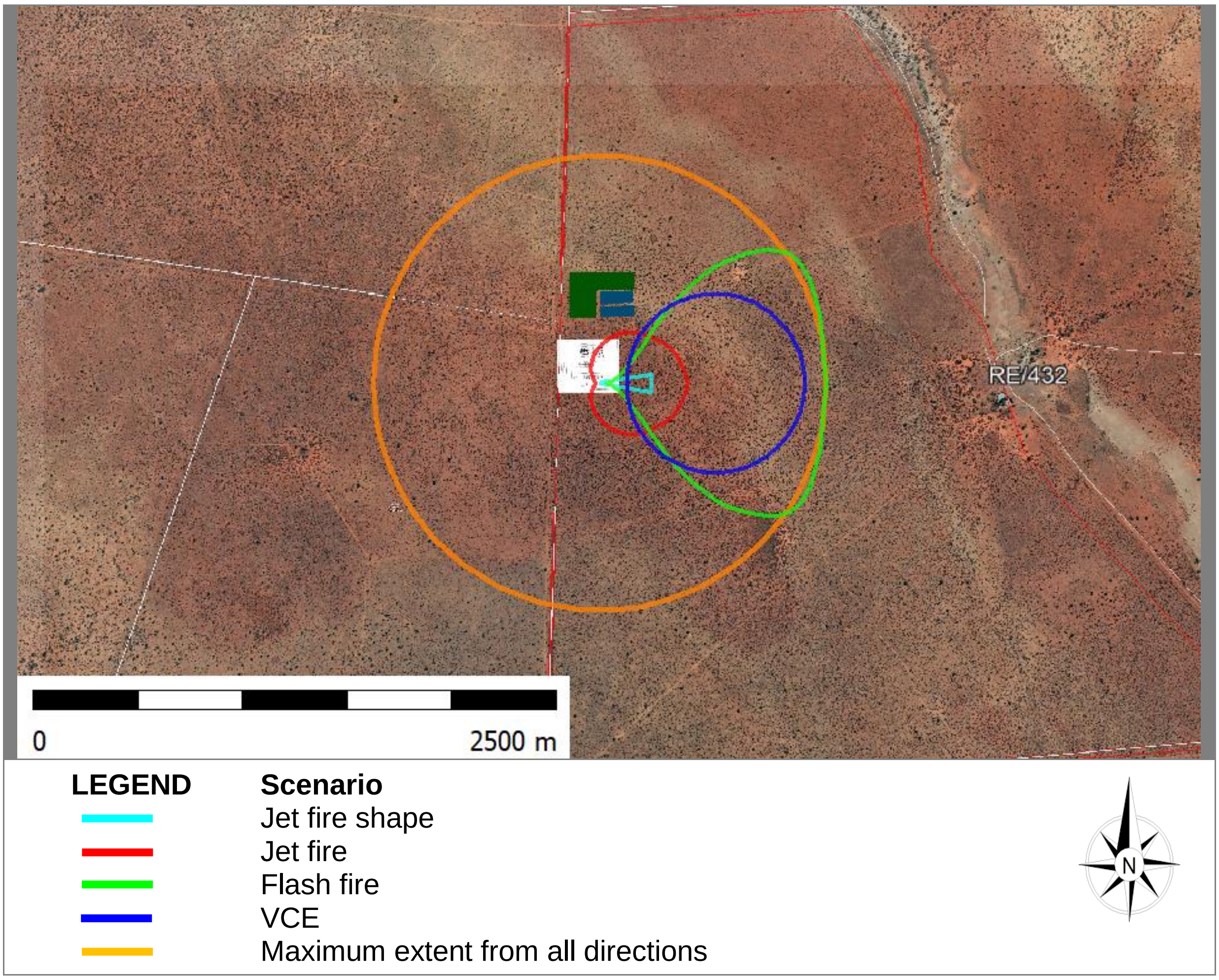


Figure 5-2: The maximum extent to the 1% fatality from the loss of containment LPG storage tank over a 10-minute period

5.1.3.3 LPG Product Pumps

The LPG from the storage bullets will be transported to the vaporisers and subsequently to the gensets via the products. A large failure of the product pump, e.g., pump casing failure will result in an outlet flow from the storage vessel at the flow rate determined by the outlet pipeline. Material will continue to flow, until stopped or the vessel has been emptied.

Figure 5-3 shows the maximum extent from the failure of the product pumps to the 1% fatality. The coloured lines show the maximum extent of the potential effects from a release in a single direction, while the orange curve indicates the maximum extent from all wind directions.

In this case, the jet fire impacts and determines the maximum extent to the 1% fatality. People in the open within the flash fire, are assumed to suffer fatal injuries. The VCE overpressure for the 1% fatality is equal to 0.1 bar overpressure, that would result in mild damage to the neighbouring property, including damage to walls and the roof.

The impacts from a large release from the product pump could extend a short distance beyond the site boundary to the west, without impacting residential areas or areas of vulnerable populations.

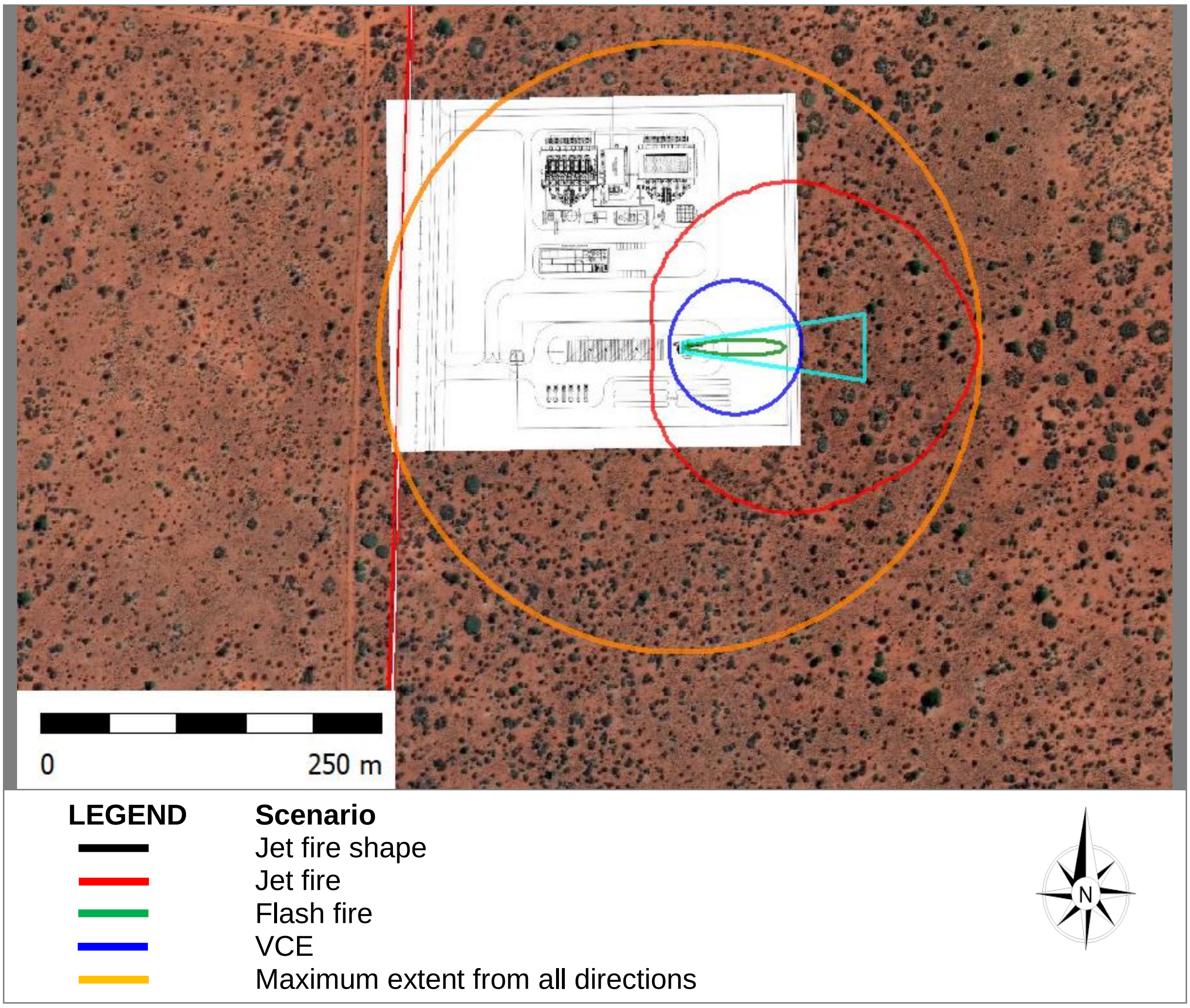


Figure 5-3: The maximum extent to the 1% fatality from the product pump failure

5.1.3.4 LPG Vaporisers

The vaporisers would be a water bath type, hereby the LPG will be vapourised into a gas phase and would exit at approximately 40ºC.

The maximum extent to the 1% fatality will occur from a catastrophic failure of a single vaporiser, as shown in Figure 5-4. The release would be in the vertical orientation. The coloured lines show the maximum extent of the potential effects from a westerly wind direction, while the orange curve indicates the maximum extent from all wind directions.

The maximum extent of the 1% fatality would not extend beyond the site boundary and no further action would be required.

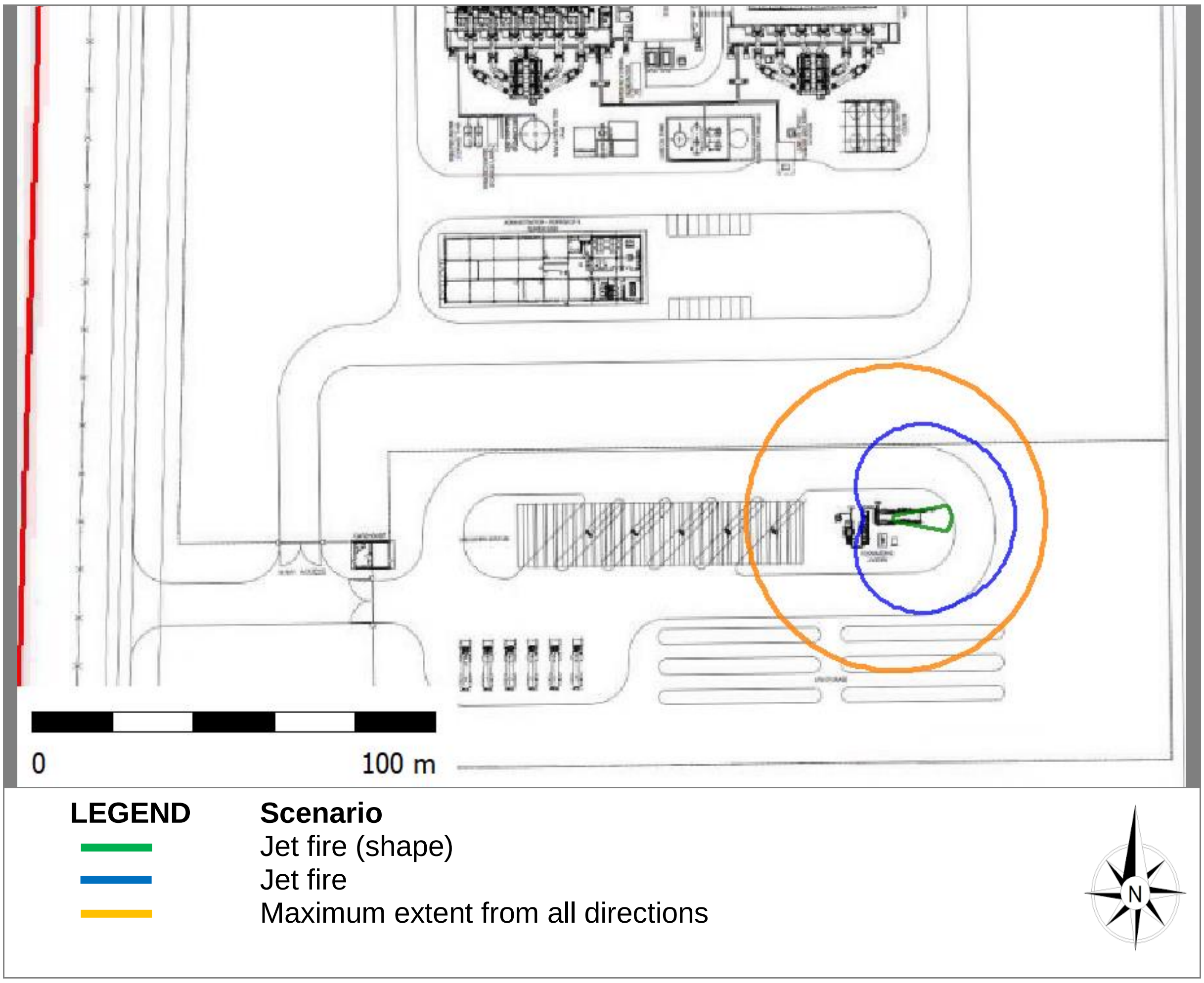


Figure 5-4: The maximum extent to the 1% fatality from a catastrophic failure of a vaporiser

5.1.3.5 Summary of Impacts

Maximum distances from the point of release to the 1% fatality, are summarised for each scenario in Table 5-2.

Table 5-2: Maximum distance to 1% fatality from the point of release

Scenarios	Max. Distance to 1% Fatality (m)
LPG Storage Bullets	
LPG Bullet - 10 mm Hole	37
LPG Bullet - Fixed duration	1115
LPG Bullet - PSV failure	39
LPG Bullet - Catastrophic failure	788
LPG Bullet - Overfill	Impacts on mound
Product Pump	
Product pump - Failure	219
Product pump- Leak	50
Vaporiser	
Vaporiser tube- Failure	11
Vaporiser Vessel failure	37
Offloading Compressor	
Offloading Compressor - Failure	100
Offloading Compressor -Leak	12
LPG Offloading Pipeline	
Pipeline - Failure	87
Pipeline Leak	
LPG Pipeline – Storage to Product Pumps	
Pipeline - Failure	
Pipeline Leak	74
	50
LPG Pipeline -Vaporiser to Power Plant	
Pipeline - Failure	116
Pipeline Leak	0

5.1.4 Maximum Individual Risk

The LPG installation consists of the LPG road tanker offloading, LPG storage, vaporisers pumps and pipelines.

The risk of $1x10^{-6}$ fatalities per person per year isopleth, due to a release of flammable LPG, extends beyond the site boundary to the west, as shown in Figure 5-5. As a result, the Hyperion facility would be within the ALARP range and alone **would be classified as a Major Hazard Installation** due to the risks imposed. The risk from fires and explosions from the LPG installation on site would be considered tolerable.

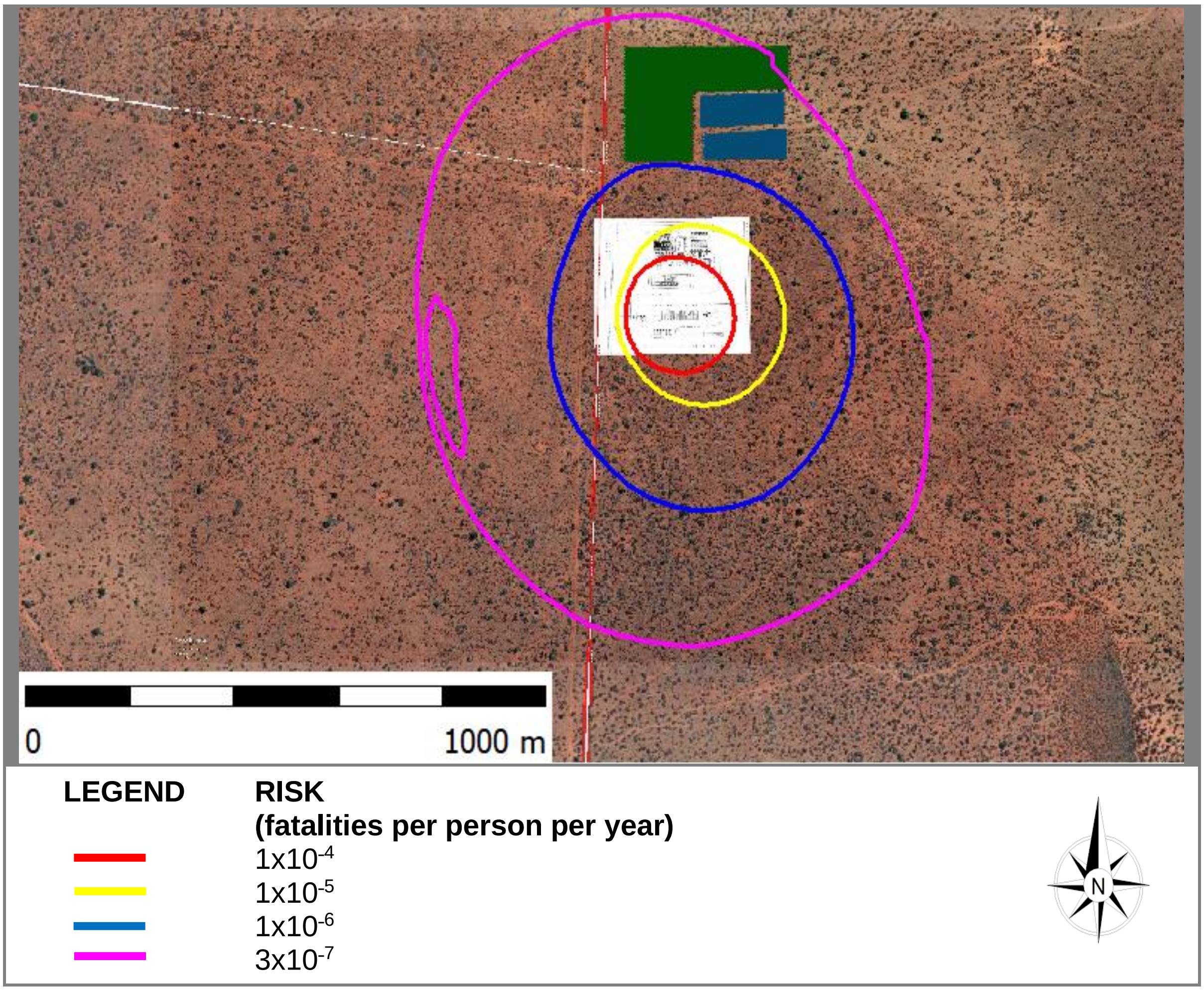


Figure 5-5: Lethal probability isopleth associated with the LPG installation at the Hyperion facility at Kathu

Risks greater than $1x10^{-4}$ fatalities per person per year are considered tolerable for industrial areas but excessive for residential areas, and will not extend beyond the Hyperion site boundary.

The risk of $3x10^{-7}$ fatalities per person per year isopleth indicates the extent for land-use that would be suitable for vulnerable populations, such as hospitals, retirement homes, nursery schools, prisons, large gatherings in the open, and so forth, extends a short distance beyond the site boundary and did not impact any vulnerable populations

No new land planning should be approved without consultation of the PADHI land-planning tables attached in Appendix D.

5.1.5 Risk Ranking

This risk assessment considered numerous scenarios determining both consequences and a probability of release. Some scenarios have more serious consequences than others. However, the scenarios of particular interest are those with high-risk frequencies extending beyond the boundary of the site.

Figure 5-6 illustrates the comparison of the 1×10^{-6} fatalities per person per year isopleth for the various site installations. The blue curve represents the total site risk, while the other installations are shown in other colours. The combined site risks are identical to the storage risks.

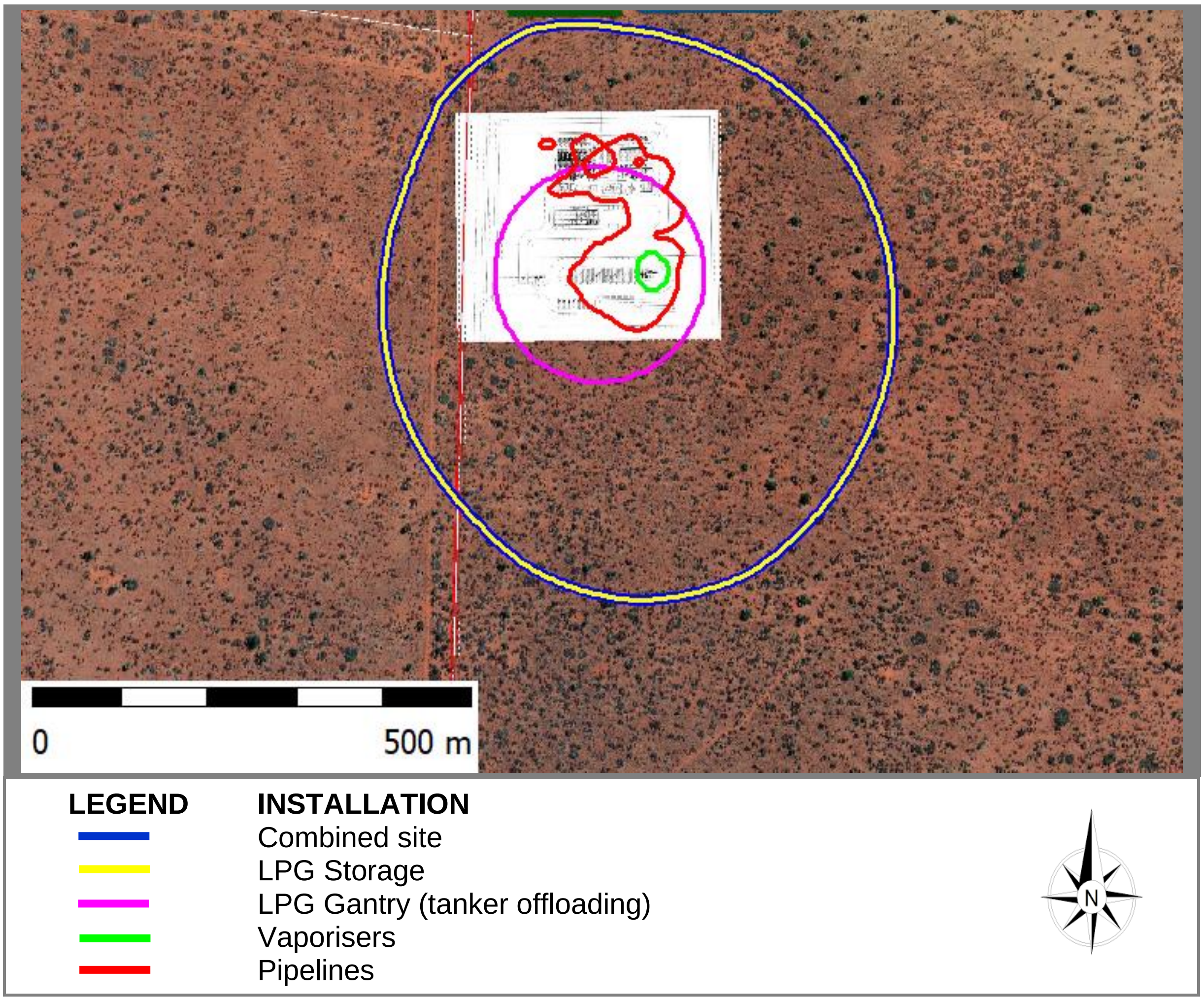


Figure 5-6: Comparison of the 1×10^{-6} fatalities per person per year isopleth for various site installations

6 IMPACT ASSESSMENT

6.1 Impact Assessment Methodology

As described in the terms of reference of the project, assessment of the Impacts of the loss of containment scenarios considered in this study took cognisance of the following aspects as they related to local population:

- An assessment of the magnitude of the impacts (the consequences of the project on members of the surrounding public);
- An assessment of the significance of the impacts, taking into account the sensitivity of the receptors;
- Development of mitigation measures to avoid, reduce or manage the impacts; and,
- Assessment of the residual significant impacts after applying the mitigation measures.

The criteria that were used in impact assessment are summarised below (verbatim from the terms of reference document):

- The **nature,** which shall include a description of what causes the effect, what will be affected and how it will be affected.
- The **extent**, wherein it will be indicated whether the impact will be local (limited to the immediate area or site of development) or regional, and a value between 1 and 5 will be assigned as appropriate (with 1 being low and 5 being high).
- The **duration**, wherein it will be indicated whether:
  - the lifetime of the impact will be of a very short duration (0–1 years) – assigned a score of 1;
  - the lifetime of the impact will be of a short duration (2-5 years) - assigned a score of 2;
  - medium-term (5–15 years) – assigned a score of 3;
  - long term (> 15 years) - assigned a score of 4; or
  - permanent - assigned a score of 5.
- The **magnitude**, quantified on a scale from 0-10, where a score is assigned:
  - 0 is small and will have no effect on the environment;
  - 2 is minor and will not result in an impact on processes;
  - 4 is low and will cause a slight impact on processes;
  - 6 is moderate and will result in processes continuing but in a modified way;
  - 8 is high (processes are altered to the extent that they temporarily cease);
  - 10 is very high and results in complete destruction of patterns and permanent cessation of processes.
- The **probability of occurrence**, which shall describe the likelihood of the impact actually occurring. Probability will be estimated on a scale of 1–5, where:
  - 1 is very improbable (probably will not happen),
  - 2 is improbable (some possibility, but low likelihood), 3 is probable (distinct possibility), 4 is highly probable (most likely); and,
  - 5 is definite (impact will occur regardless of any prevention measures).
- The **significance**, which shall be determined through a synthesis of the characteristics described above and can be assessed as low, medium or high; and,

- the **status**, which will be described as either positive, negative or neutral.
  - the degree to which the impact can be reversed.
  - the degree to which the impact may cause irreplaceable loss of resources.
  - the degree to which the impact can be mitigated.

The significance is calculated by combining the criteria in the following formula:

S = (E+D+M) P

S = Significance weighting
E = Extent
D = Duration
M =Magnitude
P = Probability

The significance weightings for each potential impact are as follows:

- < 30 points: Low (i.e., where this impact would not have a direct influence on the decision to develop in the area),
- 30-60 points: Medium (i.e., where the impact could influence the decision to develop in the area unless it is effectively mitigated),
- > 60 points: High (i.e., where the impact must have an influence on the decision process to develop in the area).

6.2 Methodology - Cumulative Impacts

“Cumulative Impact”, in relation to an activity, means the past, current and reasonably foreseeable future impact of an activity, considered together with the impact of activities associated with that activity, that in itself may not be significant, but may become significant when added to existing and reasonably foreseeable impacts eventuating from similar or diverse activities.

The role of the cumulative assessment is to test if such impacts are relevant to the proposed project in the proposed location (i.e., whether the addition of the proposed project in the area will increase the impact).

This section addresses whether the construction of the proposed development will result in:

- Unacceptable risk;
- Unacceptable loss;
- Complete or whole-scale changes to the environment or sense of place;
- Unacceptable increase in impact.

6.3 Impact Assessment of Hyperion thermal generation facility at Kathu

6.3.1 LPG Installations

The following is the impact assessment of the LPG installations:

Table 6-1: Impact Assessment of LPG Installations

Nature:

Worst case loss of containment scenario – catastrophic rupture of LPG storage vessel leading to a fireball event, flammable vapour dispersion and ignition leading to flash fire thermal radiation effects and/or vapour cloud explosion overpressure effects.

	Without Mitigation	**With Mitigation**
Extent	Low (2)	Low (1)
Duration	Very short (1)	Very short (1)
Magnitude	High (8)	High (6)
Probability	Very improbable (1)	Very improbable (1)
Significance	Low (11)	Low (11)
Status (positive or negative)	Negative	Negative
Reversibility	Irreversible	Irreversible
Irreplaceable loss of resources?	Yes (human)	Yes (human)
Can impacts be mitigated?	Yes	Yes

Mitigation:

Mitigation would include emergency response arrangements and systems, such as alarms to allow for personnel to muster in case of emergency, as well as fire-fighting systems and cooperation with emergency responders. Preventive measures could include maintenance procedures to prevent the occurrence of a catastrophic loss of containment from corrosion, fire and gas detection, and firewater systems to prevent escalation as well as strict control of ignition sources and other measures which may be required according to standards, such as those prescribed by the South African National Standards system.

Residual Risks:

Even with mitigation, there may be residual risk of occurrence due to failures in protection systems such as failure of ESD, instrumentation, firefighting and break-down in procedures and documented systems.

6.4 Cumulative Impact Assessment

This section considers all impacts in the preceding Section 6.3 and the cumulative impact of all installations.

The cumulative project risks and the LPG storage risk are identical, as given in Section 5.1.4, and thus the cumulative impact will be identical to the LPG storage.

Table 6-2: Cumulative impact of project as a whole

Nature:

Potential impact on surrounding human populations, including possibility of serious injury or death as a result of major industrial accidents from hazardous materials used on-site.

	Overall impact of the proposed project in isolation	**Cumulative impact of the project and other projects in the area**
Extent	Low (2)	Low (1)
Duration	Very short (1)	Very short (1)
Magnitude	High (8)	High (6)
Probability	Very improbable (1)	Very improbable (1)
Significance	Low (11)	Low (11)
Status (positive or negative)	Negative	Negative
Reversibility	Irreversible (worst case: death)	Irreversible (worst case: death)
Irreplaceable loss of resources?	Yes (human)	Yes (human)
Can impacts be mitigated?	Yes	Yes

Confidence in findings:

Medium to High (more process detail required to increase confidence).

Mitigation:

Mitigation would include emergency response arrangements and systems, such as alarms to allow for personnel to muster in case of emergency, as well as fire-fighting systems and cooperation with emergency responders. Preventive measures could include maintenance procedures to prevent the occurrence of a catastrophic loss of containment from corrosion, fire and gas detection and firewater systems to prevent escalation, as well as strict control of ignition sources and other measures, which may be required according to standards such as those prescribed by the South African National Standards system.

Residual Risks:

Even with mitigation, there is still possibility of human death as a result of major incidents on-site due to the nature of operations.

7 CONCLUSIONS

Risk calculations are not precise. Accuracy of predictions is determined by the quality of base data and expert judgements.

This risk assessment included the consequences of fires and explosions at the Hyperion facility in Kathu. A number of well-known sources of incident data were consulted and applied to determine the likelihood of an incident to occur.

This risk assessment was performed with the assumption that the site would be maintained to an acceptable level and that all statutory regulations would be applied. It was also assumed that the detailed engineering designs would be done by competent people, and would be correctly specified for the intended duty. For example, it was assumed that tank wall thicknesses have been correctly calculated, that vents have been sized for emergency conditions, that instrumentation and electrical components comply with the specified electrical area classification, that material of construction is compatible with the products, etc.

It is the responsibility of the owners and their contractors to ensure that all engineering designs would have been completed by competent persons and that all pieces of equipment would have been installed correctly. All designs should be in full compliance with (but not limited to) the Occupational Health and Safety Act 85 of 1993 and its regulations, the National Buildings Regulations and the Buildings Standards Act 107 of 1977 as well as local bylaws.

A number of incident scenarios were simulated, taking into account the prevailing meteorological conditions, and described in the report.

7.1 Notifiable Substances

The General Machinery Regulation 8 and its Schedule A on notifiable substances, requires any employer who has a substance equal to or exceeding the quantity listed in the regulation to notify the divisional director. A site is classified as a Major Hazard Installation if it contains one or more notifiable substances, or if the off-site risk is sufficiently high. The latter can only be determined from a quantitative risk assessment.

The notifiable threshold for LPG is listed 25 t in a single vessel. As the proposed installation exceeds the threshold limit, LPG will be classified as a notifiable substance, which would automatically **classify the facility a Major Hazard Installation**.

7.2 LPG Storage and Associated Equipment

LPG would be received from the adjacent facility via a pipeline and stored in a maximum 8 x 300 t storage vessels. The LPG would be vaporised in a vapour phase and sent to the gensets as fuel.

Depending on the physical conditions of the LPG, a large release could result in pool fires, jet fires, flash fires and vapour cloud explosions. The BLEVE consequence was prevented from occurring, because of the mounding of the vessels. All of the aforementioned effects were simulated with the largest downwind distance occurring from a large release from a LPG vessel, extending up to 1.1 km to the 1% fatality from the point of release and could impact surround areas, but would not reach the occupied residential areas.

The risk of $1x10^{-6}$ fatalities per person per year isopleth found to extend beyond the site boundary, and **that alone qualifies the site as a Major Hazard Installation**. The risk was $1x10^{-4}$ fatalities per person per year representing intolerable to the general public, did not reach the site boundary. Thus, the risks to the public would be within the ALARP range and considered tolerable.

7.3 Impacts onto Neighbouring Properties, Residential Areas and Major Hazard Installations

Most of the surrounding land has not been developed, and thus limited impacts would be experienced from a large release of LPG, within these areas. Impacts into the residential areas, recreational areas, hotels, schools, hospitals and other places of the general would not be expected.

Mitigation must be provided to stop any outflow of LPG from the tanks in the event of pipelines, pumps, etc and exacerbate the impacts from an additional LPG release.

No neighbouring property to Hyperion is classified as a Major Hazardous Installation, thus no knock-on effects from a major incident at the Hyperion power generation facility will be expected.

7.4 Major Hazard Installation

This investigation was done under the National Environmental Management Act (No. 107 of 1998) (NEMA) and its Regulations. This study concluded that under the current design conditions, the proposed Hyperion facility in Kathu **would be considered as a Major Hazard Installation** and would trigger the statutory requirement of completing a MHI risk assessment under the Occupational Health and Safety Act No. 85 of 1993, prior to construction.

The MHI is a regulated process that requires specific information to be included in the study, after completion of the final designs and prior to construction. As such, **this study is not intended to replace the Major Hazard Installation risk assessment which should be completed prior to construction of the terminal**.

7.5 Land Planning Restrictions

The risks generated from this study, concluded that the risk isopleths generated from the proposed project could have risks within the ALARP range, resulting in land planning restrictions. As the designs have not been finalised, the full land planning restrictions must be taken from the Major Hazard Installation risk assessment report.

8 RECOMMENDATIONS

As a result of the risk assessment study conducted for the proposed Hyperion facility in Kathu, a number of events were found to have risks beyond the site boundary. These risks could be mitigated to acceptable levels.

RISCOM did not find any fatal flaws that would prevent the project proceeding to the detailed engineering phase of the project.

RISCOM would support the project with the following conditions:

- Compliance with all statutory requirements, i.e., pressure vessel designs;
- Compliance with applicable SANS codes, i.e., SANS 10087, SANS 10089, SANS 10108, etc.;
- Incorporation of applicable guidelines or equivalent international recognised codes of good design and practice into the designs;
- Completion of a recognised process hazard analysis (such as a HAZOP study, FMEA, etc.) on the proposed facility prior to construction to ensure design and operational hazards have been identified and adequate mitigation put in place;
- Full compliance with IEC 61508 and IEC 61511 (Safety Instrument Systems) standards or equivalent to ensure that adequate protective instrumentation is included in the design and would remain valid for the full life cycle of the tank farm:
    - Including demonstration from the designer that sufficient and reliable instrumentation would be specified and installed at the facility;
- Preparation and issue of a safety document detailing safety and design features reducing the impacts from fires, explosions and flammable atmospheres to the MHI assessment body at the time of the MHI assessment:
    - Including compliance to statutory laws, applicable codes and standards and world's best practice;
    - Including the listing of statutory and non-statutory inspections, giving frequency of inspections;
    - Including the auditing of the built facility against the safety document;
    - Noting that codes such as IEC 61511 can be used to achieve these requirements;
- Demonstration by Hyperion or their contractor that the final designs would reduce the risks posed by the installation to internationally acceptable guidelines;
- Signature of all terminal designs by a professional engineer registered in South Africa in accordance with the Professional Engineers Act, who takes responsibility for suitable designs;
- Completion of an emergency preparedness and response document for on-site and off-site scenarios prior to initiating the MHI risk assessment (with input from local authorities);
- Permission not being granted for increases to the product list or product inventories without redoing part of or the full EIA;
- Final acceptance of the facility risks with an MHI risk assessment that must be completed in accordance to the MHI regulations:
    - Basing such a risk assessment on the final design and including engineering mitigation.

9 REFERENCES

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10 ABBREVIATIONS AND ACRONYMS

AA	“Advised Against” used in land planning decisions
AIA	See **Approved Inspection Authority**
ALARP	The UK Health and Safety Executive (HSE) developed the risk **ALARP** triangle, in an attempt to account for risks in a manner similar to those used in everyday life. This involved deciding: • Whether a risk is so high that something must be done about it; • Whether the risk is or has been made so small that no further precautions are necessary; • Whether a risk falls between these two states and has been reduced to levels ‘**as low as reasonably practicable’** (ALARP). Reasonable practicability involves weighing a risk against the trouble, time and money needed to control it.
Approved Inspection Authority	An **approved inspection authority** (AIA) is defined in the Major Hazard Installation regulations (July 2001)
Asphyxiant	An **asphyxiant** is a gas that is nontoxic but may be fatal if it accumulates in a confined space and is breathed at high concentrations since it replaces oxygen containing air.
Blast Overpressure	**Blast overpressure** is a measure used in the multi-energy method to indicate the strength of the blast, indicated by a number ranging from 1 (for very low strengths) up to 10 (for detonative strength).
BLEVE	**Boiling liquid expanding vapour explosions** result from the sudden failure of a vessel containing liquid at a temperature above its boiling point. A **BLEVE** of flammables results in a large fireball.
DAA	“Don’t Advise Against” used in land planning decisions
Detonation	**Detonation** is a release of energy caused by extremely rapid chemical reaction of a substance, in which the reaction front of a substance is determined by compression beyond the auto-ignition temperature.
DoE	The **Department of Energy** is the department of the South African government responsible for energy policy. It was established in 2009 when the former Department of Minerals and Energy was divided into the Department of Energy and the Department of Mineral Resources.
EIA	**Environmental assessment** is the assessment of the environmental consequences of a plan, policy, program, or actual projects prior to the decision to move forward with the proposed action.
Emergency Plan	An **emergency plan** is a plan in writing that describes how potential incidents identified at the installation together with their consequences should be dealt with, both on site and off site.
Explosion	An **explosion** is a release of energy that causes a pressure discontinuity or blast wave.
Flammable Limits	**Flammable limits** are a range of gas or vapour concentrations in the air that will burn or explode if a flame or other ignition source is present. The lower point of the range is called the lower flammable limit (LFL). Likewise, the upper point of the range is called the upper flammable limit (UFL).
Flammable Liquid	The Occupational Health and Safety Act 85 of 1993 defines a **flammable liquid** as any liquid which produces a vapour that forms an explosive mixture with air and includes any liquid with a closed cup flashpoint of

	less than 55°C. Flammable products have been classified according to their flashpoints and boiling points, which ultimately determine the propensity to ignite. Separation distances described in the various codes are dependent on the flammability classification. **Class Description** 0 Liquefied petroleum gas (LPG) IA Liquids that have a closed cup flashpoint of below 23°C and a boiling point below 35°C IB Liquids that have a closed cup flashpoint of below 23°C and a boiling point of 35°C or above IC Liquids that have a closed cup flashpoint of 23°C and above but below 38°C II Liquids that have a closed cup flashpoint of 38°C and above but below 60.5°C IIA Liquids that have a closed cup flashpoint of 60.5°C and above but below 93°C
Flash Fire	A **flash fire** is defined as combustion of a flammable vapour and air mixture in which the flame passes through the mixture at a rate less than sonic velocity so that negligible damaging overpressure is generated.
FMEA	Failure mode and effects analysis is the process of reviewing as many components, assemblies, and subsystems as possible to identify potential failure modes in a system and their causes and effects
Frequency	**Frequency** is the number of times an outcome is expected to occur in a given period of time.
HAZOP	A hazard and operability study (**HAZOP**) are a structured and systematic examination of a complex planned or existing process or operation in order to identify and evaluate problems that may represent risks to personnel or equipment.
HEL	**Higher Explosive Limits** (See **UEL)**
Ignition Source	An **ignition source** is a source of temperature and energy sufficient to initiate combustion.
Individual Risk	**Individual risk** is the probability that in one year a person will become a victim of an accident if the person remains permanently and unprotected in a certain location. Often the probability of occurrence in one year is replaced by the frequency of occurrence per year.
IPP	**Independent Power Producers** (IPPs) or non-utility generator (NUG) are private entities (under unbundled market), which own and or operate facilities to generate electricity and then sell it to a utility, central government buyer and end users.
Isopleth	See **Risk Isopleth**
Jet	A **jet** is the outflow of material emerging from an orifice with significant momentum.
Jet Fire or Flame	A **jet fire or flame** is combusting material emerging from an orifice with a significant momentum.
LC	**Lethal concentration** is the concentration by which a given percentage of the exposed population will be fatally injured. The LC_{50} refers to the concentration of airborne material the inhalation of which results in death of 50% of the test group. The period of inhalation exposure could be from 30 min to a few hours (up to 4 hours).

LEL	**Lower Explosive Limit**, is defined as the lowest concentration (by percentage) of a gas or vapor in air that is capable of producing a flash of fire in presence of an ignition source (arc, flame, heat). ... In concentrations of 0-5% Methane in air, the mixture is too lean to ignite or burn.
LFL	**Lower Flammable Limit** see Flammable Limits
LNG	**Liquefied natural gas** (**LNG**) is natural gas (predominantly methane, CH4, with some mixture of ethane, C2H6) that has been cooled down to liquid form for ease and safety of non-pressurized storage or transport.
LOC	See **Loss of Containment**
Local Government	**Local government** is defined in Section 1 of the Local Government Transition Act, 1993 (Act No. 209 of 1993).
Loss of Containment	**Loss of containment** (LOC) is the event resulting in a release of material into the atmosphere.
Major Hazard Installation	**Major Hazard Installation** (MHI) means an installation: • Where more than the prescribed quantity of any substance is or may be kept, whether permanently or temporarily; • Where any substance is produced, used, handled or stored in such a form and quantity that it has the potential to cause a major incident (the potential of which will be determined by the risk assessment).
Major Incident	A **major incident** is an occurrence of catastrophic proportions, resulting from the use of plant or machinery or from activities at a workplace. When the outcome of a risk assessment indicates that there is a possibility that the public will be involved in an incident, then the incident is catastrophic.
Material Safety Data Sheet	According to ISO-11014, a **material safety data sheet** (MSDS) is a document that contains information on the potential health effects of exposure to chemicals or other potentially dangerous substances and on safe working procedures when handling chemical products. It is an essential starting point for the development of a complete health and safety program. It contains hazard evaluations on the use, storage, handling and emergency procedures related to that material. An MSDS contains much more information about the material than the label and it is prepared by the supplier. It is intended to tell what the hazards of the product are, how to use the product safely, what to expect if the recommendations are not followed, what to do if accidents occur, how to recognize symptoms of overexposure and what to do if such incidents occur.
MHI	See **Major Hazard Installation**
MIR	**Maximum Individual Risk** (see Individual Risk)
MSDS	See **Material Safety Data Sheet**
NEMA	107 of 1998, abbreviated **NEMA**) is the statutory framework to enforce Section 24 of the Constitution of the Republic of **South Africa**. The **NEMA** is intended to promote co-operative governance and ensure that the rights of people are upheld, but also recognising the necessity of economic development.
OCGT	An **open cycle gas turbine** is a combustion turbine plant fired by liquid fuel to turn a generator. rotor that produces electricity. The residual heat is exhausted to atmosphere at about 550 degrees.
OHS Act	**Occupational Health and Safety Act**, 1993 (Act No. 85 of 1993)

PAC	See **Protective Action Criteria**
PADHI	**PADHI** (**planning advice for developments near hazardous installations**) is the name given to a methodology and software decision support tool developed and used in the HSE. It is used to give land-use planning (LUP) advice on proposed developments near hazardous installations. PADHI uses two inputs into a decision matrix to generate either an 'advise against' or 'don't advise against' response: • The zone in which the development is located of the three zones that HSE sets around the major hazard: o The inner zone (> $1x10^{-5}$ fatalities per person per year); o The middle zone ($1x10^{-5}$ fatalities per person per year to $1x10^{-6}$ fatalities per person per year); o The outer zone ($1x10^{-6}$ fatalities per person per year to $3x10^{-7}$ fatalities per person per year); • The 'sensitivity level' of the proposed development which is derived from an HSE categorisation system of 'development types' (see the 'development type tables' in Appendix D).
POST	**The Parliamentary Office of Science and Technology** is the Parliament of the United Kingdom's in-house source of independent, balanced and accessible analysis of public policy issues related to science and technology.
PPE	**Personal protective equipment**, commonly referred to as "PPE", is equipment worn to minimize exposure to hazards that cause serious workplace injuries and illnesses.
QRA	See **Quantitative Risk Assessment**
Quantitative Risk Assessment	A **quantitative risk assessment** is the process of hazard identification, followed by a numerical evaluation of effects of incidents, both consequences and probabilities and their combination into the overall measure of risk.
Risk	**Risk** is the measure of the consequence of a hazard and the frequency at which it is likely to occur. Risk is expressed mathematically as: **Risk = Consequence x Frequency of Occurrence**
Risk Assessment	**Risk assessment** is the process of collecting, organising, analysing, interpreting, communicating and implementing information in order to identify the probable frequency, magnitude and nature of any major incident which could occur at a major hazard installation and the measures required to remove, reduce or control potential causes of such an incident.
Risk Contour	See **Risk Isopleth**
SANAS	South African National Accreditation System
Societal Risk	**Societal risk** is risk posed on a societal group who are exposed to a hazardous activity.
UFL	**Upper Flammable Limit** (see Flammable Limits)
Vapour Cloud Explosion	A **vapour cloud explosion** (VCE) results from ignition of a premixed cloud of a flammable vapour, gas or spray with air, in which flames accelerate to sufficiently high velocities to produce significant overpressure.
VCE	See **Vapour Cloud Explosion**

11 APPENDIX A: DEPARTMENT OF LABOUR CERTIFICATE

labour

Department:
Labour
REPUBLIC OF SOUTH AFRICA

National Department of Labour
Republic of South Africa

APPROVED INSPECTION AUTHORITY

Registered in accordance with the provisions of the Occupational Health and Safety Act, Act 85 of 1993, as amended and the Major Hazard Installation Regulations.

This is to certify that:

RISCOM (PTY) LTD

has been registered by the Department of Labour as an Approved Inspection Authority: Type A, to conduct Major Hazard Installation Risk Assessment, in terms of Regulation 5(5)(a), of the Major Hazard Installation Regulations.

CONDITIONS OF REGISTRATION:

- The AIA must at all time comply with the requirements of the Occupational Health and Safety Act, Act 85 of 1993, as amended.
- This registration certificate is not transferable.
- This registration will lapse if there is a name change of the AIA or change in ownership.

CHIEF INSPECTOR

Valid from: **27 May 2017**
Expires: **26 May 2021**
Certificate Number: **CI MHI 0005**

12 APPENDIX B: SANAS CERTIFICATES

sanas
South African National Accreditation System

CERTIFICATE OF ACCREDITATION

In terms of section 22(2)(b) of the Accreditation for Conformity Assessment, Calibration and Good Laboratory Practice Act, 2006 (Act 19 of 2006), read with sections 23(1), (2) and (3) of the said Act, I hereby certify that:-

RISCOM (PTY) LTD
Co. Reg. No.: 2002/019697/07
JOHANNESBURG

Facility Accreditation Number: **MHI0013**

is a South African National Accreditation System accredited Inspection Body to undertake **TYPE A** inspection provided that all SANAS conditions and requirements are complied with

This certificate is valid as per the scope as stated in the accompanying schedule of accreditation, Annexure "A", bearing the above accreditation number for

THE ASSESSMENT OF RISK ON MAJOR HAZARD INSTALLATIONS

The facility is accredited in accordance with the recognised International Standard

ISO/IEC 17020:2012

The accreditation demonstrates technical competency for a defined scope and the operation of a management system

While this certificate remains valid, the Accredited Facility named above is authorised to use the relevant SANAS accreditation symbol to issue facility reports and/or certificates

Mr R Josias
Chief Executive Officer

Effective Date: 27 May 2017
Certificate Expires: 26 May 2021

This certificate does not on its own confer authority to act as an Approved Inspection Authority as contemplated in the Major Hazard Installation Regulations. Approval to inspect within the regulatory domain is granted by the Department of Labour.

ANNEXURE A

SCHEDULE OF ACCREDITATION

Facility Number: MHI0013

TYPE A

Permanent Address: Riscom (Pty) Ltd 33 Brigish Dr Northcliff Johannesburg 2195 Tel: (011) 431-2198 Fax: 086 624 9423 Mobile: 082 457 3258 E-mail: mike@riscom.co.za	**Postal Address:** P O Box 2541 Cresta Johannesburg 2118 Issue No.: 12 Date of issue: 28 February 2013 Expiry date: 26 May 2017	
Nominated Representative: Mr M Oberholzer	**Quality Manager:** Mr M Oberholzer **Technical Manager:** Mr M Oberholzer	**Technical Signatory:** Mr M Oberholzer
Field of Inspection	**Service Rendered**	**Codes and Regulations**
Regulatory: 1) Explosive chemicals 2) Gases: i) Flammable Gases ii) Non-flammable, non toxic gases (asphyxiants) iii) Toxic gases 3) Flammable liquids 4) Flammable solids, substances liable to spontaneous combustion, substances that on contact with water release flammable gases 5) Oxidizing substances and organic peroxides 6) Toxic liquids and solids	Specific Services: i) Frequency/ Probability Analysis ii) Consequence Modelling iii) Hazard Identification and Analysis including HAZARD and Operability studies (HAZOP) iv) Emergency planning reviews	Programmes, guidelines, regulations and codes: MHI regulation par. **5 (5) (b)** Reference Manual Bevi Risk Assessments version 3.2 (2009) CPR 18E (1999), Guideline for quantitative risk assessment ("Purple Book"), TNO Apeldoorn. CPR 14E (1997). Methods for the Calculation of Physical Effects ("Yellow Book"), 3rd Edition, TNO, Apeldoorn. CPR 16E (1992). Methods for the Determination of Possible Damage ("Green Book"), 1st Edition, TNO, Apeldoorn. Lees FP (2001). Loss Prevention in the Process Industries: Hazard Identification, Assessment and Control, 2nd Edition, Butterworths, London, UK.

Original date of accreditation: 27 May 2005

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ISSUED BY THE SOUTH AFRICAN NATIONAL ACCREDITATION SYSTEM

Field Manager

13 APPENDIX C: NOTIFICATION OF MAJOR HAZARD INSTALLATION

Prior to assessment of potential impacts of various accidental spills, reference needs to be made to the legislation, regulations and guidelines governing the operation of the development.

Section 1 of the Occupational Health and Safety Act (OHS Act; Act No. 85 of 1993) defines a "major hazard installation" to mean an installation:

" (a) *Where more than the prescribed quantity of any substance is or may be kept, whether permanently or temporarily;*

(b) *Where any substance is produced, processed, used, handled or stored in such a form and quantity that it has the potential to cause a major incident (our emphasis).* "

It should be noted that if either (a) or (b) is satisfied, the Major Hazard Installation (MHI) regulations will apply. The prescribed quantity of a chemical can be found in Section 8(1) of the General Machinery Regulation 8 (our emphasis).

A major incident is defined as: "an occurrence of catastrophic proportions, resulting from the use of plant and machinery or from activities at a workplace". Catastrophic in this context means loss of life and limbs or severe injury to employees or members of the public, particularly those who are in the immediate vicinity (our emphasis).

It is important to note that the definition refers to an occurrence, whereas Section 1b) refers to potential to cause a major incident. If potential to cause a major incident exists, then the OHS Act and the Major Hazard Installation regulations will apply (our emphasis).

On the 16th of January 1998, the MHI regulations were promulgated under the OHS Act (Act No. 85 of 1993), with a further amendment on the 30th of July 2001. The provisions of the regulations apply to installations that have on their premises a certain quantity of a substance that can pose a significant risk to the health and safety of employees and the public.

The scope of application given in Section 2 of the MHI regulations is as follows:

" (1) *Subject to the provisions of Sub regulation (3) these regulations shall apply to employers, self-employed persons and users, who have on their premises, either permanently or temporarily, a major hazard installation or a quantity of a substance which may pose a risk that could affect the health and safety of employees and the public (our emphasis);*

(2) *These regulations shall apply to local governments, with specific reference to Regulation 9.* "

It is important to note that the regulations refer to a substance, and furthermore the regulations are applicable to risks posed by the substance and **NOT** merely the potential consequences (our emphasis).

The regulations essentially consist of six parts, namely:

1. Duties for notification of a Major Hazard Installation (existing or proposed), including:
    a. Fixed (see List 1);
    b. Temporary installations;
2. Minimum requirements for a quantitative risk assessment (see List 2);
3. Requirements of an on-site emergency plan (see List 3);
4. Reporting steps of risk and emergency occurrences (see List 4);
5. General duties required of suppliers;
6. General duties required of local government.

Notification of installation (List 1) indicates that:

- Applications need to be made in writing to the relevant local authority and the provincial director for permission:
    - To erect any Major Hazard Installation;
    - Prior to the modification of any existing installation that may significantly increase risk related to it (e.g., an increase in storage or production capacity or alteration of a process);
- Applications need to include the following information:
    - The physical address of installation;
    - Complete material safety data sheets of all hazardous substances;
    - The maximum quantity of each substance envisaged to be on premises at any one time;
    - The risk assessment of the installation (see List 2);
    - Any further information that may be deemed necessary by an inspector in interests of health and safety to the public;
- Applications need to be advertised in at least one newspaper serving the surrounding communities and by way of notices posted within these communities.

The risk assessment (List 2):

- Is the process of collecting, organising, analysing, interpreting, communicating and implementing information in order to identify the probable frequency, magnitude and nature of any major incident which could occur at a Major Hazard Installation and measures required to remove, reduce or control the potential causes of such an incident;
- Needs to be undertaken at intervals not exceeding 5 years and needs to be submitted to the relevant local emergency services;
- Must be made available in copies to the relevant health and safety committee, with 60 days given to comment thereon and the results of the assessment made available to any relevant representative or committee to comment thereon;
- Should be undertaken by competent person(s) and include the following:
    - A general process description;
    - A description of major incidents associated with this type of installation and consequences of such incidents (including potential incidents);
    - An estimation of the probability of a major incident;
    - The on-site emergency plan;
    - An estimation of the total result in the case of an explosion;
    - An estimation of the effects of thermal radiation in the case of fire;
    - An estimation of concentration effects in the case of a toxic release;
    - Potential effects of a major incident on an adjacent major hazard installation or part thereof;
    - Potential effects of a major incident on any other installation, members of the public (including all persons outside the premises) and on residential areas;
    - Meteorological tendencies;
    - Suitability of existing emergency procedures for risks identified;
    - Any requirements laid down in terms of the Environmental Conservation Act of 1989 (Act No. 73 of 1989);
    - Any organisational measures that may be required;
- The employer shall ensure that the risk assessment is of an acceptable standard and shall be reviewed should:
    - It be suspected that the preceding assessment is no longer valid;
    - Changes in the process that affect hazardous substances;
    - Changes in the process that involve a substance that resulted in the installation being classified a Major Hazard Installation or in the methods, equipment or procedures for the use, handling or processing of that substance;
    - Incidents that have brought the emergency plan into operation and may affect the existing risk assessment;
- Must be made available at a time and place and in a manner agreed upon between parties for scrutiny by any interested person that may be affected by the activities.

Requirements related to the on-site emergency plan (List 3) are:

- After submission of the notification, the following shall be established:
  - An on-site emergency plan must be made available and must be followed inside the premises of the installation or the part of the installation classified as a Major Hazard Installation, in consultation with the relevant health and safety representative or committee;
  - The on-site emergency plan must be discussed with the relevant local government, taking into consideration any comment on the risk related to the health and safety of the public;
  - The on-site emergency plan must be reviewed and where necessary updated, in consultation with the relevant local government, at least once every three years;
  - A copy of the on-site emergency plan must be signed in the presence of two witnesses, who shall attest the signature;
  - The on-site emergency plan must be readily available at all times for implementation and use;
  - All employees must be conversant with the on-site emergency plan;
  - The on-site emergency plan must be tested in practice at least once a year, and a record must be kept of such testing;
- Any employer, self-employed person and user owning or in control of a pipeline that could pose a threat to the general public shall inform the relevant local government and shall be jointly responsible with the relevant local government for establishment and implementation of an on-site emergency plan.

In reporting of risk and emergency occurrences (List 4):

- Following an emergency occurrence, the user of the installation shall:
  - Subject to the provisions of Regulation 6 of the General Administrative Regulations, within 48 hours by means of telephone, facsimile or similar means of communication, inform the chief inspector, the provincial director and relevant local government of the occurrence of a major incident or an incident that brought the emergency plan into operation or any near miss;
  - Submit a report in writing to the chief inspector, provincial director and local government within seven days;
  - Investigate and record all near misses in a register kept on the premises, which shall at all times be available for inspection by an inspector and local government representatives.

The duties of the supplier refer specifically to:

- Supplying of material safety data sheets for hazardous substances employed or contemplated at the installation;
- Assessment of the circumstances and substance involved in an incident or potential incident and the informing all persons being supplied with that substance of the potential dangers surrounding it;
- Provision of a service that shall be readily available on a 24-hour basis to all employers, self-employed persons, users, relevant local government and any other body concerned to provide information and advice in the case of a major incident with regard to the substance supplied.

The duties of local government are summarised as follows:

“ 9. (1) Without derogating from the provisions of the National Building Regulations and Building Standards Act of 1977 (Act No. 103 of 1977), no local government shall permit the erection of a new major hazard installation at a separation distance less than that which poses a risk to:

(a) Airports;

(b) Neighbouring independent major hazard installations;

(c) Housing and other centres of population; or,

(d) Any other similar facility…

Provided that the local government shall permit new property development only where there is a separation distance which will not pose a risk (our emphasis) in terms of the risk assessment: Provided further that the local government shall prevent any development adjacent to an installation that will result in that installation being declared a major hazard installation.

(2) Where a local government does not have facilities available to control a major incident or to comply with the requirements of this regulation that local government shall make prior arrangements with a neighbouring local government, relevant provincial government or the employer, self-employed person and user for assistance…

(3) All off-site emergency plans to be followed outside the premises of the installation or part of the installation classified as a major hazard installation shall be the responsibility of the local government… ”

14 APPENDIX D: PADHI LAND-PLANNING TABLES

14.1 Development Type Table 1: People at Work, Parking

Development Type	Examples	Development Detail and Size	Justification
DT1.1 Workplaces	Offices, factories, warehouses, haulage depots, farm buildings, nonretail markets, builder's yards	Workplaces (predominantly nonretail), providing for less than 100 occupants in each building and less than 3 occupied storeys (Level 1)	Places where the occupants will be fit and healthy and could be organised easily for emergency action Members of the public will not be present or will be present in very small numbers and for a short time
	Exclusions		
		DT1.1 x1 Workplaces (predominantly nonretail) providing for 100 or more occupants in any building or 3 or more occupied storeys in height (Level 2 except where the development is at the major hazard site itself, where it remains Level 1)	Substantial increase in numbers at risk with no direct benefit from exposure to the risk
	Sheltered workshops, Remploy	DT1.1 x2 Workplaces (predominantly nonretail) specifically for people with disabilities (Level 3)	Those at risk may be especially vulnerable to injury from hazardous events or they may not be able to be organised easily for emergency action
DT1.2 Parking Areas	Car parks, truck parks, lockup garages	Parking areas with no other associated facilities (other than toilets; Level 1)	
	Exclusions		
	Car parks with picnic areas or at a retail or leisure development or serving a park and ride interchange	DT1.2 x1 Where parking areas are associated with other facilities and developments the sensitivity level and the decision will be based on the facility or development	

14.2 Development Type Table 2: Developments for Use by the General Public

Development Type	Examples	Development Detail and Size	Justification
DT2.1 Housing	Houses, flats, retirement flats or bungalows, residential caravans, mobile homes	Developments up to and including 30 dwelling units and at a density of no more than 40 per hectare (Level 2)	Development where people live or are temporarily resident It may be difficult to organise people in the event of an emergency
	Exclusions		
	Infill, back-land development	DT2.1 x1 Developments of 1 or 2 dwelling units (Level 1)	Minimal increase in numbers at risk
	Larger housing developments	DT2.1 x2 Larger developments for more than 30 dwelling units (Level 3)	Substantial increase in numbers at risk
		DT2.1 x3 Any developments (for more than 2 dwelling units) at a density of more than 40 dwelling units per hectare (Level 3)	High-density developments
DT2.2 Hotel or Hostel or Holiday Accommodation	Hotels, motels, guest houses, hostels, youth hostels, holiday camps, holiday homes, halls of residence, dormitories, accommodation centres, holiday caravan sites, camping sites	Accommodation up to 100 beds or 33 caravan or tent pitches (Level 2)	Development where people are temporarily resident It may be difficult to organise people in the event of an emergency
	Exclusions		
	Smaller: guest houses, hostels, youth hostels, holiday homes, halls of residence, dormitories, holiday caravan sites, camping sites	DT2.2 x1 Accommodation of less than 10 beds or 3 caravan or tent pitches (Level 1)	Minimal increase in numbers at risk
	Larger: hotels, motels, hostels, youth hostels, holiday camps, holiday homes, halls of residence, dormitories, holiday caravan sites, camping sites	DT2.2 x2 Accommodation of more than 100 beds or 33 caravan or tent pitches (Level 3)	Substantial increase in numbers at risk

Development Type	Examples	Development Detail and Size	Justification
DT2.3 Transport Links	Motorway, dual carriageway	Major transport links in their own right i.e., not as an integral part of other developments (Level 2)	Prime purpose is as a transport link Potentially large numbers exposed to risk but exposure of an individual is only for a short period
	Exclusions		
	Estate roads, access roads	DT2.3 x1 Single carriageway roads (Level 1)	Minimal numbers present and mostly a small period of time exposed to risk Associated with other development
	Any railway or tram track	DT2.3 x2 Railways (Level 1)	Transient population, small period of time exposed to risk Periods of time with no population present

Development Type	Examples	Development Detail and Size	Justification
DT2.4 Indoor Use by Public	Food and drink: restaurants, cafes, drive-through fast food, pubs Retail: shops, petrol filling station (total floor space based on shop area not forecourt), vehicle dealers (total floor space based on showroom or sales building not outside display areas), retail warehouses, super-stores, small shopping centres, markets, financial and professional services to the public Community and adult education: libraries, art galleries, museums, exhibition halls, day surgeries, health centres, religious buildings, community centres. adult education, 6th form college, college of FE Assembly and leisure: Coach or bus or railway stations, ferry terminals, airports, cinemas, concert or bingo or dance halls, conference centres, sports or leisure centres, sports halls, facilities associated with golf courses, flying clubs (e.g., changing rooms, club house), indoor go kart tracks	Developments for use by the general public where total floor space is from 250 m^2 up to 5000 m^2 (Level 2)	Developments where members of the public will be present (but not resident) Emergency action may be difficult to coordinate
	Exclusions		
		DT2.4 x1 Development with less than 250 m^2 total floor space (Level 1)	Minimal increase in numbers at risk
		DT2.4 x2 Development with more than 5000 m^2 total floor space (Level 3)	Substantial increase in numbers at risk
DT2.5 Outdoor Use by Public	Food and drink: food festivals, picnic areas Retail: outdoor markets, car boot sales, funfairs Community and adult	Principally an outdoor development for use by the general public i.e., developments where people will	Developments where members of the public will be present (but not resident)

Development Type	Examples	Development Detail and Size	Justification
	education: open-air theatres and exhibitions Assembly and leisure: coach or bus or railway stations, park and ride interchange, ferry terminals, sports stadia, sports fields or pitches, funfairs, theme parks, viewing stands, marinas, playing fields, children's play areas, BMX or go kart tracks, country parks, nature reserves, picnic sites, marquees	predominantly be outdoors and not more than 100 people will gather at the facility at any one time (Level 2)	either indoors or outdoors Emergency action may be difficult to coordinate
	Exclusions		
	Outdoor markets, car boot sales, funfairs picnic area, park and ride interchange, viewing stands, marquees	DT2.5 x1 Predominantly open-air developments likely to attract the general public in numbers greater than 100 people but up to 1000 at any one time (Level 3)	Substantial increase in numbers at risk and more vulnerable due to being outside
	Theme parks, funfairs, large sports stadia and events, open air markets, outdoor concerts, pop festivals	DT2.5 x2 Predominantly open-air developments likely to attract the general public in numbers greater than 1000 people at any one time (Level 4)	Very substantial increase in numbers at risk, more vulnerable due to being outside Emergency action may be difficult to coordinate

14.3 Development Type Table 3: Developments for Use by Vulnerable People

Development Type	Examples	Development Detail and Size	Justification
DT3.1 Institutional Accommodation and Education	Hospitals, convalescent homes, nursing homes, old people's homes with warden on site or 'on call', sheltered housing, nurseries, crèches, schools and academies for children up to school leaving age	Institutional, educational and special accommodation for vulnerable people or that provides a protective environment (Level 3)	Places providing an element of care or protection Because of age, infirmity or state of health the occupants may be especially vulnerable to injury from hazardous events Emergency action and evacuation may be very difficult
		Exclusions	
	Hospitals, convalescent homes, nursing homes, old people's homes, sheltered housing	DT3.1 x1 24-hour care where the site on the planning application being developed is larger than 0.25 hectare (Level 4)	Substantial increase in numbers of vulnerable people at risk
	Schools, nurseries, crèches	DT3.1 x2 Day care where the site on the planning application being developed is larger than 1.4 hectare (Level 4)	Substantial increase in numbers of vulnerable people at risk
DT3.2 Prisons	Prisons, remand centres	Secure accommodation for those sentenced by court, or awaiting trial, etc. (Level 3)	Places providing detention Emergency action and evacuation may be very difficult

14.4 Development Type Table 4: Very Large and Sensitive Developments

Development Type	Examples	Development Detail and Size	Justification
Note: all Level 4 developments are by exception from Level 2 or 3 and are reproduced in this table for convenient reference			
DT4.1 Institutional Accommodation	Hospitals, convalescent homes, nursing homes, old people's homes, sheltered housing	Large developments of institutional and special accommodation for vulnerable people (or that provide a protective environment) where 24-hour care is provided and where the site on the planning application being developed is larger than 0.25 hectare (Level 4)	Places providing an element of care or protection Because of age or state of health the occupants may be especially vulnerable to injury from hazardous events Emergency action and evacuation may be very difficult The risk to an individual may be small but there is a larger societal concern
	Nurseries, crèches, schools for children up to school leaving age	Large developments of institutional and special accommodation for vulnerable people (or that provide a protective environment) where day care (not 24-hour care) is provided and where the site on the planning application being developed is larger than 1.4 hectare (Level 4)	Places providing an element of care or protection Because of the occupants that may be especially vulnerable to injury from hazardous events Emergency action and evacuation may be very difficult The risk to an individual may be small but there is a larger societal concern
DT4.2 Very Large Outdoor Use by Public	Theme parks, large sports stadia and events, open air markets, outdoor concerts, pop festivals	Predominantly open-air developments where there could be more than 1000 people present (Level 4)	People in the open air may be more exposed to toxic fumes and thermal radiation than if they were in buildings Large numbers make emergency action and evacuation difficult The risk to an individual may be small but there is a larger societal concern

15 APPENDIX E: MATERIAL SAFETY DATA SHEETS

15.1 LPG (Propane)

ROPANE	ICSC: 0319
n-Propane	November 2003
CAS #: 74-98-6	
UN #: 1978	
EC Number: 200-827-9	

	ACUTE HAZARDS	PREVENTION	FIRE FIGHTING
FIRE & EXPLOSION	Extremely flammable. Gas/air mixtures are explosive.	NO open flames, NO sparks and NO smoking. Closed system, ventilation, explosion-proof electrical equipment and lighting. Prevent build-up of electrostatic charges (e.g., by grounding) if in liquid state. Use non-sparking hand tools.	Shut off supply; if not possible and no risk to surroundings, let the fire burn itself out. In other cases, extinguish with powder, carbon dioxide. In case of fire: keep cylinder cool by spraying with water. Combat fire from a sheltered position.

	SYMPTOMS	PREVENTION	FIRST AID
Inhalation	Drowsiness. Unconsciousness.	Use closed system or ventilation.	Fresh air, rest. Artificial respiration may be needed. Refer for medical attention.
Skin	ON CONTACT WITH LIQUID: FROSTBITE.	Cold-insulating gloves. Protective clothing.	ON FROSTBITE: rinse with plenty of water, do NOT remove clothes. Refer for medical attention.
Eyes	ON CONTACT WITH LIQUID: FROSTBITE.	Wear face shield.	First rinse with plenty of water for several minutes (remove contact lenses if easily possible), then refer for medical attention.
Ingestion			

SPILLAGE DISPOSAL	CLASSIFICATION & LABELLING
Evacuate danger area! Consult an expert! Personal protection: self-contained breathing apparatus. Remove all ignition sources. Ventilation. NEVER direct water jet on liquid.	**According to UN GHS Criteria**
STORAGE	**Transportation** **UN Classification** UN Hazard Class: 2.1
Fireproof. Cool.	
PACKAGING	

International Labour Organization | World Health Organization

Prepared by an international group of experts on behalf of ILO and WHO, with the financial assistance of the European Commission.

European Commission

PROPANE	ICSC: 0319
PHYSICAL & CHEMICAL INFORMATION	

Physical State; Appearance ODOURLESS COLOURLESS COMPRESSED LIQUEFIED GAS. **Physical dangers** The gas is heavier than air and may travel along the ground; distant ignition possible. The gas is heavier than air and may accumulate in lowered spaces causing a deficiency of oxygen. As a result of flow, agitation, etc., electrostatic charges can be generated. **Chemical dangers**	Formula: C_3H_8 / $CH_3CH_2CH_3$ Molecular mass: 44.1 Boiling point: -42°C Melting point: -189.7°C Relative density (water = 1): 0.5 Solubility in water, g/100ml at 20°C: 0.007 Vapour pressure, kPa at 20°C: 840 Relative vapour density (air = 1): 1.6 Flash point: -104°C Auto-ignition temperature: 450°C Explosive limits, vol% in air: 2.1-9.5 Octanol/water partition coefficient as log Pow: 2.36

EXPOSURE & HEALTH EFFECTS

Routes of exposure The substance can be absorbed into the body by inhalation. **Effects of short-term exposure** Rapid evaporation of the liquid may cause frostbite. The substance may cause effects on the central nervous system.	**Inhalation risk** On loss of containment this substance can cause suffocation by lowering the oxygen content of the air in confined areas. **Effects of long-term or repeated exposure**

OCCUPATIONAL EXPOSURE LIMITS

MAK: 1800 mg/m^3, 1000 ppm; peak limitation category: II (4); pregnancy risk group: D

ENVIRONMENT

NOTES

Check oxygen content before entering area.
Turn leaking cylinder with the leak up to prevent escape of gas in liquid state.
High concentrations in the air cause a deficiency of oxygen with the risk of unconsciousness or death.

ADDITIONAL INFORMATION

EC Classification
Symbol: F+; R: 12; S: (2)-9-16