REPORT PREPARED ON BEHALF OF
WSP FOR ANGLO PLATINUM LIMITED

QUANTITATIVE RISK ASSESSMENT OF THE PROPOSED SO_2 ABATEMENT PROJECT AT ANGLO PLATINUMS MORTIMER SMELTER NEAR NORTHAM IN THE NORTH WEST PROVINCE

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Date of Issue: 17th May 2017
Report No.: R/17/WSP-001 Rev 1

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DOCUMENT CHANGE HISTORY			
PAGE/LINE	**CHANGE**	**DATE**	**REV**
Document	Initial release	12th April 2017	0
Document	Updated to comments	17th May 2017	1

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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.

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EXECUTIVE SUMMARY

1 INTRODUCTION

Anglo American Platinum Limited (hereinafter referred to as AAP) owns and operates the Mortimer Smelter, which is near to Northam in the North West Province. The facility smelts platinum group metal (PGM) sulphide concentrates to produce a matte that contains PGMs and base metals. Off gas containing sulphur dioxide (SO_2) and a solid slag are produced as effluents.

The National Environmental Management Air Quality Act (No. 39 of 2004) (NEM:AQA) requires that furnaces at smelters be operated with efficient SO_2 abatement systems by 2015, an extension has however been granted until 2020. In order to comply with this new South African legislation and associated more stringent emission standards, an SO_2 abatement facility must be installed at the Mortimer Smelter.

AAP has resumed (postponed during December 2012) the Feasibility Study (FEL 3) for the SO_2 abatement facilities to be developed at Mortimer Smelter. WSP has prepared the scoping report (WSP (2017)) for the required Environmental Impact Assessment (EIA), of which this specialist report forms part.

Since off-site incidents may result due to the hazards of some of the materials to be stored on or transported onto site, RISCOM (PTY) LTD was commissioned to conduct a quantitative risk assessment (QRA) to quantify the extent of the impacts on and risks to the surrounding communities. The purpose of this report is to convey the essential details, which include a short description of hazards, the receiving environment and current relevant design as well as the risks and consequences of a major incident.

At this stage of the project detailed engineering designs are not yet available and it is only possible to make a preliminary determination of the Major Hazard Installation status of the site. If required an MHI risk assessment for all the retained facilities would need to be completed, using the most current detailed engineering designs, once the SO_2 Abatement project has been finalised for construction.

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 AAP SO_2 abatement facility near Northam.

This risk assessment was conducted in accordance with the Major Hazard Installation regulations (with the addition of item 5), but cannot 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. The calculation of maximum individual risk (MIR), taking into account all generic failure rates, initiating events (such as ignition), meteorological conditions and lethality;

This risk assessment is for the use of the EIA and is not intended to replace a MHI risk assessment. Furthermore, the assessment covers only acute events and sudden ruptures and not chronic and on-going releases, such as fugitive emissions.

1.2 Purpose and Main Activities

The main activity at the AAP Mortimer Smelter near Northam is the smelting of PGM sulphide concentrates to produce a PGM/base metal matte, for further processing at AAP facilities located in Rustenburg. Slag and off gas (containing SO_2) are produced during the process.

The SO_2 Abatement Project which is the focus of the current study, will require the installation of equipment to remove SO_2 from the furnace off gas to meet future legislative requirements. Sulphuric acid will be manufactured, stored and transported as a means to capture the SO_2 and remove it from site. The process requires the processing of components that are considered hazardous, such as sulphur dioxide and sulphur trioxide. Liquid petroleum gas (LPG) which is highly flammable gas will be required for start-up and to maintain the energy balance in the facility.

Acidic effluents generated as the result of the abatement processes will be neutralised using hydrated lime and flocculant prior to disposal. Gypsum produced during this process will be returned to the furnace.

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 AAP facility include exposure to:

- Toxic vapours (sulphur dioxide and sulphur trioxide);
- Spillages of reactive and corrosive chemicals (sulphuric acid and hydrated lime);
- Thermal radiation from fires (new LPG storage and relocation of the existing diesel storage).

2 ENVIRONMENT

The proposed AAP SO_2 Abatement Facility lies in the North-West Province, within the portion of Union Mine Operations (RPM-UM) that will be retained by AAP once other assets at the mine, have been disposed of. It is located west of the R510, as shown in Figure 2-1, 20 km west of Northam and 90 km north of Rustenburg.

The retained operations will be completely surrounded by the mining and ore processing activities of RPM-UM, with various residential areas and agricultural activities stretching out beyond the mine boundaries.

A proposal by Samancor Chrome exists for the establishment of a chrome mine and processing facility on the farms Nooitgedacht and Varkensvlei approximately 1900 m to the north-west of the retained AAP assets, which is between the RPM-UM mine boundary and the village of Mantserre.

None of the neighbouring facilities have made themselves known to AAP as an MHI.

The residential areas surrounding the AAP facilities include:

- Mantserre (5.6 km), Mopyane (7.6 km) and Kraalhoek (9.0 km) to the north west;
- Swartklip (4.2 km) to the north east;
- Sefikile (4.2 km), Ga-Ramodsi (4.4 km) and Mononono (9.4 km) to the south east.

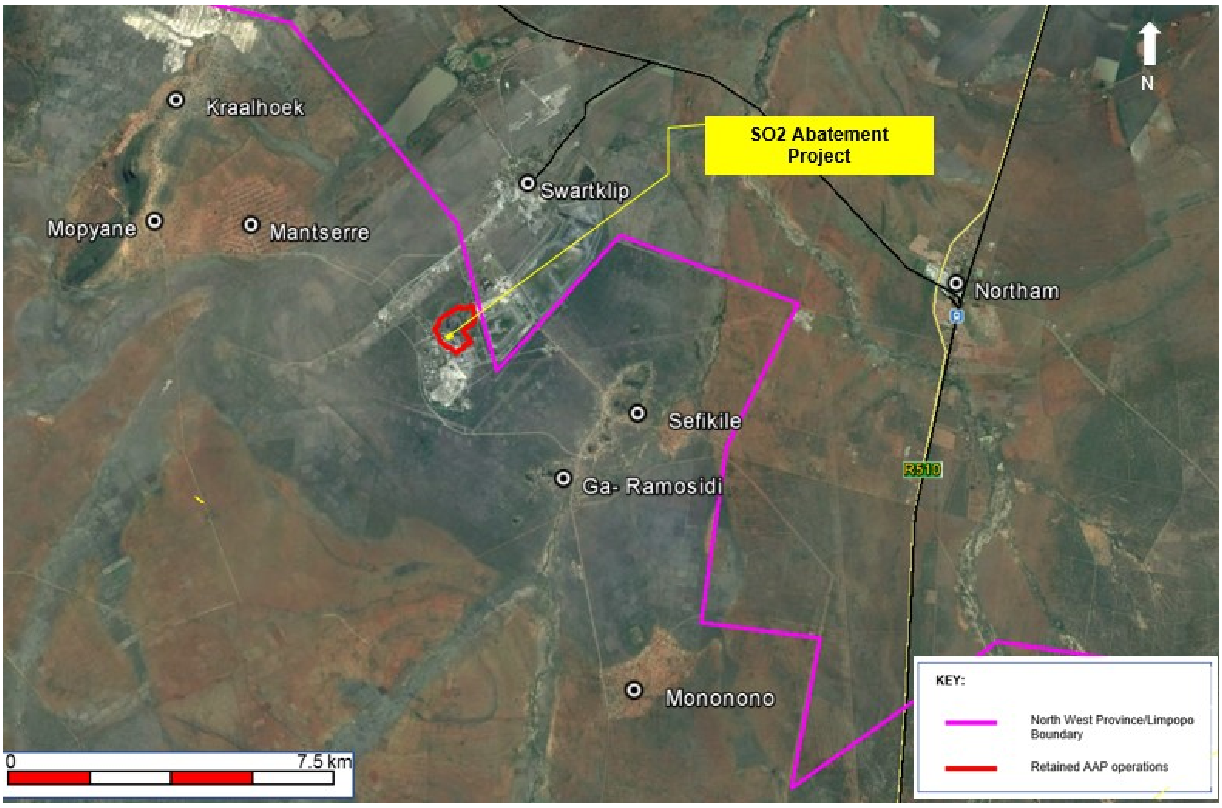

Figure 2-1: Location of the proposed AAP SO_2 Abatement Project near Northam

3 PROCESS DESCRIPTION

3.1 Site

The proposed SO2 abatement project is, superimposed (in white) on the existing Mortimer Smelter facilities in Figure 3-1. The facility consists of process piping and equipment for the production of sulphuric acid, storage vessels, an effluent treatment plant and acid road tanker loading facilities.

No.	Description	No.	Description
1	Security	2	Existing LPG storages
3	Offices	4	Existing furnace building
5	Existing stack	6	Gas cleaning and cooling
7	Acid tanker loading and bund	8	2 x 277 m3 acid storage tanks and bund
9	WSA plant	10	New off gas stack
11	Water cooling	12	Effluent plant
13	Existing workshops	14	Existing vehicle entrance/exit

Figure 3-1: Site layout

3.2 Process Description

Mortimer Smelter receives sulphide concentrates from various platinum concentrators for further processing. The concentrates are handled, blended and dryed prior to being fed to a furnace for smelting. The smelting process results in a matte that contains the Platinum Group Metals (PGM's) and base metals, which is transported to facilities in Rustenburg for further processing. A slag and furnace off gases (containing sulphur dioxide) are produced as effluent streams.

Currently furnace off gases containing particulates are passed through an electrostatic precipitator (ESP) to remove some of the particulates prior to disposal to the stack. Sulphur dioxide (SO2) gas (1.5-2 % by volume) also forms part of the discharge. More stringent environmental regulations require that the SO2 emissions be reduced prior to the disposal of the furnace off gases to the atmosphere (SO2 abatement).

A number of SO2 Abatement technologies are available, which have been accessed by AAP in previous project phases. The Haldor-Topsoe Wet Sulphuric Acid (WSA) Process has been selected as that best suited to implementation at Mortimer Smelter.

The process design basis considered in 2012 was based on assessments that may have changed in the intervening period. These include aspects such as:

- changes in the AAP mine plan which may affect concentrate grade (sulphur content) and throughput;
- potential changes in the operation of the furnace relating to power, feed rate, control, etc.

A schematic overview of the process is contained in Figure 3-2.

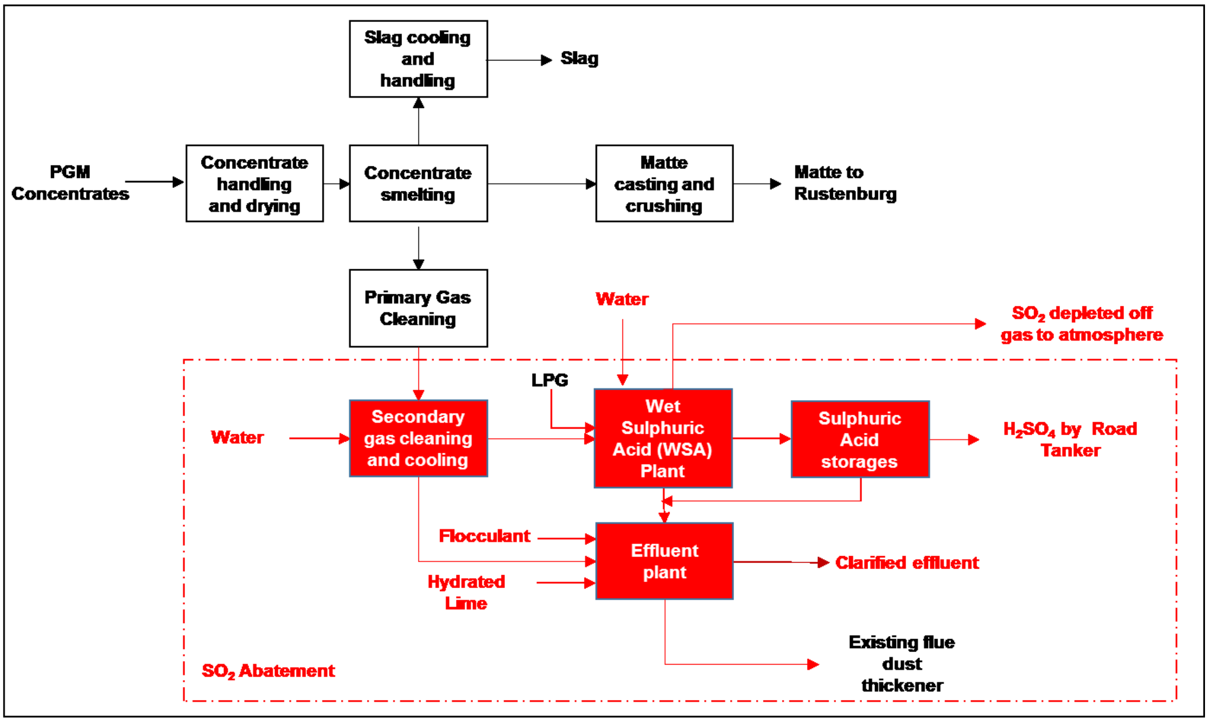

Figure 3-2: Schematic overview of the proposed process.

3.3 Primary Gas Cleaning

The furnace off-gas is initially dedusted using an ESP. The captured particulates contain valuable PGMs and are therefore fed back into the furnace.

3.4 Secondary Gas Cleaning

The furnace off-gas from primary gas cleaning contains residual dust with a concentration ranging between 200-400 mg/Nm^3; which exceeds the WSA plant requirement of less than 1 mg/Nm^3 of particulate matter and less than 20 mg/Nm^3 of SO_3. Further cleaning and cooling/conditioning of the furnace off-gas takes place ahead of the WSA Plant. Details of the additional gas cleaning and conditioning equipment are contained below.

The off-gas is saturated and cooled by water in a wet scrubber, which captures a large portion of the remaining dust in the water fed to the scrubber. A small fraction of the SO_2 will react with water to produce a weak sulphuric acid waste stream that will be pumped to the effluent treatment plant for neutralisation.

The gas is fed to a gas cooling tower, and passes through a spray cooled packed bed. In the process the off-gas is cooled to the desired WSA inlet temperature of 30 to 40°C.

Cooled off gas is then passed through the wet electro static precipitator (WESP), to reduce the particulate matter concentration in the off-gas entering the WSA plant to less than 1 mg/Nm^3 and the acid mist to below 20 mg/Nm^3.

3.5 Wet Sulphuric Acid Plant

The off-gas from the WESP enters the WSA plant. The gas is pre-heated to the required catalytic reaction temperature (405°C) before entering the SO_2 converter by passing through various heat exchangers and a support burner:

- a pre-heater that recovers heat from hot air from the acid condenser prior to the blower prior to it being mixed with gas recycled from the convertor feed using a recycle blower;
- a process gas heater that uses steam generated by the second process gas cooler (that cools the gas exiting the convertors) to heat the feed gas to the convertor;
- the first gas cooler also uses the heat of the gas exiting the convertor to heat the convertor feed gas;
- an interbed cooler cools the convertor gas between the catalyst beds to drive the SO_2 to SO_3 conversion further and heat the convertor feed gas;

Once heated, the gas then passes to support burner (LPG), which supplies any additional heat that is required to achieve auto thermal conditions (405°C), prior to the gas entering the convertor.

Heated off-gas enters the SO_2 converter, where the SO_2 is passed through beds of vanadium pentoxide catalyst. SO_2 in the off-gas is converted to SO_3 which is then reacted with water vapour in the off-gas to form H_2SO_4 vapour.

The conversion process occurs according the chemical reactions set out below:

$$\boldsymbol{SO}_2(g) + O_2(g) \rightarrow 2SO_3(g)$$

$$\boldsymbol{SO}_3(g) + H_2O(v) \rightarrow H_2SO_4(v)$$

Off-gas containing H_2SO_4 vapour and residual SO_2 is fed into a condenser where it is cooled, causing the H_2SO_4 vapour to condense on glass tubes to form H_2SO_4 liquid with a concentration of between 95 to 98 %(w/w). The acid (at approximately 260°C) is collected at the bottom of the condenser and cooled before it is sent to the two acid storages provided.

The stripped off-gas passes through a mist filter to remove any acid mist carried over from the condenser before finally being emitted to the atmosphere via the acid plant stack. The weak acid produced by the mist filter is pumped to the effluent treatment plant for neutralisation.

Areas of the WSA plant are bunded to contain any sulphuric acid spillages and prevent the ingress of acid to the ground. The available bunds are stated as having the following capacities:

- 542-SU-001: 27.6 m^3
- 542-SU-002: 57.3 m^3
- 542-SU-003: 127.4 m^3

The process design, as presented in the 2012 documentation may be incomplete, as it does not contain recent developments:

- The WSA process is well proven to produce $H_2SO_4$with a strength ≥95%(w/w) H_2SO_4 even for low strength feed gas (<1% SO2), an integrated sulphuric acid concentrator

(ISAC) may need to be added in order to produce as close to 98 %(w/w) H_2SO_4 as possible under all conditions.

The ISAC is an add-on to the acid outlet of the condenser bottom. Acid is concentrated by blowing hot, dry air at a controlled rate through the ISAC (counter current with the acid) in order to vapourise excess moisture. The ambient air used is filtered, dehumidified, pressurised with a blower and heated before entering the ISAC.

- A molten salt heat exchange system (indirect) was proposed in 2012, for the heating of the convertor inlet gas, this has been replaced with the steam based system in the most recent process descriptions.

3.6 Effluent Treatment Plant

The effluent treatment plant (ETP) is provided to treat all water effluent streams produced by the SO_2 abatement project and prevent acidic streams being discharged unprocessed into the environment. These streams will include:

- weak acid effluent (1 – 5% (w/w) H_2SO_4) generated by the wet gas cleaning equipment;
- acid mist from the mist filter in the WSA condenser;
- stormwater runoff / any acid spillages captured within the bunded plant area;
- bleed off from the cooling towers; and,
- blow-down from the steam system.

Effluents containing weak sulphuric acid are pumped to tanks located in the ETP, where they are will be neutralised by a hydrated lime slurry to produce gypsum. The solids are removed using a thickener to produce a thickened gypsum stream and a clarified water stream at neutral pH.

The ETP will have a daily throughput capacity of approximately 204m^3.

The gypsum will be fed back to the furnace at the Mortimer Smelter, and disposed of in this manner.

The area is bunded to prevent ingress of effluent and hydrated lime to the ground and the environment. Available bunded volumes are stated as being:

- 540-SU-001: 17.9m^3
- 540-SU-002: 46.4m^3

Hydrated lime delivered to site by road and stored in a dry silo prior to being used to make-up the slurry.

3.7 Acid Plant Cooling Water

Evaporative cooling towers will be used to cool the water required by the WSA and gas cleaning plant. Hot water returning from the process will be stored within a hot water tank prior to cooling in the cooling towers and recirculation.

The water will be chemically treated with flocculants, and sand filters will be utilised to remove any particulate matter. A bleed stream will be fed into the ETP.

The area will be bunded for the containment of spillages.

3.8 Sulphuric Acid Storage and Handling

The H_2SO_4 produced by the WSA process (approximately 1.6 tonnes per hour) will be stored in two closed vertical storage tanks. It is envisaged that approximately 560m^3 of acid will be stored. The stored acid will be removed by accredited transporters of acid, typically using 30 tonne road tankers.

All the acid storage and handling areas are bunded to prevent ingress of H_2SO_4 to the ground and the environment. The available bunds are stated as having the following capacities:

- 536-SU-001: 18.2 m^3
- 536-SU-002: 175.1 m^3
- 536-SU-003: 773.5 m^3

3.9 Liquid Petroleum (LPG) Storage and Handling

LPG will be required by the WSA process for support heating (when the SO_2 concentration in the furnace off-gas is below the SO_2 concentration required for autothermal operation of the acid plant) and by the Mist Control Units.

The peak LPG requirement will be during start-up of the WSA acid plant which can take up to 5 days.

One additional LPG storage bullet of 22.5m^3 will potentially be installed in the existing LPG storage area (two of 22.5m^3 bullets) on the site plan. For the purposes of this assessment the delivery of LPG to the WSA plant has been considered on an “over fence” basis.

3.10 Water Useage

The SO_2 Abatement Project will require 468m^3/day of water. It is envisaged that the water will be obtained from the existing allocation of 15 000m^3/day to Union Mine. The Mortimer Smelter currently utilises 400m^3/day water.

3.11 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	Sulphuric acid (98%)	7664-93-9	280 m3
2	Sulphuric acid (98%)	7664-93-9	280 m3
3	Intermediate Acid Storage (98%)	7664-93-9	5 m3
4	Off spec Sulphuric acid (95%)		50 m3
5	Hydrated lime	1305-62-0	85 m3 vertical silo

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.

Due to the absence of South African legislation regarding determination methodology for quantitative risk assessment (QRA), the methodology of this assessment is based on the legal requirements of the Netherlands, outlined in CPR 18E (Purple Book; 1999) and RIVM (2009). The evaluation of the acceptability of the risks is done in accordance with the UK Health and Safety Executive (HSE) ALARP criteria that clearly cover land use, based on determined risks.

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;
5. Using the population density near the facility, determination of societal risk posed by the facility.

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.

4.1 Study Objectives

The Final EIA Scoping Report for the proposed Mortimer Smelter SO_2 Abatement has identified the risk of major incidents associated with the storage of hazardous substances to be a potential environmental impact on occupational and community safety (medium significance without mitigation).

Riscom is a registered MHI AIA accredited with the Department of Labour and SANAS (See Appendix A) has been requested to complete an appropriate level of quantitative risk assessment (QRA) based on the accepted methodologies used for MHI status determination to investigate this aspect.

The risk assessment is required to contain a statement from a professional person (See Appendix B) covering the following questions:

1. Whether the proposed project would likely be considered an MHI based on the hazardous materials to be stored, handled and produced on site;
2. If it is likely to be considered an MHI, whether it would meet the requirements of the MHI regulations and whether the risks could be engineered or managed to meet acceptable risks;
3. Whether there are any factors that will prevent the project from proceeding to the next phase of implementation or whether the project could continue under certain conditions or mitigations;
4. Completion of an environmental significance assessment based on the methodologies provided by WSP;
5. Whether there are any special requirements that local authorities need to know when evaluating the proposal.

4.2 Assumptions and Limitations

The risk assessment was based on the feasibility (FEL3) designs of the project, as proposed by AAP in December 2012. EIAs are intended to suggest mitigation which may alter the design and layout of the project. It is therefore understood that detailed designs would be required to be completed after an EIA. A Record of Decision to complete the project with a view to construction commencing would also be required.

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 at the EIA.

The risk assessment excludes the following aspects:

- other processes and equipment outside of the Mortimer SO_2 Abatement Project;
- natural events such as earthquakes and floods;
- the development of an emergency plan.

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 as well as toxic and asphyxiant releases at the proposed AAP facility in Northam. 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 statuary regulations would be applied. It was also assumed that the detailed engineering designs would be finalised 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 the materials of construction are compatible with the products, etc.

It is the responsibility of AAP 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, as 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 as listed in the regulation to notify the divisional inspector. 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.

None of the hazardous materials to be stored on site is listed as notifiable.

5.1 Toxic Releases

Sulphur dioxide and sulphur trioxide are both considered acutely toxic components.

The 1% fatality isopleths for sulphur dioxide do not extend beyond the site boundary of the AAP retained operations at Mortimer, and no further analysis was required.

The 1% fatality isopleths for sulphur trioxide did extend the site boundary of the AAP retained operations at Mortimer, and further analysis was required. The risk of $1x10^{-6}$ fatalities per person per year isopleth was however found not to extend beyond the site boundary, and **the site would not qualify as a Major Hazard Installation on this basis**.

The risks were also less than $3x10^{-7}$ fatalities per person per year at the site boundary. The risks to the public would be considered trivial.

5.3 Fires

The 1% fatality for LPG (jet fire) does not extend beyond the site boundary, and no further analysis was required.

5.4 Explosions

No vapour explosions would be expected.

5.5 Impacts onto Neighbouring Properties, Residential Areas and MHIs

Toxic impacts due to sulphur dioxide and sulphur trioxide would not extend into any of the surrounding residential areas. This would include some of the informal dwellings that have developed along the mine access road from the village of Sefikile.

The facilities of RPM-U may be slightly affected by the toxic effects of SO_3 in the event of a loss of containment of furnace gas, in the areas adjacent to the site boundary. More distant neighbours such as the proposed Samancor Varkensvlei project would not be affected.

None of the neighbouring companies have identified themselves to AAP as being classified as a Major Hazard Installation.

5.6 Societal Risks

Societal risks were not assessed, as the SO_2 Abatement Project would not contribute to the site being classified as an MHI.

5.7 Major Hazard Installation

There is insufficient information available to make a classification for all the retained operations of AAP at Mortimer Smelter. This investigation has however concluded that under the current design conditions the proposed AAP SO_2 Abatement Project facility near Northam **would not be considered a Major Hazard Installation (MHI).**

This study is not intended to replace the Major Hazard Installation risk assessment which should be completed for all the retained operations prior to construction of the facility (if required).

5.8 Impact Assessment

The impact of the project on the public and neighbouring sites, due to the handling, production and storage of hazardous materials, would be low. Some potential does exist for the occurrence of Section 30 incidents, but the impact significance of these has been assessed as being low (based on the controls put in place, the short duration of events, etc.).

A loss of secondary containment of H_2SO_4 or hydrated lime, would not directly endanger the public, but may give rise to a Section 30/30A, if it were allowed to enter the ground or surface water. Effective bunding and other mitigation measures would be required when storing or handling these materials.

The available information allows a medium confidence level in the assessment, this is based on the information provided is based on a FEL 3 study, which has the potential for changes during implementation and construction. Typically, a high level of confidence would only be assigned based on a review based on designs that are finalised for construction.
Mitigation measures proposed in this report should be considered for implementation, if not already in place.

5.9 Emergency Planning

The on-site emergency plan will need to be updated to ensure that it reflects the impacts of the changes to plant and additions to the chemical inventory.

It is not anticipated that the addition of the new plant facilities will result in the entire facility becoming an MHI, but this would need to be verified by assessing the entire site.

In the event of the entire facility changing its MHI status, the MHI requirements for an on-site emergency plan would be triggered.

The emergency response plan must be updated to include the handling of environmental incidents if it does not already do so.

6 RECOMMENDATIONS

As a result of the risk assessment study conducted for the proposed AAP SO2 Abatement facility near Northam the risks associated with losses of containment associated with hazardous materials were not found to have risks that extend beyond the site boundary. On this basis, the proposed facility was found to have acceptable risks.

RISCOM has not established any fatal flaws based on the quantitative risk or impact assessments that would prevent the project proceeding with the detailed engineering phase required for construction of the project.

RISCOM would support the project with the following conditions:

1. full compliance with all statutory requirements;
2. compliance with applicable SANS codes, i.e. SANS 10087-3 (LPG), SANS 10400, SANS 10108, etc.;
3. incorporation of applicable guidelines or equivalent international recognised codes of good design and practice into the designs;
4. completion of a recognised process hazard analysis (such as a HAZOP study, FMEA, etc.) for the proposed facility prior to construction to ensure design and operational hazards have been identified and adequate mitigation put in place;
5. preparation and issue of a safety document detailing safety and design features of the design for reducing the impacts from toxic releases, loss of containment, fires, explosions and flammable atmospheres to form part of the required input to a quantitative risk assessment
    a. including compliance to statutory laws, applicable codes and standards and
    b. world’s best practice;
    c. including the listing of statutory and non-statutory inspections, giving frequency
    d. of inspections;
    e. including the auditing of the built facility against the safety document;
    f. noting that codes such as IEC 61511 can be used to achieve these
    g. requirements;
6. demonstration by AAP or their contractor that the final designs would reduce the risks posed by the installation to internationally acceptable guidelines;
7. sign-off for all SO2 Abatement Project designs by a professional engineer registered in South Africa in accordance with the Professional Engineers Act, who takes responsibility for suitable designs;
8. completion of an emergency preparedness and response document for on-site and off-site scenarios prior;
9. permission not being granted for increases to the product list or product inventories without redoing part of or the full EIA;
10. final acceptance of the facility risks for all the retained AAP operations at Mortimer with a quantitative risk assessment that must be completed in according to a process based on a process similar to the one required for to the MHI regulations:
    a. Basing such a risk assessment on the final design and including engineering mitigation.

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QUANTITATIVE RISK ASSESSMENT OF THE PROPOSED SO2 ABATEMENT PROJECT AT ANGLO PLATINUMS MORTIMER SMELTER NEAR NORTHAM IN THE NORTH WEST PROVINCE

1 INTRODUCTION

Anglo American Platinum Limited (hereinafter referred to as AAP) owns and operates the Mortimer Smelter, which is near to Northam in the North West Province. The facility smelts platinum group metal (PGM) sulphide concentrates to produce a matte that contains PGMs and base metals. Off gas containing sulphur dioxide (SO_2) and a solid slag are produced as effluents.

The National Environmental Management Air Quality Act (No. 39 of 2004) (NEM:AQA) requires that furnaces at smelters be operated with efficient SO_2 abatement systems by 2015, an extension has however been granted until 2020. In order to comply with this new South African legislation and associated more stringent emission standards, an SO_2 abatement facility must be installed at the Mortimer Smelter.

AAP has resumed (postponed during December 2012) the Feasibility Study (FEL 3) for the SO_2 abatement facilities to be developed at Mortimer Smelter. WSP has prepared the scoping report (WSP (2017)) for the required Environmental Impact Assessment (EIA), of which this specialist report forms part.

Since off-site incidents may result due to the hazards of some of the materials to be stored on or transported onto site, RISCOM (PTY) LTD was commissioned to conduct a quantitative risk assessment (QRA) to quantify the extent of the impacts on and risks to the surrounding communities. The purpose of this report is to convey the essential details, which include a short description of hazards, the receiving environment and current relevant design as well as the risks and consequences of a major incident.

At this stage of the project detailed engineering designs are not yet available and it is only possible to make a preliminary determination of the Major Hazard Installation status of the site. If required an MHI risk assessment for all the retained facilities would need to be completed, using the most current detailed engineering designs, once the SO_2 Abatement project has been finalised for construction.

1.1 Study Objectives

The Final EIA Scoping Report for the proposed Mortimer Smelter SO_2 Abatement has identified the risk of major incidents associated with the storage of hazardous substances to be a potential environmental impact on occupational and community safety (medium significance without mitigation).

Riscom is a registered MHI AIA accredited with the Department of Labour and SANAS (See Appendix A) has been requested to complete an appropriate level of quantitative risk assessment (QRA) based on the accepted methodologies used for MHI status determination to investigate this aspect.

The risk assessment is required to contain a statement from a professional person (See Appendix B) covering the following questions:

1. Whether the proposed project would likely be considered an MHI based on the hazardous materials to be stored, handled and produced on site;
2. If it is likely to be considered an MHI, whether it would meet the requirements of the MHI regulations and whether the risks could be engineered or managed to meet acceptable risks;
3. Whether there are any factors that will prevent the project from proceeding to the next phase of implementation or whether the project could continue under certain conditions or mitigations;
4. Completion of an environmental significance assessment based on the methodologies provided by WSP;
5. Whether there are any special requirements that local authorities need to know when evaluating the proposal.

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 AAP SO_2 abatement facility near Northam.

This risk assessment was conducted in accordance with the Major Hazard Installation regulations (with the addition of item 5), but cannot be used as notification for the facility. The scope of the risk assessment included:

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

This risk assessment is for the use of the EIA and is not intended to replace a MHI risk assessment. Furthermore, the assessment covers only acute events and sudden ruptures and not chronic and on-going releases, such as fugitive emissions.

1.3 Assumptions and Limitations

The risk assessment was based on the feasibility (FEL3) designs of the project, as proposed by AAP in December 2012. EIAs are intended to suggest mitigation which may alter the design and layout of the project. It is therefore understood that detailed designs would be required to be completed after an EIA. A Record of Decision to complete the project with a view to construction commencing would also be required.

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 at the EIA.

The risk assessment excludes the following aspects:

- other processes and equipment outside of the Mortimer SO_2 Abatement Project;
- natural events such as earthquakes and floods;
- the development of an emergency plan.

1.4 Legislation

This report contains information summaries with a special focus on QRA and with comment on on-site emergency plans. The requirements following an incident and the general duties required from the supplier and local government will merely be repeated from the regulations.

Risk assessments are conducted when required 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.

1.4.1 National Environmental Management Act (No. 107 of 1998; NEMA) and its regulations

The National Environmental Management Act (No. 107 of 1998; NEMA) contains the principal South African environmental legislation. Its primary objective is to make provision for cooperative governance by establishing principles for decision making on matters related to 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.

Section 30 of the NEMA 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 Major Hazard Installation (MHI) as defined in the Occupational Health and Safety Act (OHS Act) 85 of 1993 and its MHI regulations.

Section 28 of the NEMA makes provision for anyone who causes pollution or degradation of the environment to be made responsible for the prevention of the occurrence, continuation or reoccurrence of related impacts and for the costs of repair to 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… "*

1.4.2 Environmental Amendment Act (N$^{o.}$ 30 of 2013)

Section 30 of NEMA, has been amended the insertion of section 30A, which came into effect on 18 December 2014. The amendment provides for emergency situations, which are defined differently to an emergency incident. An emergency situation is defined as:

> *" a situation that has arisen suddenly that poses an imminent and serious threat to the environment, human life or property, including 'disaster' as defined in section 1 of the Disaster Management Act, 2002 (Act No. 57 of 2002) but does not include an incident referred to in section 30 of this Act… "*

A competent authority is allowed in terms of 30A (1) to issue verbal and written directives to the person responsible for undertaking listed or specified activities without obtaining the prerequisite environmental authorization, in order to prevent or contain an emergency situation or to prevent, contain or mitigate the effects of an emergency situation.

It is important to be able to distinguish between an incident and an emergency situation. One must look to the Disaster Management for a definition of what constitutes a disaster for guidance

> ***"*** *A disaster is defined as "a progressive or sudden, widespread or localised, natural or human--caused occurrence which –*
>
> *(a) Causes or threatens to cause*
> ***(i)*** *Death, injury or disease;*
> ***(ii)*** *Damage to property, infrastructure or the environment; or*
> ***(iii)*** *Disruption of the life of a community; and*
>
> *(b) Is of a magnitude that* ***exceeds the ability of those affected by the disaster cope with its effects using only their own resources… "***

A determination is required to be made by the responsible person as to whether an incident constitutes the potential to be considered a situation rather than an incident. An assessment of the potential severity of the impact of incidents on the environment, workers and the public, together with an assessment of the ability and resources to deal with an incident, would be key considerations in determining the potential for other parties such competent authorities to become involved. This is a similar requirement to that imposed by the OSH MHI Regulations.

1.4.3 Mine Health and Safety Act (N°. 29 of 1996: MHS Act)

The purpose of the Act is to provide for protection of the health and safety of employees and other persons at mines. The Mortimer Smelter falls within a mine and thus falls under these auspices of this legislation.

With the encroachment of vulnerable populations (the public) onto mines, it may now be time to take into account the impact of mining operations onto the public. Currently the MHS Act is deemed not to include the type of approach that is contemplated in the OHS Major Hazard Installation (MHI) Regulations for ensuring the safety of the public.

Regulation 103 of the MHS does however make the following provision:

“The Occupational Health and Safety Act, 1993 (Act No. 85 of 1993), is not applicable to any matter in respect of which any provision of this Act is applicable.”

It would thus be possible for the (Department of Mineral Resources) DMR to adopt the requirements of the OHS MHI regulations with itself as the regulator, given that this matter is not provided for in the MHS.

1.4.4 The Occupational Health and Safety Act (No. 85 of 1993; OHS Act)

The Occupational Health and Safety Act (No. 85 of 1993; OHS Act) is primarily intended for the health and safety of the workers, whereas its MHI regulations are 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. ”

1.4.4.1 Major Hazard Installation (MHI) regulations

The Major Hazard Installation (MHI) regulations (2001) published under Section 43 of the Occupational Health and Safety Act (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 workers and the public to conduct a risk assessment in accordance with the legislation. In accordance with legislation, the risk assessment must be done by an approved inspection authority (AIA), which is registered with the Department of Labour and accredited by the South African Accreditation System (SANAS), **prior to construction of the facility**.

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 workers 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 workers and the public.

It is important to note that the MHI regulations are applicable to the risks posed and not merely the consequences. This implies that both the consequence and likelihood of an event need to be evaluated, with the classification of an installation being determined on the risk posed to workers and the public.

Notification of the MHI classification 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, essentially consist 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.

1.4.4.2 Pressure Equipment Regulations

These regulations apply to the design, manufacture, operation, repair, modification, maintenance, inspection and testing of pressure equipment, with a design pressure equal to or greater than 50 kPa, with a view to health and safety.

1.4.4.3 National Building Regulations and Building Standards Act (No. 103 of 1977)

National Building Regulations and Building Standards Act (No. 103 of 1977) governs how buildings should be constructed. The legislation became enforceable as law in September 1985 and two years later was published by the South African Bureau of Standards (SABS) as part of the original Code of Practice for the Application of the National Building Regulations (SABS 0400-1987).

1.5 Purpose and Main Activities

The main activity at the AAP Mortimer Smelter near Northam is the smelting of PGM sulphide concentrates to produce a PGM/base metal matte, for further processing at AAP facilities located in Rustenburg. Slag and off gas (containing SO_2) are produced during the process.

The SO_2 Abatement Project which is the focus of the current study, will require the installation of equipment to remove SO_2 from the furnace off gas to meet future legislative requirements. Sulphuric acid will be manufactured, stored and transported as a means to capture the SO_2 and remove it from site. The process requires the processing of components that are considered hazardous, such as sulphur dioxide and sulphur trioxide. Liquid petroleum gas (LPG) which is highly flammable gas will be required for start-up and to maintain the energy balance in the facility.

Acidic effluents generated as the result of the abatement processes will be neutralised using hydrated lime and flocculant prior to disposal. Gypsum produced during this process will be returned to the furnace.

1.6 Main Hazards Due to Substance and Process

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

- Toxic vapours (sulphur dioxide and sulphur trioxide);
- Spillages of reactive and corrosive chemicals (sulphuric acid and hydrated lime);
- Thermal radiation from fires (new LPG storage and relocation of the existing diesel storage).

1.7 Facility Inspection

The proposed site of the AAP SO_2 Abatement Project located at Mortimer Smelter near Northam was inspected on the 29th of March 2017, with the objective of verifying that information supplied to RISCOM reflected the built information and also to examine certain aspects of the operation to ensure a representative risk assessment of the facility.

The inspector representing RISCOM during the site visit was Mr I D Ralston. The AAP representative during the site visit was Ms V F Mugivhi (Environmental Officer).

During the site visit the following observations were made:

- the intended site for the project is located in within the existing smelter fenced area, which has access control;
- it is required to be located in close proximity to the stack based on process requirements;
- the site is flat and largely clear of existing infrastructure. A diesel storage and small cable yard will have to relocated to accommodate the new infrastructure for the project;
- the SO_2 Abatement facilities are located 180 m away from the western site boundary;
- the potential additional LPG storage tank is proposed to be located in the existing LPG storage area, which is located 90 m away from the western site boundary.

1.8 Satellite Imagery

The AAP SO_2 Abatement Project was located at 24°58'16.46"S 27° 8'32.24"E on satellite imagery, dated 02/12/2017 and a site layout drawing of the proposed project area was superimposed (Drawing $N^{o.}$ HS341232-0000-00521-0002).

1.9 Software

Physical consequences were calculated with DNV's PHAST v. 6.7 and the data derived was entered into TNO's RISKCURVES v. 9.0.26. All calculations were performed by Mr I.D Ralston and checked by Mr M.P Oberholzer.

These models were then inserted into the satellite image mentioned above to obtain graphic representations of the various consequences and risk isopleths.

2 ENVIRONMENT

2.1 General Background

The proposed AAP SO_2 Abatement Facility lies in the North-West Province, within the portion of Union Mine Operations (RPM-UM) that will be retained by AAP once other assets at the mine, have been disposed of. It is located west of the R510, as shown in Figure 2-1, 20 km west of Northam and 90 km north of Rustenburg.

The retained operations will be completely surrounded by the mining and ore processing activities of RPM-UM, with various residential areas and agricultural activities stretching out beyond the mine boundaries.

A proposal by Samancor Chrome exists for the establishment of a chrome mine and processing facility on the farms Nooitgedacht and Varkensvlei approximately 1900 m to the north-west of the retained AAP assets, which is between the RPM-UM mine boundary and the village of Mantserre.

None of the neighbouring facilities have made themselves known to AAP as an MHI.

The residential areas surrounding the AAP facilities include:

- Mantserre (5.6 km), Mopyane (7.6 km) and Kraalhoek (9.0 km) to the north west;
- Swartklip (4.2 km) to the north east;
- Sefikile (4.2 km), Ga-Ramodsi (4.4 km) and Mononono (9.4 km) to the south east.

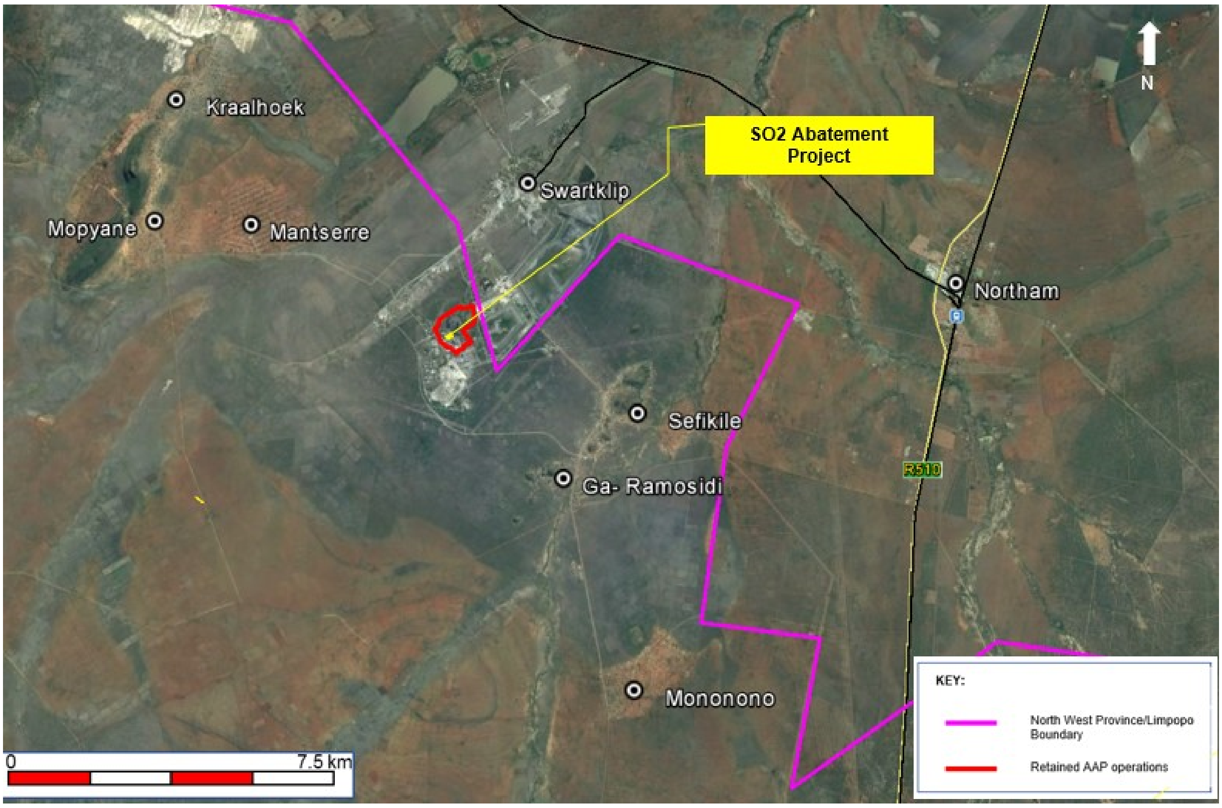

Figure 2-1: Location of the proposed AAP SO_2 Abatement Project near Northam

2.2 Meteorology

Meteorological mechanisms govern dispersion, transformation and eventual removal of hazardous vapours from the atmosphere. The extent to which hazardous vapours 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 of vertical and horizontal components of motion. The stability and the depth of the atmosphere from the surface (known as the mixing layer) define the vertical component. The horizontal dispersion of hazardous vapours in the atmospheric boundary layer is primarily a function of wind field. Wind speed determines both the distance of downwind transport and the rate of dilution as a result of stretching of the plume, and generation of mechanical turbulence is a function of the wind speed in combination with surface roughness. Wind direction and variability in wind direction both determine the general path hazardous vapours will follow and the extent of crosswind spreading.

Concentration levels of hazardous vapours therefore fluctuate in response to changes in atmospheric stability, to concurrent variations in the mixing layer depth and to shifts in the wind field.

The proposed Mortimer SO_2 Project lies in the subtropical high pressure belt.

For this report, the meteorological conditions at Weather Station WA0587139-Middelkop, as measured by the South African Weather Bureau (SAWB) were used as the basis for temperature, and precipitation. The conditions at the Mortimer Hostel Weather Station, as measured by AAP, were used as the basis of wind speed and direction and atmospheric stability.

2.2.1 Surface Winds

Hourly averages of wind speed and direction recorded at Mortimer Hostel were provided by WSP from AAP for the period from the 1st of January 2013 to the 31st of December 2015. The data was transformed into a suitable format for use in the simulation software.

The winds in the Mortimer area are expected to originate mainly from the east-south-east and east, with wind speeds being low to moderate (1.5 to 4 m/s).

2.2.2 Precipitation

The long-term rainfall recorded at Middelkop, was obtained from the TSP AAP for the period from 1904 to 2000, as given in Table 2-1.

At Weather Station WA0587139-Middelkop there is an average annual rainfall of 643 mm with the dry maximum rainfall occurring from November to March. Whereas summer months receive about 89% of the rainfall, the winter months are normally dry.

Table 2-1: Long-term rainfall at Weather Station WA0587139-Middelkop

Month	Precipitation		
	Average Monthly (mm)	**Maximum Monthly (mm)**	**Minimum Monthly (mm)**
January	137	388	0
February	91	256	0
March	93	282	0
April	40	133	0
May	10	59	0
June	5	99	0
July	4	81	0
August	2	23	0
September	12	108	0
October	54	118	4.4
November	93	209	3.5
December	101	249	0
Year	643	2 003	7.9

2.2.3 Temperature

The long-term temperatures recorded at Weather Station WA0587139-Middelkop was obtained from the SAWB AAP for the period from 1904 to the 2000, as given in Table 2-2.

The surrounding region has a temperate climate with the average daily maximum between 22.1°C and 31.8°C. Temperatures rarely dip below freezing, with the mean average of the daily temperature being 19.9°C.

Table 2-2: Long-term temperatures measured at Weather Station WA0587139-Middelkop

Month	Temperature (°C)		
	Average Daily Mean	Average Daily Maximum	Average Daily Minimum
January	25.2	31.8	18.6
February	24.3	30.7	17.9
March	23.1	30.0	16.2
April	19.5	27.3	11.6
May	15.4	25.3	5.5
June	12.0	22.1	1,9
July	12.5	22.5	2.4
August	15.7	25.4	6.0
September	20.0	28.4	11.6
October	22.7	29.8	15.7
November	23.9	30.6	17.1
December	24.3	30.5	18.2
Year	**19.9**	**27.9**	**11.9**

2.2.4 Atmospheric Stability

Atmospheric stability is frequently categorised into one of six stability classes. These are briefly described in Table 2-3. Atmospheric stability, in combination with wind speed, is important in determining the extent of a particular hazardous vapour release.

A very stable atmospheric condition, typically at night, would have low wind speeds and produce the greatest endpoint for a dense gas. Conversely, a buoyant gas would have the greatest endpoint distance at high wind speeds.

Table 2-3: Classification scheme for atmospheric stability

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

The atmospheric stability for Mortimer Hostel, as a function of the wind class, was calculated from hourly weather values supplied by the WSP (Mortimer Hostel) for the period 1st of January 2013 to the 31st of December 2015, as given in Figure 2-2.

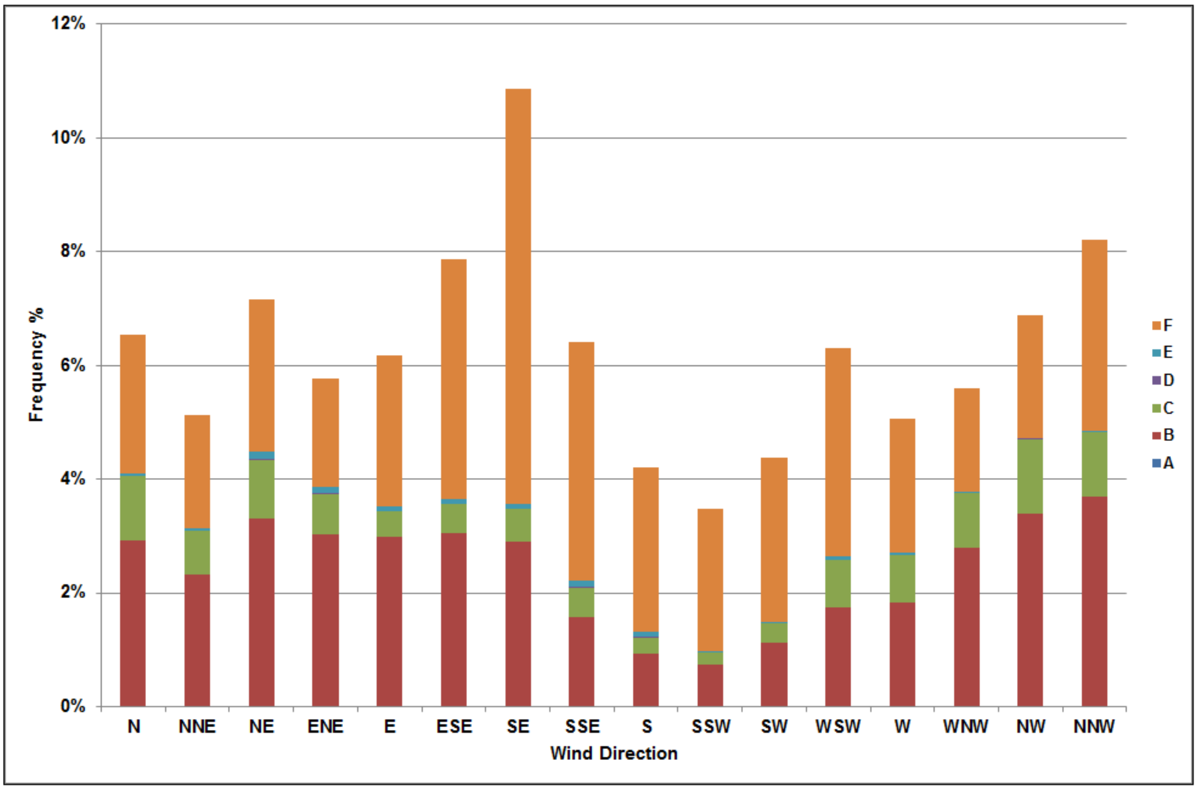

Figure 2-2: Atmospheric stability as a function of wind direction

Calculations for this risk assessment are based on six representative weather classes covering stability conditions of stable, neutral and unstable as well as low and high wind speeds. In terms of Pasquill classes, 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 vector quantities (having speed and direction) and blow preferentially in certain directions, it is mathematically incorrect to give an average wind speed over 360° of wind direction; the result would be incorrect risk calculations.

It would also be incorrect to base risk calculations on one wind category, such as 1.5/F for example. In order to obtain representative risk calculations, hourly weather data for wind speed and direction was analysed over a three-year period and categorised into the six wind classes for day and night conditions and 16 wind directions. The risk was then determined using contributions from 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 given in

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>

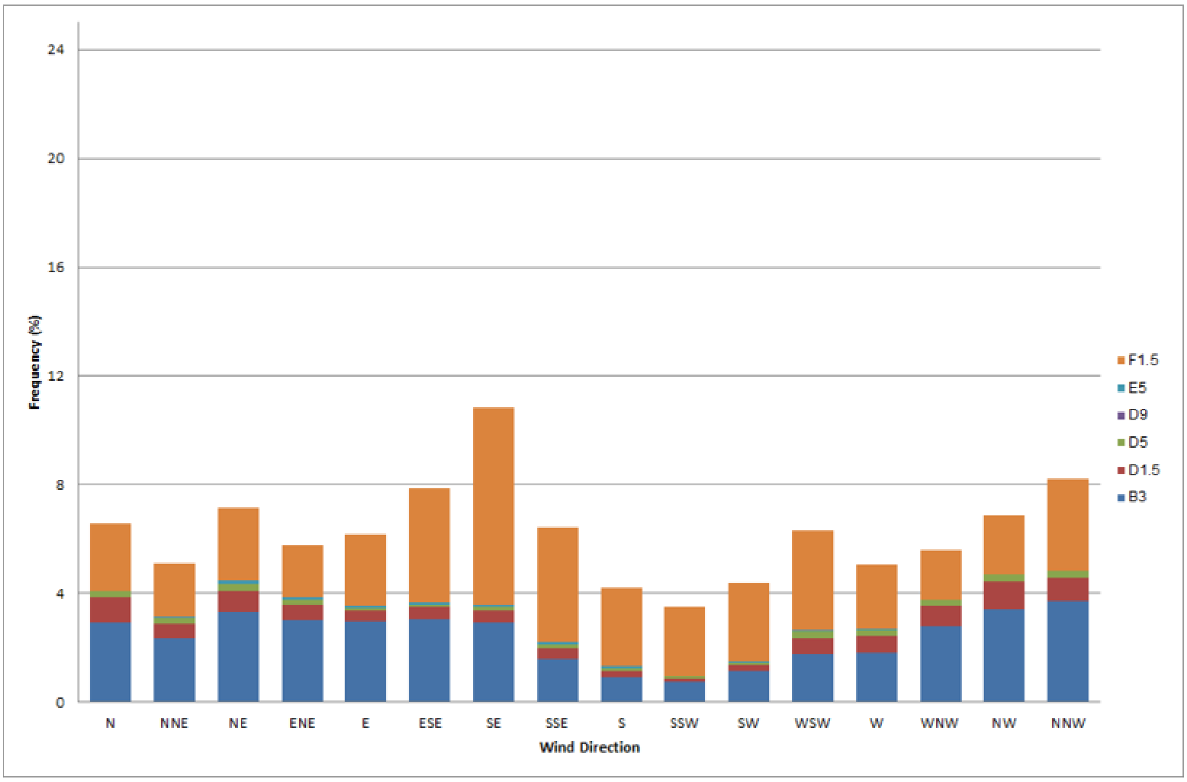

Figure 2-3: **Representative weather classes for the Mortimer Hostel Weather Station**

2.2.5 Default Meteorological Values

Default meteorological values used in simulations, based on local conditions, are given in Table 2-6.

Table 2-6: **Default meteorological values used in simulations, based on local conditions**

Parameter	Default Value (Day)	Default Value (Night)
Ambient temperature (°C)	27.9	11.9
Substrate or bund temperature (°C)	19.9	19.9
Water temperature (°C)	19.9	19.9
Air pressure (bar)	0.91	0.89
Humidity (%)	*0.1	*0.1
Fraction of a 24 hour period	0.5	0.5
Mixing height	[1]	[1]

* Not available conservative value used for purposes of simulation.

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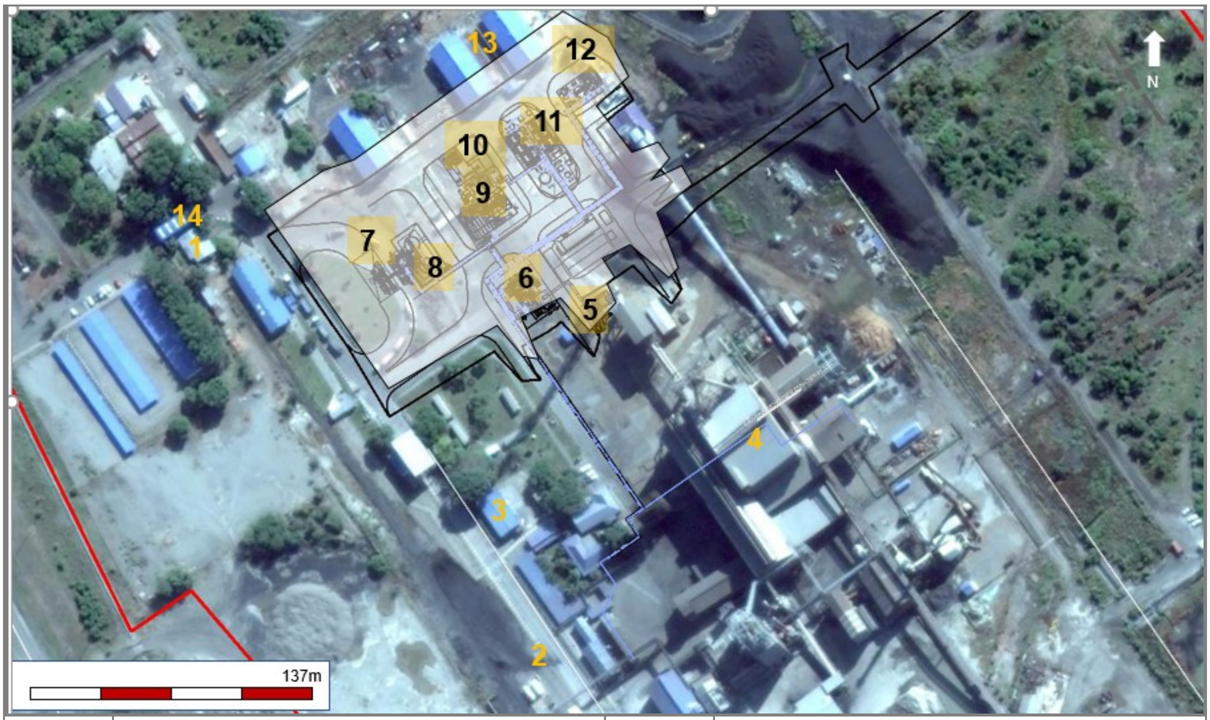
[1] The default values for the mixing height, which are included in the model, are: 1500 m for Weather Category B3; 300 m for Weather Category D1.5; 500 m for Weather Category D5 and Weather Category D9; 230 m for Weather Category E5; and, 50 m for Weather Category F1.5.

3 PROCESS DESCRIPTION

3.1 Site

The proposed SO_2 abatement project is, superimposed (in white) on the existing Mortimer Smelter facilities in Figure 3-1. The facility consists of process piping and equipment for the production of sulphuric acid, storage vessels, an effluent treatment plant and acid road tanker loading facilities.



No.	Description	No.	Description
1	Security	2	Existing LPG storages
3	Offices	4	Existing furnace building
5	Existing stack	6	Gas cleaning and cooling
7	Acid tanker loading and bund	8	2 x 277 m^3 acid storage tanks and bund
9	WSA plant	10	New off gas stack
11	Water cooling	12	Effluent plant
13	Existing workshops	14	Existing vehicle entrance/exit

Figure 3-1: Site layout

3.2 Process Description

Mortimer Smelter receives sulphide concentrates from various platinum concentrators for further processing. The concentrates are handled, blended and dryed prior to being fed to a furnace for smelting. The smelting process results in a matte that contains the Platinum Group Metals (PGM's) and base metals, which is transported to facilities in Rustenburg for further processing. A slag and furnace off gases (containing sulphur dioxide) are produced as effluent streams.

Currently furnace off gases containing particulates are passed through an electrostatic precipitator (ESP) to remove some of the particulates prior to disposal to the stack. Sulphur dioxide (SO_2) gas (1.5-2 % by volume) also forms part of the discharge. More stringent environmental regulations require that the SO_2 emissions be reduced prior to the disposal of the furnace off gases to the atmosphere (SO_2 abatement).

A number of SO_2 Abatement technologies are available, which have been accessed by AAP in previous project phases. The Haldor-Topsoe Wet Sulphuric Acid (WSA) Process has been selected as that best suited to implementation at Mortimer Smelter.

The process design basis considered in 2012 was based on assessments that may have changed in the intervening period. These include aspects such as:

- changes in the AAP mine plan which may affect concentrate grade (sulphur content) and throughput;
- potential changes in the operation of the furnace relating to power, feed rate, control, etc.

A schematic overview of the process is contained in Figure 3-2.

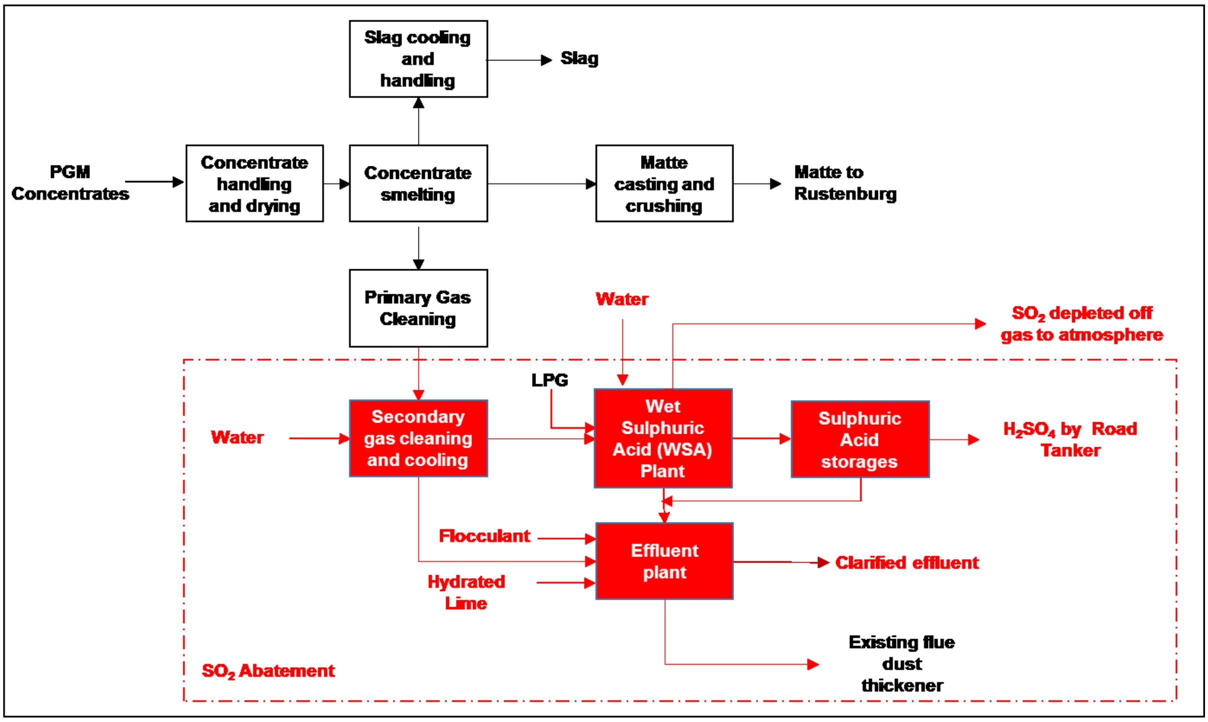


Figure 3-2: Schematic overview of the proposed process.

3.3 Primary Gas Cleaning

The furnace off-gas is initially dedusted using an ESP. The captured particulates contain valuable PGMs and are therefore fed back into the furnace.

3.4 Secondary Gas Cleaning

The furnace off-gas from primary gas cleaning contains residual dust with a concentration ranging between 200-400 mg/Nm^3; which exceeds the WSA plant requirement of less than 1 mg/Nm^3 of particulate matter and less than 20 mg/Nm^3 of SO_3. Further cleaning and cooling/conditioning of the furnace off-gas takes place ahead of the WSA Plant. Details of the additional gas cleaning and conditioning equipment are contained below.

The off-gas is saturated and cooled by water in a wet scrubber, which captures a large portion of the remaining dust in the water fed to the scrubber. A small fraction of the SO_2 will react with water to produce a weak sulphuric acid waste stream that will be pumped to the effluent treatment plant for neutralisation.

The gas is fed to a gas cooling tower, and passes through a spray cooled packed bed. In the process the off-gas is cooled to the desired WSA inlet temperature of 30 to 40°C.

Cooled off gas is then passed through the wet electro static precipitator (WESP), to reduce the particulate matter concentration in the off-gas entering the WSA plant to less than 1 mg/Nm^3 and the acid mist to below 20 mg/Nm^3.

3.5 Wet Sulphuric Acid Plant (WSA) Plant

The off-gas from the WESP enters the WSA plant. The gas is pre-heated to the required catalytic reaction temperature (405°C) before entering the SO_2 converter by passing through various heat exchangers and a support burner:

- a pre-heater that recovers heat from hot air from the acid condenser prior to the blower prior to it being mixed with gas recycled from the convertor feed using a recycle blower;
- a process gas heater that uses steam generated by the second process gas cooler (that cools the gas exiting the convertors) to heat the feed gas to the convertor;
- the first gas cooler also uses the heat of the gas exiting the convertor to heat the convertor feed gas;
- an interbed cooler cools the convertor gas between the catalyst beds to drive the SO_2 to SO_3 conversion further and heat the convertor feed gas;

Once heated, the gas then passes to support burner (LPG), which supplies any additional heat that is required to achieve auto thermal conditions (405°C), prior to the gas entering the convertor.

Heated off-gas enters the SO_2 converter, where the SO_2 is passed through beds of vanadium pentoxide catalyst. SO_2 in the off-gas is converted to SO_3 which is then reacted with water vapour in the off-gas to form H_2SO_4 vapour.

The conversion process occurs according the chemical reactions set out below:

$$SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$$

$$SO_3(g) + H_2O(v) \rightarrow H_2SO_4(v)$$

Off-gas containing H_2SO_4 vapour and residual SO_2 is fed into a condenser where it is cooled, causing the H_2SO_4 vapour to condense on glass tubes to form H_2SO_4 liquid with a concentration of between 95 to 98 %(w/w). The acid (at approximately 260°C) is collected at the bottom of the condenser and cooled before it is sent to the two acid storages provided.

The stripped off-gas passes through a mist filter to remove any acid mist carried over from the condenser before finally being emitted to the atmosphere via the acid plant stack. The weak acid produced by the mist filter is pumped to the effluent treatment plant for neutralisation.

Areas of the WSA plant are bunded to contain any sulphuric acid spillages and prevent the ingress of acid to the ground. The available bunds are stated as having the following capacities:

- 542-SU-001: 27.6 m^3
- 542-SU-002: 57.3 m^3
- 542-SU-003: 127.4 m^3

The process design, as presented in the 2012 documentation may be incomplete, as it does not contain recent developments:

- The WSA process is well proven to produce $H_2SO_4$with a strength ≥95%(w/w) H_2SO_4 even for low strength feed gas (<1% SO2), an integrated sulphuric acid concentrator

(ISAC) may need to be added in order to produce as close to 98 %(w/w) H_2SO_4 as possible under all conditions.

The ISAC is an add-on to the acid outlet of the condenser bottom. Acid is concentrated by blowing hot, dry air at a controlled rate through the ISAC (counter current with the acid) in order to vapourise excess moisture. The ambient air used is filtered, dehumidified, pressurised with a blower and heated before entering the ISAC.

- A molten salt heat exchange system (indirect) was proposed in 2012, for the heating of the convertor inlet gas, this has been replaced with the steam based system in the most recent process descriptions.

3.6 Effluent Treatment Plant

The effluent treatment plant (ETP) is provided to treat all water effluent streams produced by the SO_2 abatement project and prevent acidic streams being discharged unprocessed into the environment. These streams will include:

- weak acid effluent (1 – 5% (w/w) H_2SO_4) generated by the wet gas cleaning equipment;
- acid mist from the mist filter in the WSA condenser;
- stormwater runoff / any acid spillages captured within the bunded plant area;
- bleed off from the cooling towers; and,
- blow-down from the steam system.

Effluents containing weak sulphuric acid are pumped to tanks located in the ETP, where they are will be neutralised by a hydrated lime slurry to produce gypsum. The solids are removed using a thickener to produce a thickened gypsum stream and a clarified water stream at neutral pH.

The ETP will have a daily throughput capacity of approximately $204m^3$.

The gypsum will be fed back to the furnace at the Mortimer Smelter, and disposed of in this manner.

The area is bunded to prevent ingress of effluent and hydrated lime to the ground and the environment. Available bunded volumes are stated as being:

- 540-SU-001: $17.9m^3$
- 540-SU-002: $46.4m^3$

Hydrated lime delivered to site by road and stored in a dry silo prior to being used to make-up the slurry.

3.7 Acid Plant Cooling Water

Evaporative cooling towers will be used to cool the water required by the WSA and gas cleaning plant. Hot water returning from the process will be stored within a hot water tank prior to cooling in the cooling towers and recirculation.

The water will be chemically treated with flocculants, and sand filters will be utilised to remove any particulate matter. A bleed stream will be fed into the ETP.

The area will be bunded for the containment of spillages.

3.8 Sulphuric Acid Storage and Handling

The H_2SO_4 produced by the WSA process (approximately 1.6 tonnes per hour) will be stored in two closed vertical storage tanks. It is envisaged that approximately 560m^3 of acid will be stored. The stored acid will be removed by accredited transporters of acid, typically using 30 tonne road tankers.

All the acid storage and handling areas are bunded to prevent ingress of H_2SO_4 to the ground and the environment. The available bunds are stated as having the following capacities:

- 536-SU-001: 18.2 m^3
- 536-SU-002: 175.1 m^3
- 536-SU-003: 773.5 m^3

3.9 Liquid Petroleum Gas (LPG) Storage and Handling

LPG will be required by the WSA process for support heating (when the SO_2 concentration in the furnace off-gas is below the SO_2 concentration required for autothermal operation of the acid plant) and by the Mist Control Units.

The peak LPG requirement will be during start-up of the WSA acid plant which can take up to 5 days.

One additional LPG storage bullet of 22.5m^3 will potentially be installed in the existing LPG storage area (two of 22.5m^3 bullets) on the site plan. For the purposes of this assessment the delivery of LPG to the WSA plant has been considered on an “over fence” basis.

3.10 Water Useage

The SO_2 Abatement Project will require 468m^3/day of water. It is envisaged that the water will be obtained from the existing allocation of 15 000m^3/day to Union Mine. The Mortimer Smelter currently utilises 400m^3/day water.

3.11 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 N^{o.}	Inventory
1	Sulphuric acid (98%)	7664-93-9	280 m^3
2	Sulphuric acid (98%)	7664-93-9	280 m^3
3	Intermediate Acid Storage (98%)	7664-93-9	5 m^3
4	Off spec Sulphuric acid (95%)		50 m^3
5	Hydrated lime	1305-62-0	85 m^3 vertical silo

4 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 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 as listed in the regulation to notify the divisional inspector. 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.

None of the hazardous materials to be stored on site is listed as notifiable.

4.2 Substance Hazards

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

4.2.1 Chemical Properties

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

- **Sulphur Dioxide (SO_2)**

Sulphur dioxide is a colourless gas or compressed liquefied gas with a choking or suffocating odour. It has a boiling point of -10°C and is heavier than air. It is very toxic and is listed by the Environmental Agency of the United States as an extremely hazardous chemical.

Sulphur dioxide is acidic and reacts exothermically with bases such as amines, amides, metal oxides and hydroxides. It is frequently used as a reducing agent, although it is not a powerful one. However, it can also act as an oxidizing agent. It supports combustion of powdered aluminium and manganese and reacts explosively with fluorine. It is readily liquefied by compression. Contact between the liquid form and water may result in vigorous or violent boiling and extremely rapid vaporization. If the water is hot, an explosion may occur. Pressures may build to dangerous levels if the liquid contacts water in a closed container. Sulphur dioxide supports incandescent combustion of monocaesium acetylide, monopotassium acetylide, caesium oxide, iron (II) oxide, tin oxide and lead oxide.

It can be absorbed into the body by inhalation. A harmful and fatal concentration of this gas in the air will be reached very quickly on loss of containment. Inhalation of the gas may cause lung oedema and may affect the respiratory tract resulting in asthma-like reactions, reflex spasm of the larynx and respiratory arrest.

On exposure, sulphur dioxide may irritate the eyes and the respiratory tract. Rapid evaporation of the liquid may cause frostbite.

Sulphur dioxide in the atmosphere is absorbed by soils and plants. Even low concentrations of sulfur dioxide can harm plants and trees and reduce crop productivity. Higher levels, and especially the acidic deposits from acid rain, will adversely affect both land and water ecosystems.

The smelting operations at Mortimer Smelter produce elevated levels of sulphur dioxide in the furnace off gas. The SO_2 Abatement Project is aimed at reducing the SO_2 emissions and their impact on the environment, by capturing the SO2 as sulphuric acid.

- **Sulphur Trioxide (SO_3)**

Sulphur trioxide is a colourless to white crystalline solid that can also exist as a liquid or gas. It is not combustible but is a fire risk when it comes into contact with organic materials, such as wood, cotton, fibreboard, etc. The vapours are extremely toxic when inhaled.

Sulphur trioxide gas (heavier than air) is an intermediate in the production of sulphuric acid and can also be formed slowly in air from sulphur dioxide. Sulphur trioxide reacts readily with the moisture in the air to form submicron sulphuric acid drops that have the appearance of a dense white smoke or fog.

It has a strong affinity for water and may react with water, with explosive violence, to generate sulphuric acid. It dehydrates many organic substances exothermically, resulting in charring and burning. It is acidic and could react exothermically to neutralize bases. The solution in water it is a strong acid, reacts violently with bases and is corrosive to metals forming hydrogen, which is a flammable and explosive gas. The substance is a strong oxidant and reacts violently with combustible, reducing and organic components, causing fire and explosion hazards.

Acute health effects may occur immediately or shortly after exposure. Contact can severely irritate and burn the skin and eyes. Inhalation of sulphur trioxide may irritate the nose and throat and lungs and may cause a build-up of fluid in the lungs (pulmonary oedema), a medical emergency, with severe shortness of breath. High levels of exposure can cause headaches, nausea and dizziness and possibly death.

The ready reaction between water and sulphur trioxide to form sulphuric acid ensures that it does not persist in the environment except for very short periods when it may be present in the air as a gas.

- **Sulphuric Acid (H_2SO_4)**

Sulphuric acid is a clear, colourless, oily liquid. When heated, it will emit highly toxic fumes, which include sulphur trioxide. It is non-flammable, but when it comes in contact with other flammable materials it may react resulting in fires.

It can have violent reactions with water and strong bases, generating heat. The reaction with water can generate toxic vapours and accumulation of rainwater in sulphuric acid storage area bunds must not be permitted.

It is not compatible with organic materials, chlorates, carbides, fulminates and powdered metals. In contact with metal, it releases flammable hydrogen gas that will explode if ignited in enclosed spaces.

Sulphuric acid is hazardous for skin contact, inhalation, or ingestion. It is corrosive to the skin, eyes, nose, mucous membranes, respiratory and gastrointestinal tracts or any tissue with which it comes in contact. Severe burns can occur, with necrosis and scarring, and may result in death. Milder exposures can cause irritation of the eyes, skin, mucous membranes and respiratory as well as digestive tracts.'

Chronic exposure may be associated with changes in pulmonary function, chronic bronchitis, conjunctivitis and overt symptoms resembling acute viral respiratory tract infection. Discoloration and erosion of dental enamel can occur. Long-term exposure may cause mutations in living cells, bronchitis, emphysema, erosion and pitting of teeth, running nose, upset stomach and tearing of the eyes.

Sulphuric acid will exist as particles or droplets in the air if released to the atmosphere. It dissolves when mixed with water. Sulphuric acid is very corrosive and would badly burn any plants, birds or land animals exposed to it. It has moderate chronic (long-term) toxicity to aquatic life. Chronic effects on plants, birds or land animals have not been determined. Small quantities of sulfuric acid will be neutralised by the natural alkalinity in aquatic systems. Larger quantities may lower the pH for extended periods of time and contribute to acid mine drainage if allowed to enter the ground.

- **Hydrated Lime (Calcium Hydroxide $Ca(OH)_2$)**

Also, commonly referred to as slaked lime; calcium hydroxide is formed as a result of hydrating lime (calcium oxide, CaO). It is to be used as a slurry in the effluent plant to neutralise acidic effluent streams from the SO_2 Abatement facility.

Hydrated lime is a colourless white or greyish powder. Contact can cause irritation to the eyes, skin respiratory systems and gastrointestinal tract.

Hydrated lime is not flammable, or combustible. It reacts vigorously with acids and may release sufficient heat to ignite combustible materials in specific circumstances. Hydrated lime is not considered to be an explosion hazard, but may react vigorously with acids and other incompatible substances and rupture containers.

As the result of its high pH, it would be expected to produce significant ecotoxicity upon exposure to aquatic organisms and systems in high concentrations.

- **Liquid Petroleum Gas (LPG)**

LPG typically consists primarily of propane, but can contain significant quantities of other components such as butane. Propane is a colourless gas at room temperature with an 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 set on fire by many sources such as pilot lights, welding equipment, electrical motors, switches, etc. It is heavier than air and can travel along ground for some distance to an ignition source, or it can persist as pockets in areas of restricted airflow, that could pose a risk of delayed ignition. As a flammable gas LPG would fall into Category 0.

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

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

Overexposure to propane may cause dizziness and drowsiness. Effects of a single (acute) overexposure may result in asphyxiation, due to lack of oxygen that could be fatal. Self-contained breathing apparatus may be required by rescue workers. Moderate concentrations may cause headache, 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.

4.3 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.

A number of substances stored on site are considered corrosive, including sulphuric acid, sulphur dioxide, sulphur trioxide, and hydrated lime.

Liquid acids, with low vapour pressure, such as sulphuric acid, which are located sufficiently far from the site boundary, are not considered to be harmful to the public. The toxic effects from airborne releases of corrosive substances are covered in the subsection on toxic components.

4.4 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 stored on or delivered to site are considered thermally stable in atmospheric conditions. Reactions with air is covered under the subsection dealing with ignition probabilities.

4.5 Flammable and Combustible Components

Flammable and combustible components are those that can ignite and give a number of possible 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 stored on or delivered to site are listed in Table 4-1.

Table 4-1: Flammable and combustible components to be stored on or delivered to Site

Compound	Flash Point (°C)	Boil Point (°C)	Comment
LPG/Propane	-103.5	-42	Flammable Gas

4.6 Toxic Components

Toxic components of interest to this study are those that could produce dispersing vapour clouds upon release into the atmosphere. These could subsequently cause harm through inhalation or absorption through the skin. Typically, the hazard posed by toxic components will depend on both concentration of the material in the air and the exposure duration.

Sulphur dioxide gas, and sulphur trioxide gas are components that are fed to or produced in the WSA process that would be considered acutely toxic.

The acute exposure guideline levels (AEGLs) are given in Table 4-2.

Table 4-2: Guideline levels for toxic and asphyxiant components

Component	***AEGL-1**		***AEGL-2**		***AEGL-3**	
	mg/m^3	**ppm**	**mg/m^3**	**ppm**	**mg/m^3**	**ppm**
Sulphur trioxide	0.2	0.06	8.7	2.7	160	51.6
Sulphur dioxide	0.524	0.2	1.96	0.75	78.5	30

* the AEGL's contained in the table are based on a 1 hour "exposure duration" as typically used for emergency planning purposes.

4.7 Physical Properties

For this study, LPG was modelled as a pure component, as given in Table 4-3. The physical properties used in the simulations were based on the DIPPR[1] data base. See Appendix C for the physical and toxicological values used in the simulations.

Table 4-3: Representative components

Component	**Modelled as**
LPG	propane

4.8 Components Excluded from the Study

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

Table 4-4: Components excluded from the study

Component	**Reasons for Exclusion**
*Sulphuric acid	Sulphuric acid will be stored at a distance well away from site the boundary in bunded areas with little impact on the public.
Liquid Petroleum Gas (LPG) offloading and storage	The LPG tank will be located together with two existing tanks in an existing facility of similar size. LPG has been treated as being supplied to the project on an "over the fence basis.
* Hydrated lime	Hydrated lime will be stored at a distance well away from site the boundary in bunded areas with little impact on the public.

*****Both sulphuric acid and hydrated lime have however been considered for the purposes of the environmental impact assessment later in the report.

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[1] Design Institute for Physical PRoperties

5 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.

5.1 Multiple Consequence Scenarios

5.1.1.1 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 5-1. The pool, formed after flashing, then evaporates at a rate proportional to the pool area, surrounding temperature and wind velocity.

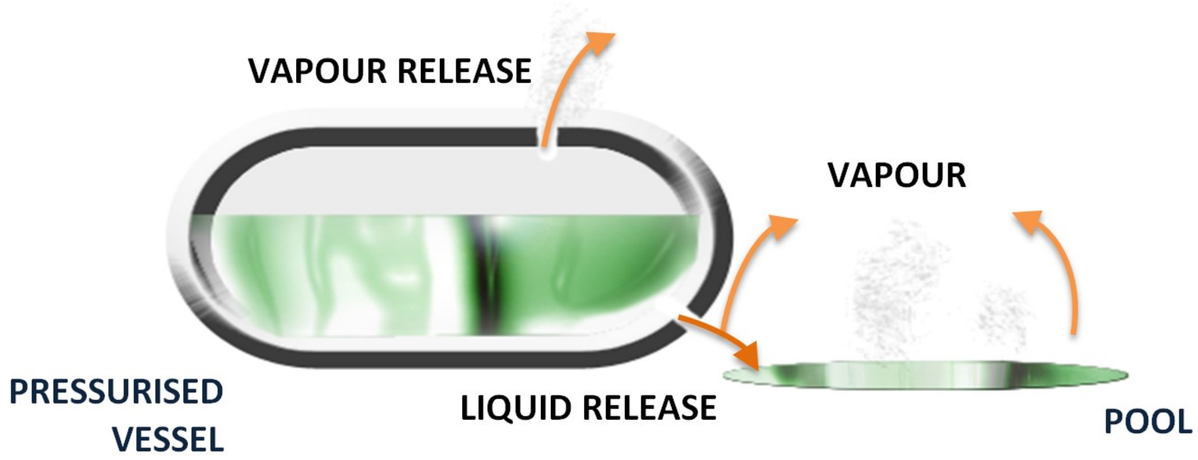


Figure 5-1: **Airborne vapours from a loss of containment of liquefied gas stored in a pressurised vessel**

5.1.1.2 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 5-2. 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.

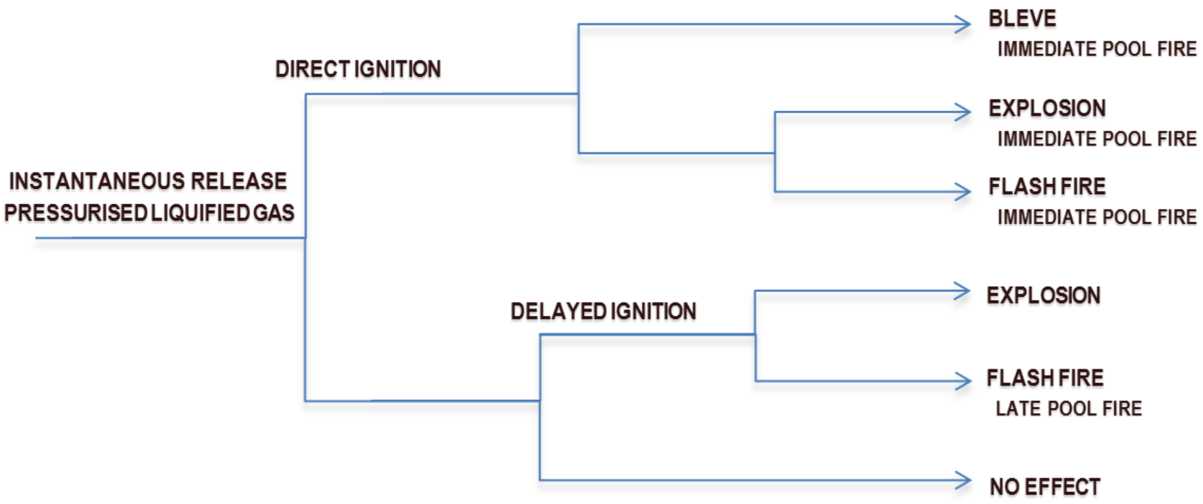


Figure 5-2: **Event tree for an instantaneous release of a liquefied flammable gas**

5.1.1.3 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 5-3. 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.

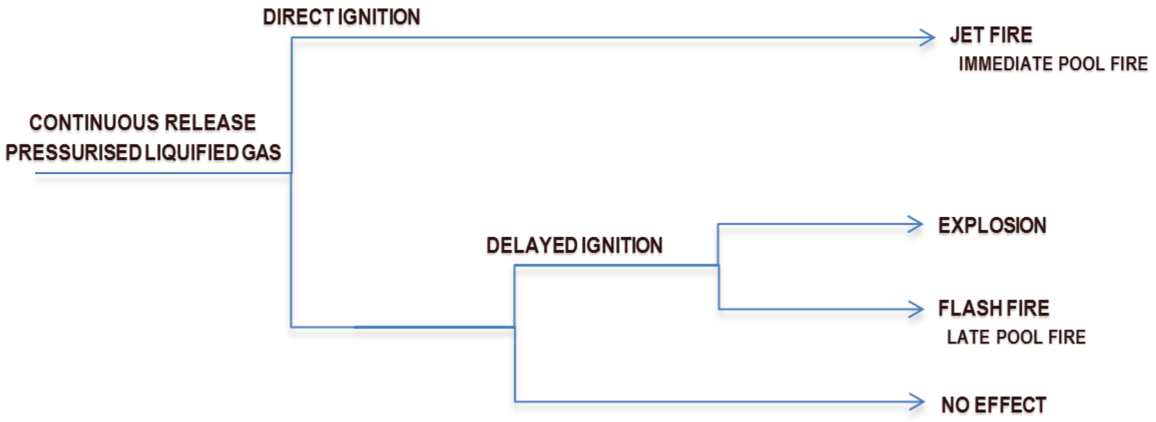


Figure 5-3: **Event tree for a continuous release of a liquefied flammable gas**

5.1.1.4 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 5-4. 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.

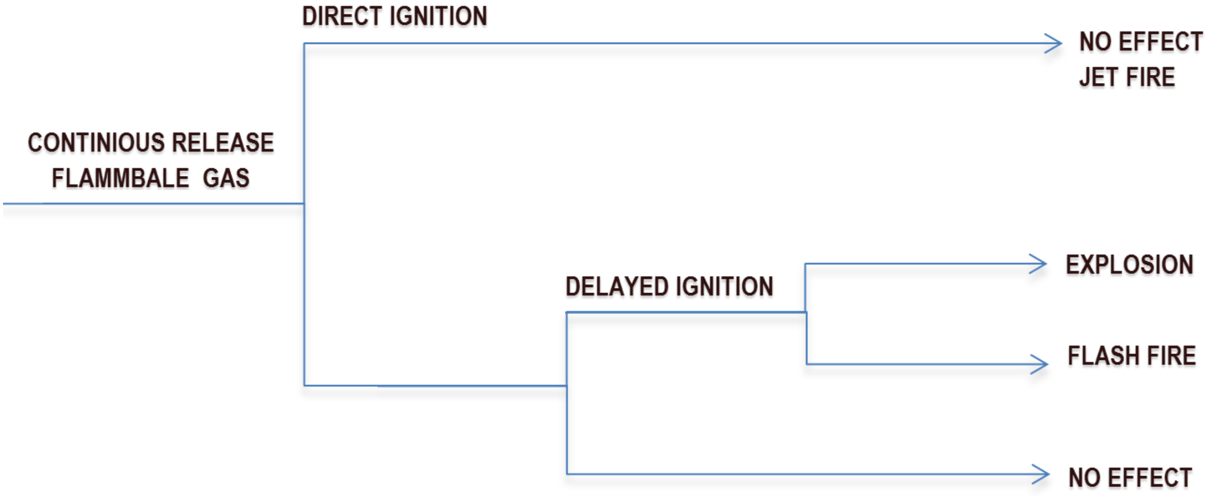


Figure 5-4: **Event tree for a continuous release of a flammable gas**

5.1.1.5 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 5-5. 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.

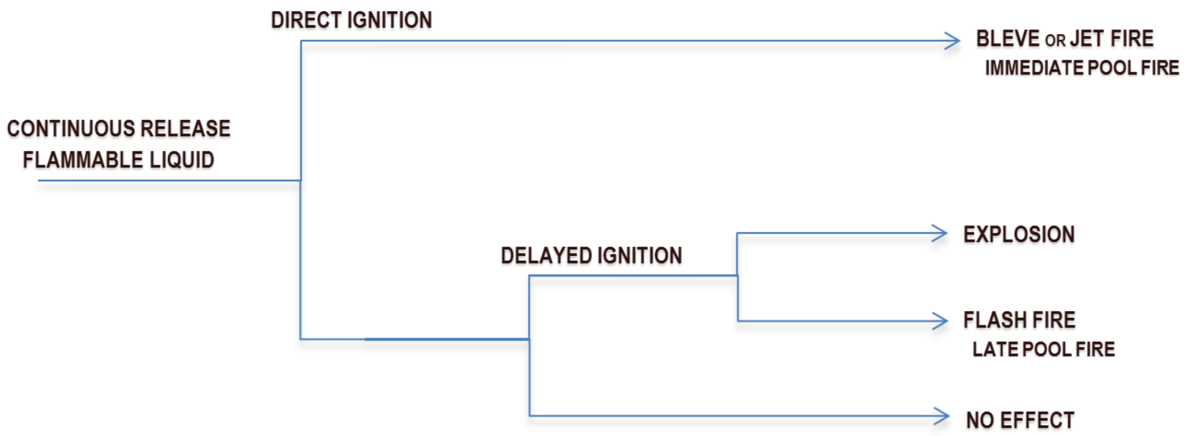


Figure 5-5: **Event tree for a continuous release of a flammable liquid**

5.2 Toxic Vapour Clouds

The purpose of considering vapour clouds emanating from toxic components is to identify sections of the surrounding community that may be affected by exposure or individuals in the community who may be subject to injury or death from an accidental release.

A toxic vapour cloud can occur when:

- Toxic gas is released under pressure;
- Toxic liquid spills and evaporates;
- Components combust forming toxic gases;
- Components react forming toxic gases.

In the case of a toxic liquefied gas, the rate of the component becoming airborne must be estimated as input for dispersion modelling. The pressure of contained liquefied gas is dependent on its temperature, and it remains liquefied due to the pressure inside the tank.

Quantification of the adverse impacts associated with a substance is made possible through dose-response analysis and exposure assessment. A large release of a toxic, flammable or explosive substance may result in death, nonlethal injury or irritation to humans and in damage to property. The characterisation of such impacts would be based on the calculation of downwind distances to various acute exposure guidelines.

Limits for brief exposure to potentially lethal levels are given in terms of lethal concentration and lethal dose. Lethal concentration and lethal dose are determined by tests on animals. Lethal concentration LC_{50} refers to the concentration of airborne material 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 (normally up to 4 hrs.). Lethal dose LD_{50} refers to the quantity of material administered, either orally or by skin adsorption, which results in death of 50% of the test group.

An approach that may be adopted involves comparison of predicted concentrations to exposure guidelines. These guidelines may include the following occupational exposure limits: the threshold limit values (TLVs); the immediately dangerous to life or health (IDLH) values; or, the acute exposure guideline level (AEGL) values.

AEGL values were developed by the US Environmental Protection Agency (EPA) and are defined as the maximum concentrations that individuals could be exposed to for a period of one hour before certain health effects would occur in sensitive populations. In the event that AEGL values are not yet available for a particular component, emergency response planning guideline (ERPG) values or temporary emergency exposure limits (TEELs) could be used.

This study refers to the AEGL values for the assessing of emergency response plans and LC_1 (1% fatality based on inhaled dosages derived from probit values) for determining the significance and extent off-site impacts. In this report, all AEGL values are based on one hour.

5.2.1 Sulphur Dioxide and Sulphur Trioxide

Sulphur dioxide gas is a product of smelting PGM concentrates which is converted to sulphur trioxide gas, which is used to produce sulphuric acid. Both sulphur dioxide and sulphur trioxide are intermediate products, which are consumed on a continuous basis in the process, without the accumulation of significant inventories.

Sulphur dioxide and sulphur trioxide are both considered to be acutely toxic. A loss of containment in the process could result in a release of sulphur dioxide and sulphur trioxide to the atmosphere.

Accidental releases at various points in the process were simulated to determine the endpoints to the 1% fatality and the AEGL-2 guideline. The release rate, temperatures and pressures were based on the mass balance supplied by AAP.

Releases for sulphur dioxide and sulphur trioxide were simulated for a full-capacity rupture. The orientation of the releases was simulated as horizontal. The release rates for a full-capacity rupture are given in Table 5-1 and are based on the mass balance contained in Drawing No. S-02799 P41024 in Appendix D.

The downwind distances to the acute exposure guideline limit 1% fatality and AEGL-2 for SO_2 are contained in are given in Table 5-2 and those for SO_3 are contained in Table 5-3.

Table 5-1: Release rates from accidental ruptures

Parameter	Stream No.	1	*10*	*100*	*180*	*835*
	Description	Feed to Secondary Gas Cleaning	Feed to WSA plant	Converter Inlet	Converter Exit	Stack
		Full-Bore Rupture	Full-Bore Rupture	Full-Bore Rupture	Full-Bore Rupture	Full-Bore Rupture
Sulphur dioxide	kg/s	0.32	0.32	0.32	0.009	0.009
Sulphur trioxide	kg/s	0	0	0	0.39	0
Volumetric Flowrate	Nm^3	26 000	26 000	26 537	26 126	34676
$S0_2$ Concentration	% (v/v)	1.5	1.5	1.47	379 ppm	286 ppm
$S0_3$ Concentration	%(v/v)	0	0	0	0.6	0
Temperature	°C	280	40	405	270	80
Pressure	kPag		>9	7.0	-0.5	0

Table 5-2: Sulphur dioxide maximum endpoint to the 1% Fatality and AEGL-2 guideline

Parameter	Scenario No.	SO2-1	SO2-10	SO2-100	SO2-180	SO2-835
	Scenario	Full-Bore Rupture	Full-Bore Rupture	Full-Bore Rupture	Full-Bore Rupture	Full-Bore Rupture
1 % Fatality	m	47.2	68.2	22.4	22.2	19.4
AEGL-2	m	4476	>10 000	2485	3973	1896

Table 5-3: Sulphur trioxide maximum endpoint to the 1% Fatality and AEGL-2 guideline

Parameter	Unit	SO3-180
		Full-Bore
1 % Fatality	m	481.8
AEGL-2	m	6050

Figure 5-6 illustrates the various scenarios for SO_2 dispersion. The maximum extent for the 1% fatality for sulphur dioxide under low wind conditions (1.5 m/s), occurs for the cool gas feed to the WSA (blue isopleths). The thin lines indicate the cloud plume from a northerly wind direction, while the thicker lines represent the extent of the plume from all wind directions.

The 1% fatality isopleth does not extend over the site boundary with major failures of the piping, but does indicate the potential for onsite fatalities. Further analysis for the purposes of determining the MHI status of the project would not be required.

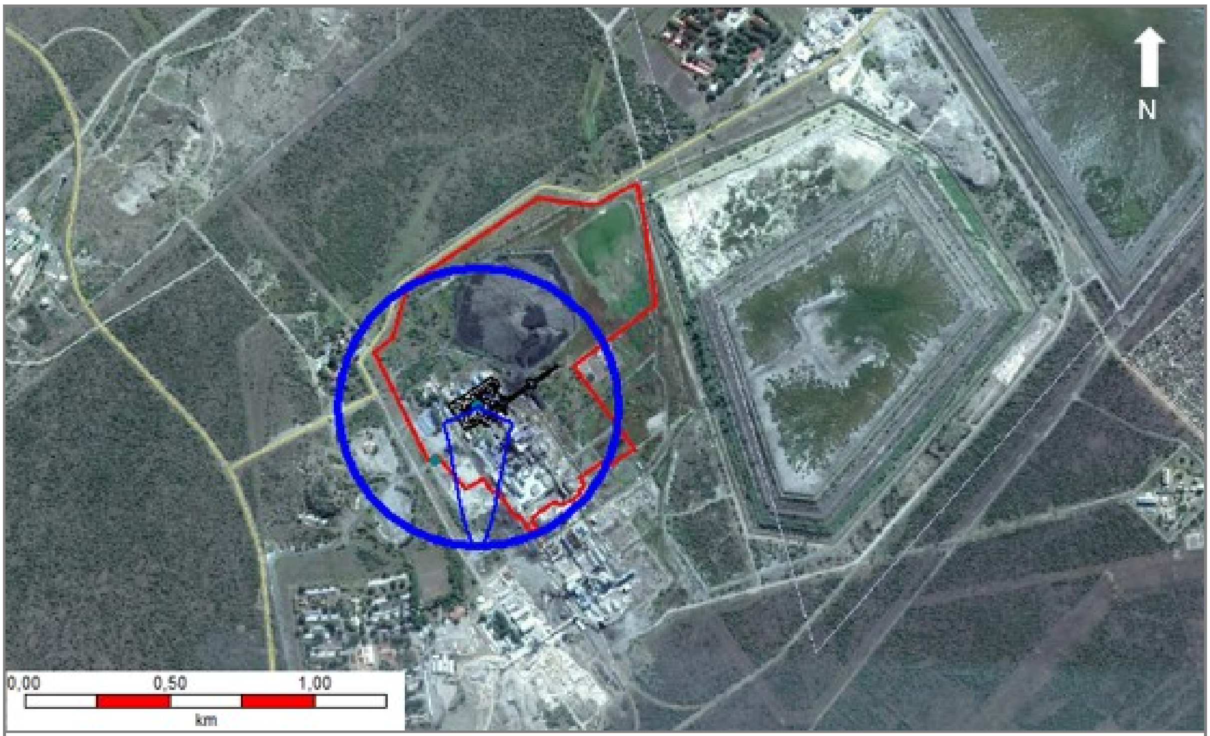
LEGEND	SCENARIO	
🟪	SO2-1	Full-bore rupture
🟥	SO2-180	Full-bore rupture
🟨	SO2-835	Full-bore rupture
🟦	SO2-10	Full-bore rupture (maximum extent)

Figure 5-6: Maximum extent of the 1% fatality for major releases of sulphur dioxide

The occurrence of sulphur trioxide SO_3 is very limited in the process. It is limited to the areas around the convertor and process feed piping to the acid condenser.

Figure 5-7 shows the scenarios with the largest distances to the 1% fatality for sulphur trioxide associated with loss of containment after the conversion of SO_2 to SO_3. The thin line indicates the cloud plume from a northern wind direction, while the thicker line represents the extent of the plume from all wind directions.

The 1% fatality for a major piping failure does extend over the site boundary of the area retained by AAP into UPM. Further analysis would be required to determine the risk associated with these scenarios.



LEGEND	**SCENARIO**	
━	32-SO3	190 Full-bore rupture

Figure 5-7: **Maximum extent of the 1% fatality for major releases of sulphur trioxide**

5.2.2 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.

5.2.2.1 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 5-4.

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

Table 5-4: 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.

5.2.2.2 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.

No pool fires were predicted from the simulations.

5.2.2.3 Jet Fires

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

In the 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’.

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.

The worst-case jet fire would be from a catastrophic failure a 40mm pipeline feeding the LPG support burner on the convertor, with a subsequent ignition. The thin lines indicate the radiation from a single orientation, while the thicker lines indicate the thermal radiation from all directions.

The 10 kW/m^2 thermal radiation, representing the 1% fatality, would not extend beyond the site boundary. No further analysis would be required.

Depending on the position of the releases there would be potential for the jet fire to reach process equipment adjacent to the support burner, causing damage to that process equipment. This would result in a knock-on effect with toxic and flammable consequences.

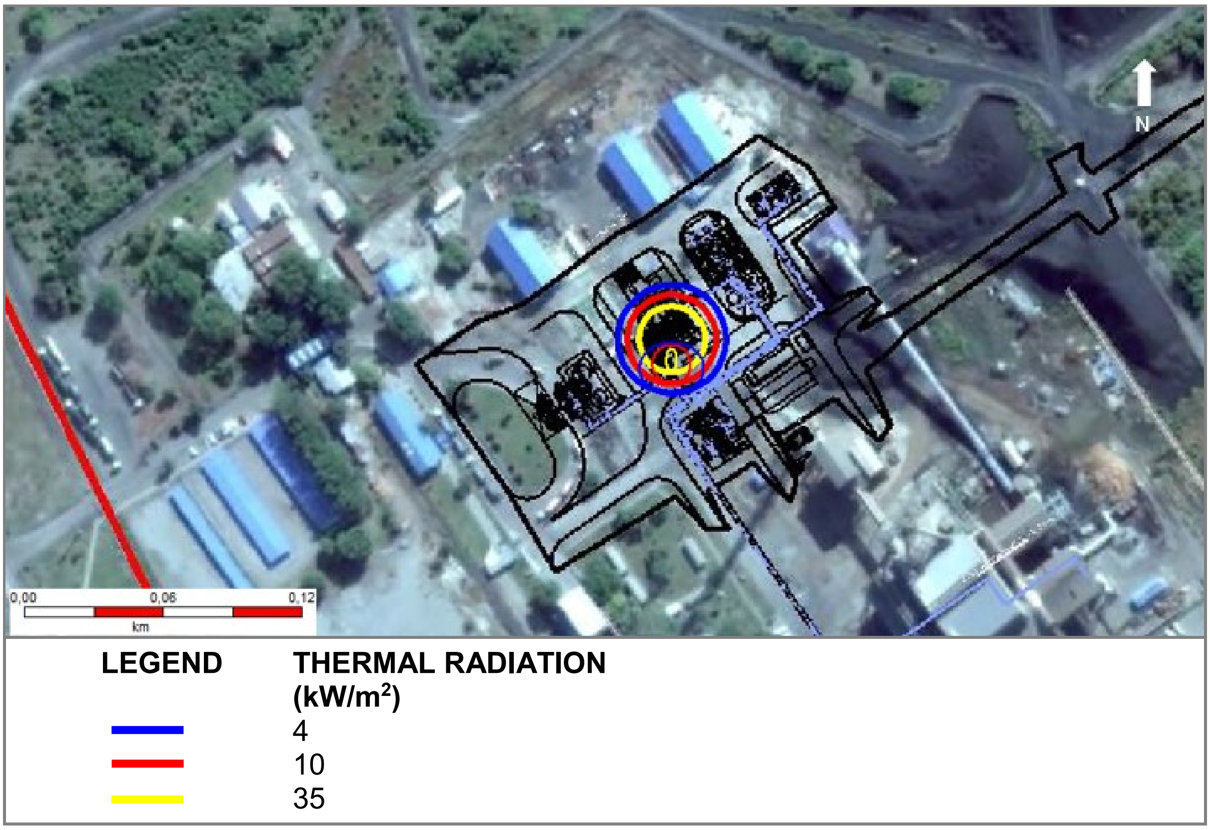


Figure 5-8: **Thermal radiation from large flammable LPG gas fires in the burner area**

5.2.2.4 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.

5.2.3 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.

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 a probability of death equal to 1.0 for unprotected people in the open;
- 0.7 bar overpressure, corresponding to an almost entire destruction of buildings and 100% fatality for people in the open.

No explosions were predicted from the simulations.

5.3 Risk Analysis

5.3.1 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 5-5.

Table 5-5: 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 address 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.

5.3.2 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.

5.3.2.1 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. Analysis was completed using published failure rate data. 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;
- Release of toxic or asphyxiant components.

- **Storage Vessels**

Scenarios involving storage vessels can include catastrophic failures that would lead to leakage into the bund with a possible bund fire. A tank-roof failure could result in a possible tank-top fire. The fracture of a nozzle or transfer pipeline could also result in leakage into the bund.

Typical failure frequencies for atmospheric and pressure vessels are listed, respectively, in Table 5-6 and Table 5-7.

Table 5-6: 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 5-7: Failure frequencies for pressure vessels

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

- **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 5-8 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 5-8: 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	$1x10^{-7}$	$5x10^{-7}$

For scenarios and failure frequencies no distinction is made between process pipes and transport pipes, the materials from which a pipeline is made, the presence of cladding, the design pressure of a pipeline or its location on a pipe bridge. However, a distinction is made between aboveground pipes and underground pipes. The scenarios for aboveground pipes are given in Table 5-9, and those for underground pipes are given in Table 5-10.

Transport pipelines aboveground can be compared, under certain conditions, with underground pipes in a pipe bay. The necessary conditions for this are external damage being excluded, few to no flanges and accessories present and the pipe is clearly marked. In very specific situations the use of a lower failure frequency for transport pipes aboveground can be justified.

Table 5-9: Failure frequencies for aboveground transport pipelines

Description	Frequency (per meter per annum)		
	Nominal Diameter < 75 mm	**75 mm > Nominal Diameter > 150 mm**	**Nominal Diameter > 150 mm**
Full bore rupture	$1x10^{-6}$	$3x10^{-7}$	$1x10^{-7}$
Leak with an effective diameter of 10% of the nominal diameter, up to a maximum of 50 mm	$5x10^{-6}$	$2x10^{-6}$	$5x10^{-7}$

Table 5-10: Failure frequencies for underground transport pipelines

Description	Frequency (per meter per annum)		
	Pipeline in Pipe Lane[1]	**Pipeline Complies with NEN 3650**	**Other Pipelines**
Full bore rupture	$7x10^{-9}$	$1.525x10^{-7}$	$5x10^{-7}$
Leak with an effective diameter of 20 mm	$6.3x10^{-8}$	$4.575x10^{-7}$	$1.5x10^{-6}$

---

[1] A pipeline located in a 'lane' is a pipeline located with a group of pipelines on a dedicated route. Loss-of-containment frequencies for this situation are lower because of extra preventive measures.

- **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 5-11 and Table 5-12.

Table 5-11: Failure frequency for centrifugal pumps and compressors

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

Table 5-12: Failure frequency for reciprocating pumps and compressors

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

- **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 5-13.

Table 5-13: Failure frequencies for loading and offloading arms and hoses

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

- **Road or Rail Tankers within the Establishment**

Road or rail tankers are transport vehicles with fixed and removable tanks. In addition, they include battery wagons and, insofar as these are fitted on a transport vehicle, tank containers, swap-body tanks and MEGCs (multiple element gas containers).

The failure rate of tankers on an establishment is dependent on the pressure rating of the tank and is given in Table 5-14 and Table 5-15.

Table 5-14: Failure frequencies for road tankers with an atmospheric tank

Event	Frequency (per annum)
Instantaneous release of the entire contents	1×10^{-5}
Release of contents from the largest connection	5×10^{-7}

Table 5-15: Failure frequencies for road tankers with a pressurised tank

Event	Frequency (per annum)
Instantaneous release of the entire contents	1×10^{-7}
Release of contents from the largest connection	5×10^{-7}

It should be noted that no scenarios are included for loss of containment as a result of external damage to tanker or fire in the surrounding areas. It is assumed that sufficient measures are taken to prevent external damage to the tanker.

- **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 5-16 (along with classification of flammable substances in Table 5-17). 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 5-16: 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 5-17: 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.

5.3.3 Risk Calculations

5.3.3.1 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.

5.3.3.2 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 5-9.

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.

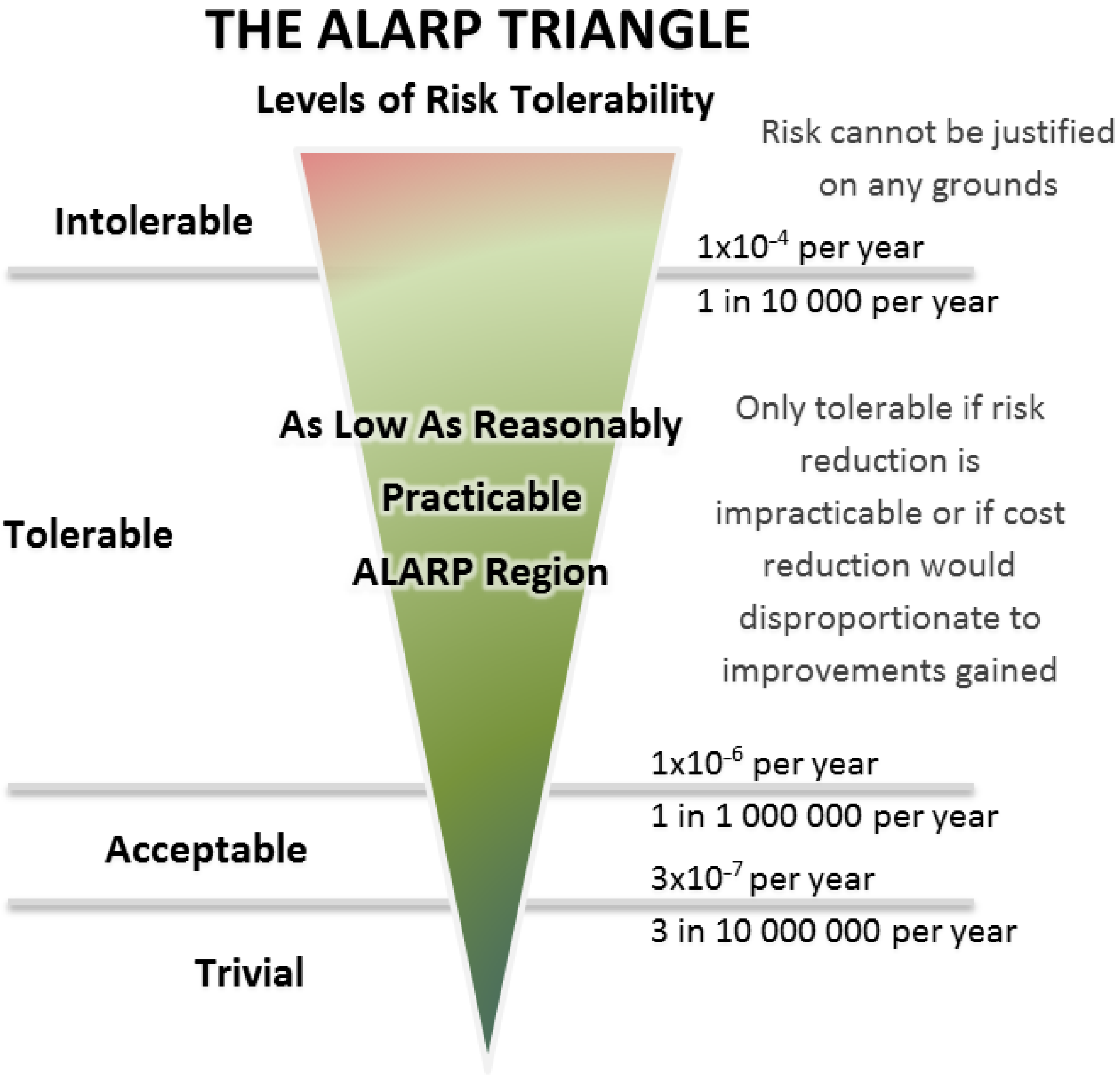


Figure 5-9: UK HSE decision-making framework

It should be emphasised that the risks considered acceptable to workers are different to those considered acceptable to the public. This is due to the fact that workers 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.* “

5.3.3.3 Land Planning

There are no legislative land-planning guidelines in South Africa and in many parts of the world. Further to this, land-planning guidelines vary from one country to another, and thus it is not easy to benchmark the results of this study to international criteria. In this instance, RISCOM would only advise on applicable land planning and would require governmental authorities to make final decisions.

Land zoning applied in this study follows the 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 5-10 and Figure 5-11.

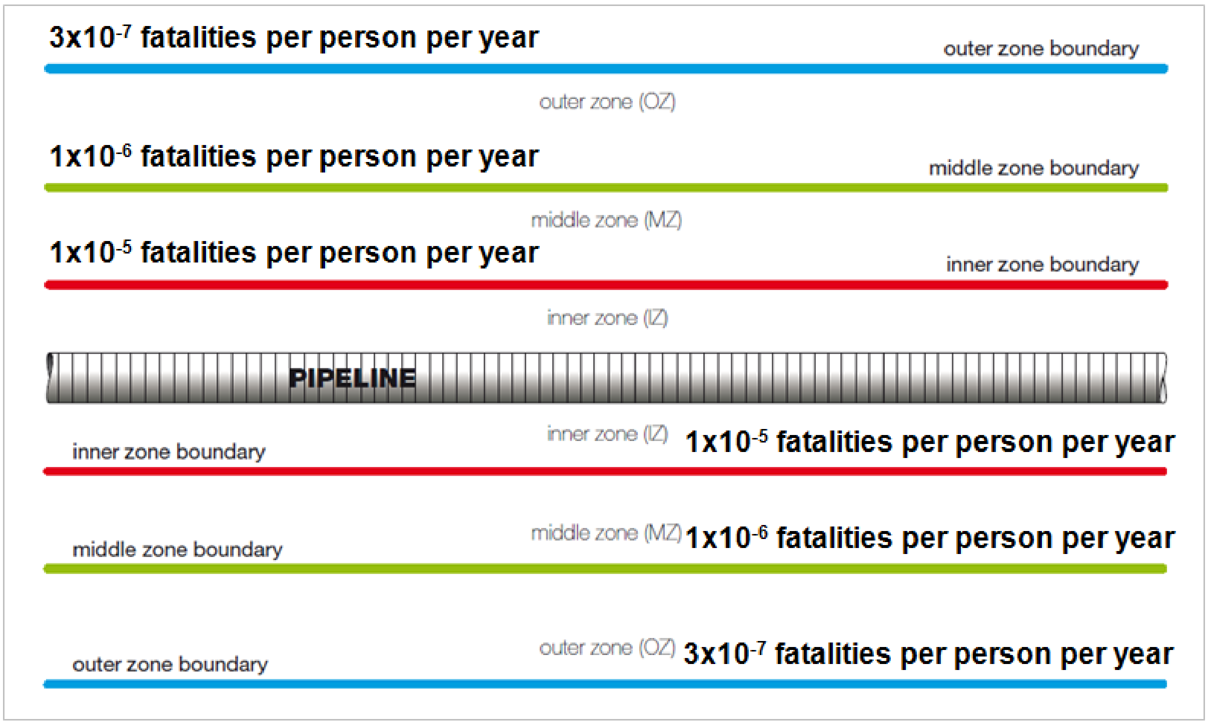


Figure 5-10: Town-planning zones for pipelines

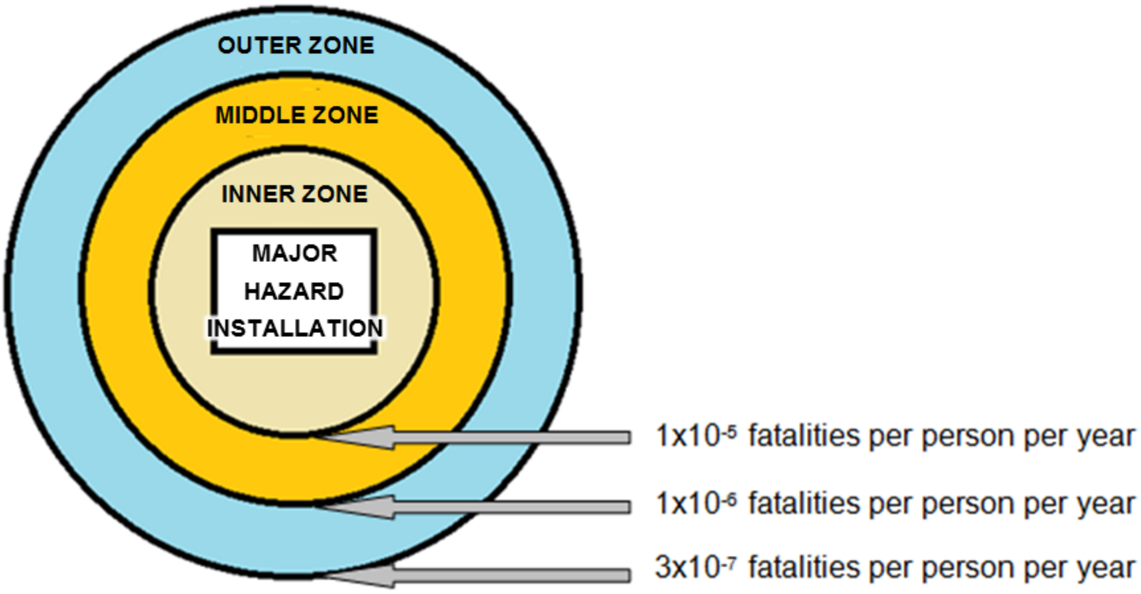


Figure 5-11: Town-planning zones

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 5-18. There are no land-planning restrictions beyond the outer zone.

Table 5-18: 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 E 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.

5.3.3.4 Societal Risk Parameter

Risk criteria discussed so far have been for individual risks. There is also a need to consider incidents in the light of their effect on many people at the same time. Public response to an incident that may harm many people is thought to be worse than the response to many incidents causing the same number of individual deaths. Compliance with an individual risk criterion is necessary but not always sufficient. Even if it were sufficient, societal risk would also have to be examined in some circumstances.

Societal risk is risk of widespread or large-scale harm from a potential hazard. The implication is that consequence would be on such a scale as to provoke a major social or political response and may lead to public discussion about regulation in general. Societal risk therefore takes into account the density of the population around a Major Hazard Installation site and is the probability in any one year (F) of an event affecting at least a certain number (N) of people (also known as an FN curve).

Societal risk used in this study is based on legal requirements in the Netherlands and may differ from risk criteria and requirements in other parts of the world.

5.4 Quantitative Risk Assessment (QRA) Scenarios

5.4.1 Methodology

Due to the absence of South African legislation regarding determination methodology for quantitative risk assessment (QRA), the methodology of this assessment is based on the legal requirements of the Netherlands, outlined in CPR 18E (Purple Book; 1999) and RIVM (2009).

The evaluation of the acceptability of the risks is done in accordance with the Health and Safety Executive (HSE; UK) ALARP criteria, which clearly covers land use, based on the determined risks.

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;
5. Using the population density near the facility, determination of societal risk posed by the facility (if required).

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.

5.4.2 Scenario Selection

Guidelines for selection of scenarios is given in RIVM (2009) and CPR 18E (Purple Book; 1999). A particular scenario may produce more than one major consequence. In such cases, consequences are evaluated separately and assigned failure frequencies in the risk analysis. Some of these phenomena are described in the subsections that follow.

5.4.3 Maximum Individual Risk

5.4.3.1 Sulphur Trioxide

Sulphur Trioxide is generally considered acutely toxic by the EPA and will be produced as an intermediate product in the production of sulphuric acid.

The risk of $1x10^{-6}$ fatalities per person per year isopleth, due to a release of toxic sulphur trioxide, did not extend beyond the site boundary, as depicted in Figure 5-12. As a result, the AAP SO_2 Abatement facility wo**uld not be classified as a Major Hazard Installation**.

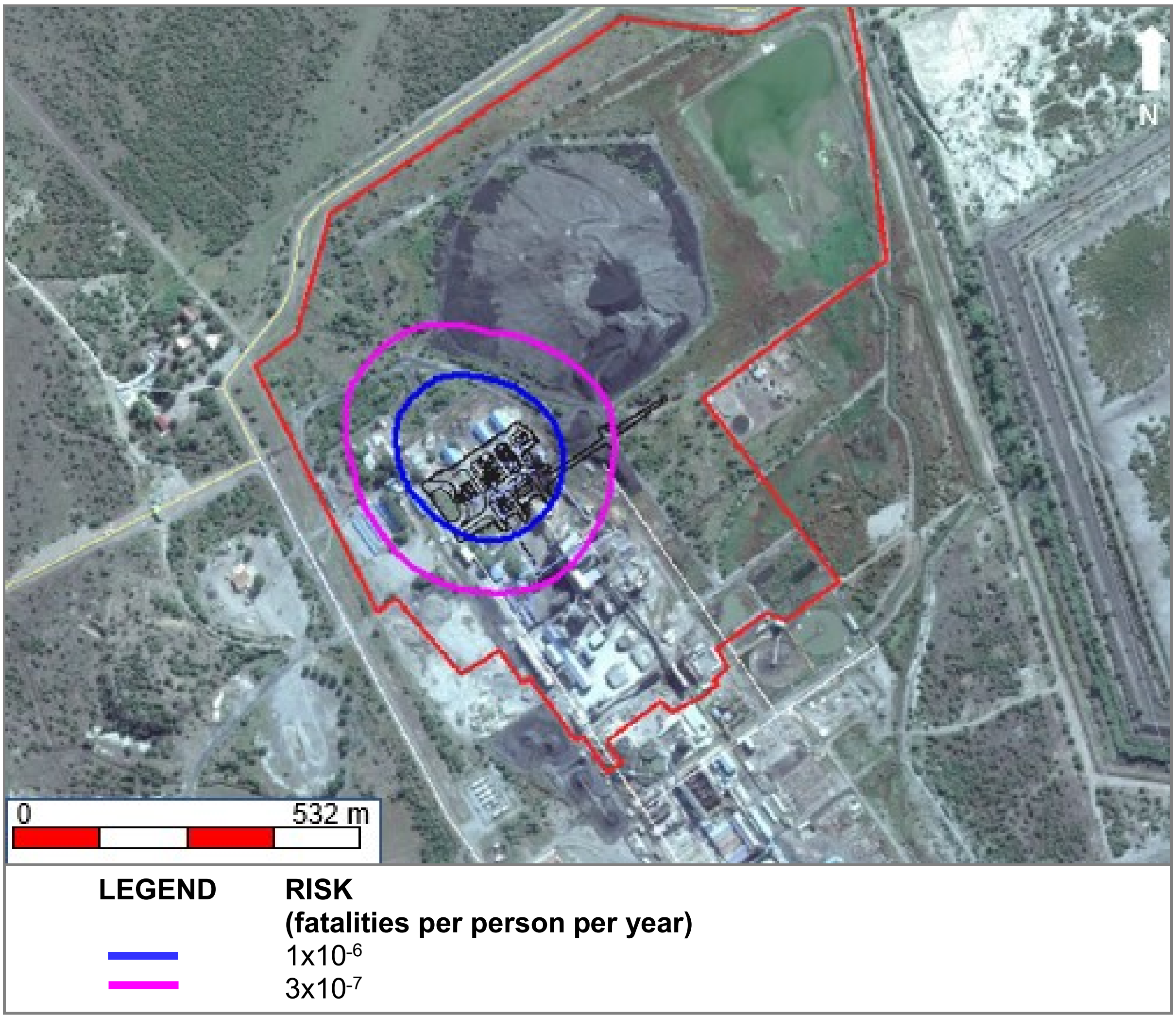


Figure 5-12: Lethal probability isopleths associated with toxic sulphur trioxide gas

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.

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

5.5 Societal Risk

Societal risks were not assessed, as the SO_2 Abatement Project would not contribute to the site being classified as an MHI.

6 REDUCTION OF RISK

From the simulations performed, the area of highest risk has been identified as the loss of containment of toxic sulphur trioxide. This would not result in an unacceptable risk, and mitigation would be up to the discretion of the management of AAP.

Implementation of any mitigation should always be done in accordance with recognised engineering practices, using applicable codes and standards.

7 IMPACT ASSESSMENT

7.1 Potential Impacts of the Project

The potential environmental impacts of the SO_2 Abatement Project associated with the production, handling and storage of hazardous chemicals have been identified, based on the QRA techniques used for the evaluation of the MHI status of a facility as outlined in the previous sections.

7.2 Impact Assessment Methodology

The EIA uses the framework developed by WSP | Parsons Brinckerhoff which is contained in Appendix I, to meet the combined requirements of international best practice and NEMA, Environmental Impact Assessment Regulations, 2014 (GN No. 982) (the “EIA Regulations”). This is the basis used for developing the significance rating for each of the identified impacts.

7.3 Considerations

The SO_2 Abatement Project assessment was based on the considerations listed below:

- construction phase risk assessment;
- operational phase risk assessment;
- decommissioning phase risk assessment;
- cumulative impacts;
- no-go impacts (impacts if the project does not proceed);
- confidence.

7.4 Construction Phase Risk Assessment

Small quantities of hazardous materials such as diesel, gasoline, lubricants and paints and solvents will be stored on site during construction. with minimal potential for impacts to the environment and the public.

The Mortimer Smelter is an operational site and will continue to produce off-gas containing sulphur dioxide during the construction phase of the project. A loss of containment would impact the construction site, but would not impact the public.

No additional acutely hazardous materials will be produced (sulphur trioxide and sulphuric acid) or stored (sulphuric acid) in bulk during the construction phase.

7.5 Operational Phase Risk Assessment

Hazardous materials will be produced and stored as the result of the implementation of the SO_2 Abatement project. Sulphur dioxide contained in the furnace off-gas will be converted to a sulphur trioxide intermediate (no storage) which will be used to produce sulphuric acid which will be stored in storage tanks. Losses of containment of process gases could result in toxic releases that could impact the environment.

A number of control measures are indicated in the project P&IDs to reduce the frequency and extent of sulphuric acid spillages. These include:

- The sulphuric acid storage, pumping and road tanker loading areas will be provided with bunds (secondary containment) to contain spillages and prevent losses to the ground and into surface water;
- Level indication and controls are indicated to prevent overfilling of the acid storage tanks and when loading acid road tankers;
- Gantries and loading arms have been provided for the loading of sulphuric acid tankers.

Lime/hydrated lime will be used to neutralise acidic effluents generated from the process in the effluent plant. Bunded areas have been provided at the effluent plant to prevent lime slurry and untreated effluent streams from entering the ground or surface water.

LPG will be required to fuel the burner. The potential exists for loss of containment and with the application of an ignition source this can lead to fires and explosions. Full application of the relevant SANS codes, in particular SANS 100087-3, would effectively mitigate against this.

7.5.1 Potential Section 30 Incidents/30 A Situation

The production, use and storage of bulk hazardous materials generates the potential for Section 30 incidents during the operational phase of the project which may include:

- Loss of primary containment (leaks in process equipment and piping) of sulphur dioxide to the atmosphere prior to the WSA convertor;
- Loss of primary containment (leaks in process equipment and piping) of sulphur trioxide to the atmosphere after the WSA convertor;
- Loss of primary containment (process piping) of sulphuric acid during processing into the ground or surface water;
- Loss of secondary containment (bunds) of sulphuric acid during storage, pumping or road tanker loading into the ground or surface water;
- Loss of secondary containment (bunds) of hydrated lime slurry and acidic effluents in the effluent plant into the ground or surface water.

AAP’s ability to identify, mitigate and/or prevent emergency incidents (section 30), is a key determinant in determining, whether there is the potential for an incident to escalate into a situation that will require external assistance or attract the attention of competent authorities.

7.5.2 Significance Rating

The significance rating for the various possible scenarios have been summarised in Table 2-1.

Table 7-1: Operational Phase Significance Rating Table

Potential Impact		**Extent**	**Duration**	**Magnitude**	**Probability**	**Significance**		**Status**
		(E)	**(D)**	**(M)**	**(P)**	**(S=(E+D+M)*P)**		**(+ve or -ve)**
Loss of primary containment of SO3 gas in WSA plant	**Nature of impact:**	Direct						
	Without Mitigation	2	1	4	2	**14**	**Low**	-
	degree to which impact can be reversed:	Irreversible						
	degree of impact on irreplaceable resources:	Negligible						
	Mitigation Measures	SO_3 monitoring and effective plant shutdown procedures. Bypass of furnace off-gas to the stack in extreme instances.						
	With Mitigation	1	1	2	2	**8**	**Low**	-
Loss of primary containment of SO2 gas in WSA plant	**Nature of impact:**	Direct						
	Without Mitigation	1	1	4	2	**12**	**Low**	-
	degree to which impact can be reversed:	Irreversible						
	degree of impact on irreplaceable resources:	Negligible						
	Mitigation Measures	SO_2 monitoring and effective shutdown procedures.						
	With Mitigation	1	1	2	2	**8**	**Low**	-

Potential Impact		**Extent**	**Duration**	**Magnitude**	**Probability**	**Significance**		**Status**
		(E)	**(D)**	**(M)**	**(P)**	**(S=(E+D+M)*P)**		**(+ve or -ve)**
Loss of secondary containment of sulphuric acid (storage and loading areas)	**Nature of impact:**	Direct						
	Without Mitigation	1	1	2	2	**8**	**Low**	-
	degree to which impact can be reversed:	Irreversible						
	degree of impact on irreplaceable resources:	Negligable						
	Mitigation Measures	Ensure bund integrity and piping, maintain bunds empty by draining spillage and rainfall, supervision of acid offloading operations, monitor effluents at the site boundary.						
	With Mitigation	1	1	2	1	**4**	**Low**	-
Loss of secondary containment of Hydrated Lime/effluent	**Nature of impact:**	Direct						
	Without Mitigation	1	1	2	2	**8**	**Low**	-
	degree to which impact can be reversed:	Irreversible						
	degree of impact on irreplaceable resources:	Negligable						
	Mitigation Measures	Ensure bund and piping integrity, maintain bunds empty by draining spillage and rainfall, monitor effluents at the site boundary.						
	With Mitigation	1	1	2	1	**4**	**Low**	-

7.5.3 Mitigation Measures

These would largely be organisational in nature and might include:

- The bypass of furnace off-gas to the stack in extreme instances to reduce the impact of loss of primary containment of process gases in the WSA;
- SO_2/SO_3 monitoring and shutdown procedures;
- regular inspection and maintenance of ducting and equipment (WSA is a wet plant with the potential for corrosion);
- regular inspection of bunded areas to ensure integrity and that are they are kept free of spillage and rainwater. Sulphuric acid bunded areas to be kept clear of rainwater, to prevent violent reaction with acid spillages which may be accompanied by the generation of toxic vapours.
- routine monitoring of plant effluent streams to identify possible losses of hazardous chemicals in the process.

7.6 Decommissioning Phase Risk Assessment

Once the facility is decommissioned all activities will cease. There is a requirement to minimise the risk of environmental impacts that may result from the decommissioning and closure of the site.

On decommissioning the production and storage of hazardous materials would be discontinued. All hazardous material storages would be drained, cleaned and dismantled, as per the closure plan.

7.7 Cumulative Impacts

The Bojanala-Waterberg is an area where emissions from mining operations have been identified as having a very significant impact on ambient air quality.

The cumulative impact of the SO_2 Abatement Project would be a positive resulting in an overall reduction in sulphur emissions as toxic sulphur dioxide gas. This is a requirement given the Bojanala-Waterberg area has priority status, for the roll out of an ambient air management plan by the Department of Environmental Affairs.

Sulphur trioxide is an acutely toxic component that would be produced as a direct result of the project, but it is anticipated that the additional impact would be negligible, as it will be limited to a very small section of the WSA plant.

7.8 No-go Impacts

The key consideration would remain the legal requirement for the site to obtain compliance with the legal requirements by 2020 for sulphur dioxide emissions (from an air quality perspective). The no-go option would not be a feasible option.

Based on the considerations of this study, it is anticipated that the no-go impacts would be neutral from the perspective of this specialist report.

7.9 Confidence

The available information allows a medium confidence level in the assessment, this is based on the information provided is based on a FEL 3 study, which has the potential for changes during implementation and construction. Typically, a high level of confidence would only be assigned based on a review based on designs that are finalised for construction.

8 EMERGENCY PLANNING

An on-site emergency plan specifies procedures for the handling of sudden or unexpected situations that may arise at a site. Such a plan must be appropriate to the hazards (consequences) and risks that exist at a facility and be specific to the requirements of that facility.

The MHI regulations places various responsibilities on employers (on-site) and local governments (off-site) to ensure that suitable emergency plans are in place to protect employees and the public. MHI's are required to meet specific requirements in respect of their emergency planning, which would be good practice for potentially non-MHI sites such as AAP Mortimer Smelter.

The objective is to be prepared in the event of an emergency situation to:

- Prevent fatalities and injuries both on and off-site;
- reduce damage to buildings, and equipment both on and off-site;
- protect the environment and the public;
- accelerate the resumption of normal operations.

The development of a plan begins with the systematic identification of emergency events and developing an understanding of the combination of consequence and frequency (risk) associated with them. It is only on this basis that suitable responses/controls can be developed and allocation of resources made, as part of an emergency plan. This MHI Risk Assessment report contains information regarding the hazards posed at the site that would be of benefit in this regard.

General requirements are stipulated for onsite emergency plans in the MHI regulations (r.6, DOL (2001)). It is not intended to be a comprehensive review of the on-site emergency plan.

8.1 Risks to Workers

This report has highlighted the potential (1% fatality) for onsite fatalities as the result of losses of containment of furnace gases and fires (LPG), at the SO_2 Abatement Project.

Sulphur trioxide, bulk sulphuric acid and hydrated lime will be introduced to the site chemical inventory.

The introduction of a burner at the WSA will require additional LPG storage and piping.

The onsite emergency plan will require to be modified prior to the completion of an MHI risk assessment of the entire site, if this assessment is considered to be required. The statutory requirements for the onsite emergency plan for an MHI site are laid out in section 8.4.

8.2 Risks to the Public

MHI's (r.6 (1(a)), DOL (2001) are required to identify risks that may extend beyond their premises and affect the health and safety of the public and discuss them with the relevant local government. This is required to assist with the development of off-site emergency planning which is the responsibility of local authorities.

It is anticipated that the SO_2 Abatement Project will **not** result in risks to the public which extend over the retained boundaries of the Mortimer Smelter. It is not anticipated that the introduction of the new facilities would result in the site becoming an MHI. An MHI risk assessment that is inclusive of the entire site would, however be required to make a conclusive determination of this. Such an assessment should be considered given that the site boundaries will be significantly altered on the disposal of the non-retained assets at Union Mine.

On completion of an MHI risk assessment for the entire site, it would be possible to engage with the local authorities regarding the off-site emergency plan requirements for a MHI site (if this is required).

A key consideration in this regard may be the capacity of the local authorities to assist with this aspect.

8.3 Risks to the Environment

It would be necessary to anticipate the occurrence of environmental incidents or situations, which may occur to circumstances that can evolve on site. These events cannot be predicted and procedures would be required to be put in place to assist with mitigation, remediation and conservation of the environment on a coordinated and sustained basis.

Procedures should take the following aspects into consideration:

- Formal identification of potential Section 30 incidents/Section 30A situations for capture in a schedule of potential incidents;
- the effect of abnormal working conditions that could contribute to an incident or situation;
- the potential requirement for the intervention of a competent body to address a situation (Section 30-A);
- the response to the situation which may include the requirement for co-ordination of efforts with competent bodies, local authorities, etc.

8.4 MHI Emergency Plan Requirements

Employers at MHI facilities are required to establish an on-site emergency plan and review it at least every 3 years in consultation with the safety representatives or safety committee and local government to ensure the continuous safety of the workers and the public in the event of an emergency situation.

A copy of the emergency plan is required to be signed in the presence of two witnesses, and the plan must be readily available on site for implementation and use.

All workers must be conversant with the plan and the plan must at least be tested in practice (drills) at least once a year and a record of the exercise must be kept.

9 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 as well as toxic and asphyxiant releases at the proposed AAP facility in Northam. 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 statuary regulations would be applied. It was also assumed that the detailed engineering designs would be finalised 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 the materials of construction are compatible with the products, etc.

It is the responsibility of AAP 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, as described in the report.

9.1 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 as listed in the regulation to notify the divisional inspector. 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.

None of the hazardous materials to be stored on site is listed as notifiable.

9.2 Toxic and Asphyxiant Releases

Sulphur dioxide and sulphur trioxide are both considered acutely toxic components.

The 1% fatality isopleths for sulphur dioxide do not extend beyond the site boundary of the AAP retained operations at Mortimer, and no further analysis was required.

The 1% fatality isopleths for sulphur trioxide did extend the site boundary of the AAP retained operations at Mortimer, and further analysis was required. The risk of $1x10^{-6}$ fatalities per person per year isopleth was however found not to extend beyond the site boundary, and **the site would not qualify as a Major Hazard Installation on this basis**.

The risks were also less than $3x10^{-7}$ fatalities per person per year at the site boundary. The risks to the public would be considered trivial.

9.3 Fires

The 1% fatality for LPG (jet fire) does not extend beyond the site boundary, and no further analysis was required.

9.4 Explosions

No vapour explosions would be expected.

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

Toxic impacts due to sulphur dioxide and sulphur trioxide would not extend into any of the surrounding residential areas. This would include some of the informal dwellings that have developed along the mine access road from the village of Sefikile.

The facilities of RPM-U may be slightly affected by the toxic effects of SO_3 in the event of a loss of containment of furnace gas, in the areas adjacent to the site boundary. More distant neighbours such as the proposed Samancor Varkensvlei project would not be affected.

None of the neighbouring companies have identified themselves to AAP as being classified as a Major Hazard Installation.

9.6 Societal Risks

Societal risks were not assessed, as the SO_2 Abatement Project would not contribute to the site being classified as an MHI.

9.7 Major Hazard Installation

There is insufficient information available to make a classification for all the retained operations of AAP at Mortimer Smelter. This investigation has however concluded that under the current design conditions the proposed AAP SO_2 Abatement Project facility near Northam **would not be considered a Major Hazard Installation (MHI).**

This study is not intended to replace the Major Hazard Installation risk assessment which should be completed for all the retained operations prior to construction of the facility (if required).

9.8 Impact Assessment

The impact of the project on the public and neighbouring sites, due to the handling, production and storage of hazardous materials, would be low. Some potential does exist for the occurrence of Section 30 incidents, but the impact significance of these has been assessed as being low (based on the controls put in place, the short duration of events, etc.).

A loss of secondary containment of H_2SO_4 or hydrated lime, would not directly endanger the public, but may give rise to a Section 30/30A, if it were allowed to enter the ground or surface water. Effective bunding and other mitigation measures would be required when storing or handling these materials.

The available information allows a medium confidence level in the assessment, this is based on the information provided is based on a FEL 3 study, which has the potential for changes during implementation and construction. Typically, a high level of confidence would only be assigned based on a review based on designs that are finalised for construction.
Mitigation measures proposed in this report should be considered for implementation, if not already in place.

9.9 Emergency Planning

The on-site emergency plan will need to be updated to ensure that it reflects the impacts of the changes to plant and additions to the chemical inventory.

It is not anticipated that the addition of the new plant facilities will result in the entire facility becoming an MHI, but this would need to be verified by assessing the entire site.

In the event of the entire facility changing its MHI status, the MHI requirements for an on-site emergency plan would be triggered.

The emergency response plan must be updated to include the handling of environmental incidents if it does not already do so.

10 RECOMMENDATIONS

As a result of the risk assessment study conducted for the proposed AAP SO2 Abatement facility near Northam the risks associated with losses of containment associated with hazardous materials were not found to have risks that extend beyond the site boundary. On this basis, the proposed facility was found to have acceptable risks.

RISCOM has not established any fatal flaws based on the quantitative risk or impact assessments that would prevent the project proceeding with the detailed engineering phase required for construction of the project.

RISCOM would support the project with the following conditions:

1. full compliance with all statutory requirements;
2. compliance with applicable SANS codes, i.e. SANS 10087-3 (LPG), SANS 10400, SANS 10108, etc.;
3. incorporation of applicable guidelines or equivalent international recognised codes of good design and practice into the designs;
4. completion of a recognised process hazard analysis (such as a HAZOP study, FMEA, etc.) for the proposed facility prior to construction to ensure design and operational hazards have been identified and adequate mitigation put in place;
5. preparation and issue of a safety document detailing safety and design features of the design for reducing the impacts from toxic releases, loss of containment, fires, explosions and flammable atmospheres to form part of the required input to a quantitative risk assessment
    a. including compliance to statutory laws, applicable codes and standards and world's best practice;
    b. including the listing of statutory and non-statutory inspections, giving frequency of inspections;
    c. including the auditing of the built facility against the safety document;
    d. noting that codes such as IEC 61511 can be used to achieve these requirements;
6. demonstration by AAP or their contractor that the final designs would reduce the risks posed by the installation to internationally acceptable guidelines;
7. sign-off for all SO_2 Abatement Project designs by a professional engineer registered in South Africa in accordance with the Professional Engineers Act, who takes responsibility for suitable designs;
8. completion of an emergency preparedness and response document for on-site and off-site scenarios prior;
9. permission not being granted for increases to the product list or product inventories without redoing part of or the full EIA;
10. final acceptance of the facility risks for all the retained AAP operations at Mortimer with a quantitative risk assessment that must be completed in according to a process based on a process similar to the one required for to the MHI regulations:
    a. Basing such a risk assessment on the final design and including engineering mitigation.

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12 ABBREVIATIONS AND ACRONYMS

AEGL	**Acute exposure guideline levels** are values published by the US Environmental Protection Agency (EPA). AEGL values represent threshold exposure limits for the general public applicable to five emergency exposure periods (10 minutes, 30 minutes, 1 hour, 4 hours and 8 hours) and are distinguished by varying degrees of severity of toxic effects. **AEGL-1** is the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation or certain asymptomatic nonsensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure. **AEGL-2** is the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long lasting adverse health effects or an impaired ability to escape. **AEGL-3** is the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death. Although the AEGL values represent threshold levels for the general public, including susceptible subpopulations, such as infants, children, the elderly, persons with asthma and those with other illnesses, it is recognized that individuals, subject to unique or idiosyncratic responses, could experience the effects described at concentrations below the corresponding AEGL value.
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.
Deflagration	**Deflagration** is a chemical reaction of a substance, in which the reaction front advances into the unreacted substance at less than sonic velocity.

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.
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.
ERPG	**Emergency response planning guidelines** were developed by the American Industrial Hygiene Association. **ERPG-1** is the maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing anything other than mild transient adverse health effects or perceiving a clearly defined objectionable odour. **ERPG-2** is the maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action. **ERPG-3** is the maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.
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.
Frequency	**Frequency** is the number of times an outcome is expected to occur in a given period of time.

IDLH	**Immediately dangerous to life or health** values were developed by the National Institute of Occupational Safety and Health (NIOSH). **IDLH** value refers to a maximum concentration to which a healthy person may be exposed for 30 minutes and escape without suffering irreversible health effects or symptoms that impair escape (ranging from runny eyes that temporarily impair eyesight to a coma). IDLH values are intended to ensure that workers can escape from a given contaminated environment in the event of failure of the respiratory protection equipment.
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.
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).
LFL	**Lower Flammable Limit** see Flammable Limits
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**
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 X).
Protective Action Criteria	**Protective action criteria** (PAC) for emergency planning of chemical release events are based on the following chemical exposure limit values: • Acute exposure guideline level (AEGL) values published by the US Environmental Protection Agency (EPA); • Emergency response planning guideline (ERPG) values produced by the American Industrial Hygiene Association (AIHA); • Temporary emergency exposure limit (TEEL) values developed by the Subcommittee on Consequence Assessment and Protective Actions (SCAPA).
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**
Societal Risk	**Societal risk** is risk posed on a societal group who are exposed to a hazardous activity.
Temporary Installation	A **temporary installation** is an installation that can travel independently between planned points of departure and arrival for the purpose of transporting any substance and which is only deemed to be an installation at the points of departure and arrival, respectively.
TLV-STEL	**Short-term exposure threshold limit values** are the concentrations to which workers can be exposed continuously for a short period (15 minutes) of time without suffering from: irritation; chronic or irreversible tissue damage; or, narcosis to a sufficient degree to increase the likelihood of accidental injury, impair self-rescue or materially reduce work efficiency, provided that the daily TLV-TWA is not exceeded.
TLV-TWA	**Time weighted average threshold limit values** are the concentrations for a normal 8-hour workday and a 40-hour workweek, to which nearly all workers may be repeatedly exposed day after day, without adverse effects.
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**

13 APPENDIX A: MHI AIA ACCREDITATION

13.1 Department of Labour Approved Inspection Authority

Republic of South Africa

Department of Labour

Certificate

This is to certify that

RISCOM (PTY) LTD

Has been approved as an

APPROVED INSPECTION AUTHORITY

Type A; Explosive Chemicals, Gases, Flammable Gases, Non-Flammable, Non toxic gases (asphyxiants), Toxic gases and Flammable liquids, Flammable solids, Substances liable to spontaneous combustion, Substances that on contact with water release flammable gasses, Oxidizing substances and organic peroxides, Toxic liquids and Solids.

In terms of the Occupational Health and Safety Act, 1993, read with the Major Hazard Installation Regulations 5(5) (a) regarding risk assessments

………………………………………………………………

Chief Inspector

Valid From: 27 May 2013 **Expires: 26 May 2017**

MHI 0005

…………………………………………

Certificate Number

13.2 SANAS Accreditation Certificate and Schedule

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

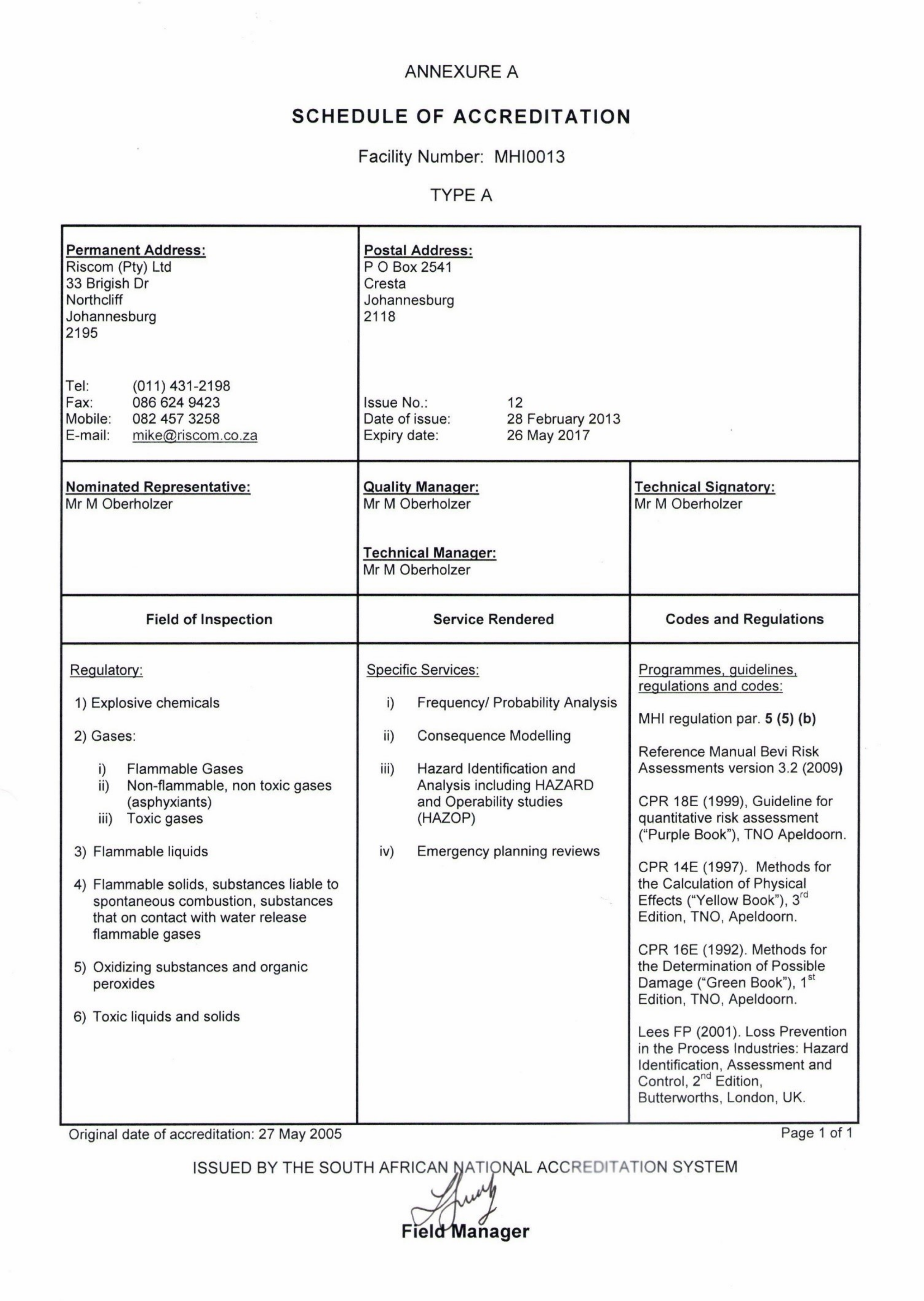
The accreditation demonstrates technical competency for a defined scope and the operation of a quality management system

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 2013
Certificate Expires: 26 May 2017

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

14 APPENDIX B: SPECIALIST DECLARATION AND DETAILS

As required by Appendix 6, of the Government N$^{o.}$ 38282 (December 2014) the following details are attached.

14.1 Declaration by Specialist

environmental affairs

Department:
Environmental Affairs
REPUBLIC OF SOUTH AFRICA

DETAILS OF SPECIALIST AND DECLARATION OF INTEREST

	(For official use only)
File Reference Number:	12/12/20/ or 12/9/11/L
NEAS Reference Number:	DEA/EIA
Date Received:	

Application for integrated environmental authorisation and waste management licence in terms of the-

(1) National Environmental Management Act, 1998 (Act No. 107 of 1998), as amended and the Environmental Impact Assessment Regulations, 2014; and

(2) National Environmental Management Act: Waste Act, 2008 (Act No. 59 of 2008) and Government Notice 921, 2013

PROJECT TITLE

PROPOSED INSTALLATIONOF SULPHUR DIOXIDE (SO2) ABATEMENT EQUIPMENT AT ANGLO AMERICAN PLATINUM LIMITED: MORTIMER SMELTER -NW30/5/1/2/3/2/1/366EM

Specialist:	Riscom (Pty) Ltd (Process Safety and Risk Concsultants)		
Contact person:	Ian Ralston		
Postal address:	P.O Box 2541, Cresta		
Postal code:	2188	Cell:	+27 83 308 2106
Telephone:	+27 11 704 1593	Fax:	+ 27 86 624 9423
E-mail:	ian@riscom.co.za		
Professional affiliation(s) (if any)	Professional Engineer (Reg No. 920262)		

Project Consultant:	WSP | Parsons Brinckerhoff		
Contact person:	Anri Scheepers		
Postal address:	PO Box 98864, Sloane Park, South Africa		
Postal code:	2151	Cell:	+27 82 701 7690
Telephone:	+27 11 300 6089	Fax:	+27 11 361 1381
E-mail:	Anri.Scheepers@wspgroup.co.za		

4.2 The specialist appointed in terms of the Regulations_

I, **Ian Duncan Ralston** , declare that –

General declaration:

I act as the independent specialist in this application;
I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
I declare that there are no circumstances that may compromise my objectivity in performing such work;
I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, Regulations and any guidelines that have relevance to the proposed activity;
I will comply with the Act, Regulations and all other applicable legislation;
I have no, and will not engage in, conflicting interests in the undertaking of the activity;
I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing - any decision to be taken with respect to the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
all the particulars furnished by me in this form are true and correct; and
I realise that a false declaration is an offence in terms of regulation 48 and is punishable in terms of section 24F of the Act.

I.D Ralston Pr. Eng
Signature of the specialist:

Riscom (Pty) Ltd
Name of company (if applicable):

Wednesday, April 12, 2017
Date:

14.2 Professional Affiliations

Engineering Council of South Africa

This is to certify that **Ian Duncan Ralston**

is registered as **Professional Engineer**

in terms of the Engineering Profession of South Africa Act, 1990 (Act 114 of 1990)

date **9 July 1992**

registration number **920262**

RSLouber

President

Registrar

Institution of Chemical Engineers

This is to Certify that

Ian Ralston

was elected a

Chartered Chemical Engineer

in the class of

Members

on this *24th* day of *September 2015*

President

J S Parkinson

Hon. Registrar

Issued at One Portland Place, London, UK

IChemE ADVANCING CHEMICAL ENGINEERING WORLDWIDE

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

WE,
THE VICE-CHANCELLOR AND PRINCIPAL,
THE DEAN OF THE FACULTY OF ENGINEERING
AND THE REGISTRAR,
CERTIFY THAT
AT A CONGREGATION OF THE UNIVERSITY
HELD ON THIS DAY

IAN DUNCAN RALSTON

WAS ADMITTED TO THE DEGREE OF

BACHELOR OF SCIENCE IN ENGINEERING

IN THE BRANCH OF
CHEMICAL ENGINEERING
MINERALS PROCESS ENGINEERING OPTION

Dean of the Faculty

Vice-Chancellor and Principal

Registrar

JOHANNESBURG,

YEAR 1983 MONTH DECEMBER DAY 14

Penrose

14.3 Curriculum Vitae

CURRICULUM VITAE (CV) FOR PROPOSED PROFESSIONAL STAFF

IAN DUNCAN RALSTON

Position:	Process Safety Engineer
Name of Firm:	RISCOM (PTY) LTD
Name of Staff:	Ian Duncan Ralston
Profession:	Chemical Engineer
Date of Birth:	21 June 1960
Years with Firm/Entity:	12 months
Nationality:	South African/British

Membership of Professional Societies:

- Registered Professional Engineer (Registration N°: 920262) with the Engineering Council of South Africa (ECSA)
- Fellow Southern African Institute of Mining and Metallurgy
- Member of the South African Institute of Chemical Engineers
- Member of the Institute of Chemical Engineers (UK)
- Member of the South African Mine Metallurgical Managers Association

Key Qualifications:

Ian Ralston is currently a process safety engineer with RISCOM. He is a registered professional engineer and holds a BSc (Chemical Engineering, Minerals Processing) from the University of the Witwatersrand (1983). Ian has over 30 years of experience with Anglo American in all aspects of metallurgical plant operations and project implementation. This has included roles such as Plant Manager, Lead Process Engineer (Projects and Project Reviews), Process Simulation Engineer, Commissioning Manager and Safety Audit Manager. Since leaving Anglo, Ian has used his simulation and process safety skills to complete risk assessment studies for Riscom.

Relevant projects are included in the following sections.

FAST MOVING CONSUMER GOODS AND PACKAGED HAZARDOUS MATERIALS

Lead Process Safety Engineer for quantitative risk assessment of:

2017	SPAR Lowveld Distribution Centre, Nelspruit, Mpumalanga
2016	Freightmax , Hazardous Materials Warehouse,

PHARMACEUTICALS

Lead Process Safety Engineer for quantitative risk assessment of:

2016	South African National Blood Service (SANBS) and National Biological Institute blood and plasma processing facility, Pinetown.

TANK FARM AND FLAMMABLE STORAGE AND TRANSPORTATION

Lead Process Safety Engineer for quantitative risk assessment of:

2017	Trellidor LPG storage in Phoenix Industrial Park Durban
2017	Q-fuels bulk storage of diesel in Delmas.
2016	Enco Bulk bulk petrol and diesel storage facility in Polokwane.
2016	Puma Energy petrol and diesel storage facility in Hectorspruit.
2016	Rocolor bulk storage of diesel in Bronkhorstspruit.

Education:

BSc (Chemical Engineering, Minerals Processing Option), University of the Witwatersrand, South Africa, 1983
BCom (Quantitative Management (Operations Management) and Business Economics), University of South Africa, 1992

Employment Record:

2015	**Vice-President, Sales, Proposals and Marketing – Minerals Processing Outotec, South Africa** Managed the sales, proposals and marketing of minerals processing equipment for a large international equipment company (26 reports).
2010-2014	**Principal Metallurgist , Anglo American TBCG, Group Metallurgy, South Africa** Management of and process (including safety requirements) input to the review of major capital projects (due diligence). Operational Reviews of Group operations.
2002-2010	**Principal Process Engineer , Anglo American, Anglo Technical Division, Johannesburg, South Africa** Lead Process Engineer for various capital projects in South and West Africa (design, construction and commissioning). Technical support for various Mondi Paper projects. Safety Peer Review leader for various sites. Development of the Amira P754 Metal Accounting Code (co-author of international code).

2000-2002	**Lead Process Engineer Waterval 400 ktpm Concentrator Anglo American Technical Services/Murray & Roberts JV, Johannesburg, South Africa** Development of the concentrator designs (included Hazop) for the JV and responsibility for all process decisions during the implementation of the project. Appointed by Anglo Platinum as the owners team commissioning manager on site with responsibility for the development and execution of commissioning plan requirements (multi-disciplinary team) for the concentrator and its associated infra-structure. The concentrator was successfully commissioned (February 2002) and ramped up to 400 ktpm in 3 months. At the time it was the largest platinum concentrator in Anglo American Platinum of any type.
1998-2002	**Senior Process Engineer, Anglo American Technical Services, Johannesburg, South Africa** Lead Process Engineer for various projects in West (Mali) and Southern Africa (FEL 1-3), across a range of commodities (gold, vanadium, nickel and platinum). Development of a wide range of activities starting with metallurgical testwork through to commissioning.
1996-1998	**Senior Control and Instrumentation Engineer (Simulation), Anglo American Technical Services, Johannesburg, South Africa** Plant and mine simulation using various packages. Development and commissioning of advanced control solutions for metallurgical plants.
1996-1998	**Plant Manager N°1 Gold Plant, West Rand Region of Anglo American Gold Division** Management of 140 000 tpm Carbon In Pulp Plant including responsibility for safety, security, maintenance and slimes dam management. Development and implementation of business plan for the plant.
1983-1996	**Various Production Positions, Vaal Reefs, Anglo American Gold Division** Completed National Service and Anglo Americans ECSA approved training programme. Advanced through a series of promotions, culminating in Production Superintendent West Uranium Plant (1st June 1989). Responsible for the production management of a 260 000 tpm Uranium Plant followed by a 260 000 tpm Flotation Plant and 212 tpd sulphuric acid plant (including calcine gold production).

Languages:

	Speaking	**Reading**	**Writing**
English (first)	Excellent	Excellent	Excellent
Afrikaans	Good	Good	Average

Certification:

I, the undersigned, certify that to the best of my knowledge and belief, this data correctly describes me, my qualifications and my experience.

.... **Date**: Friday, 07 April 2017

Full name of staff member: Ian Duncan Ralston

15 APPENDIX C: PHYSICAL PROPERTIES

Relevant physical properties for the significant hazardous substances are summarised in the following subsections.

15.1 Sulphur Dioxide

15.1.1 Sulphur Dioxide Constants

Constants	Unit	Value
Acentric Factor		0.245 4
Critical Pressure	bar	78.84
Critical Temperature	°C	157.6
Dangerous Toxic Load		7.45E+07
ERPG-1 (60 min)	ppm	0.3
ERPG-2 (60 min)	ppm	3
ERPG-3 (60 min)	ppm	25
Emissive Power Length Scale	m	0
Heat of Solution	kJ/kg	219
Melting Point	°C	-73.15
Molecular Weight		64.06
Solubility in Water		0.1
Toxic Property A		-16.75
Toxic Property B		1
Toxic Property N		2.4
Triple Point Pressure	bar	0.016 74
Triple Point Temperature	°C	-75.48

15.1.2 Sulphur Dioxide Coefficients

Parameter	Equation Number	Lower Temp. Limit (°C)	Upper Temp. Limit (°C)	Coefficient A	Coefficient B	Coefficient C	Coefficient D	Coefficient E
Vapour Viscosity	102	-75.48	726.9	6.86E-07	0.6112	217	0	
Vapour Thermal Conductivity	102	-23.15	626.9	10.53	-0.7732	-1333	1.51E+06	
Vapour Pressure	101	-75.48	157.6	47.37	-4085	-3.647	1.80E-17	6
Trimer Coefficients	101			0	0	0	0	0
Surface Tension	106	-75.48	157.6	0.0872	1.181	0	0	0
Second Virial Equation Coefficient	104	-57.75	1235	0.0679	-60.06	-7.03E+06	-8.65E+17	-2.59E+20
Saturated Liquid Density	105	-75.48	157.6	2.106	0.2584	430.8	0.2895	
Octamer Coefficients	101			0	0	0	0	0
Liquid Viscosity	101	-48.15	126.9	46.22	-1378	-8.748	0	0
Liquid Thermal Conductivity	100	-75.48	126.9	0.3822	-0.0006254	0	0	0
Liquid Heat Capacity	100	-75.48	76.85	8.57E+04	5.744	0	0	0
Ideal Gas Heat Capacity	107	-173.1	1227	3.34E+04	2.59E+04	932.8	1.09E+04	423.7
Hexamer Coefficients	101			0	0	0	0	0
Dimer Coefficients	101			0	0	0	0	0

15.2 Sulphur Trioxide

15.2.1 Sulphur Trioxide Constants

Constant	Unit	Value
Critical Pressure	bar	0.245 4
Critical Temperature	°C	78.84
Dangerous Toxic Load		157.6
ERPG-1 (60 min)	ppm	2
ERPG-2 (60 min)	ppm	10
ERPG-3 (60 min)	ppm	120
Flammable or Toxic Flag		-73.15
Heat of Solution	kJ/kg	64.06
Liquid Water Surface Tension	dyne/cm	0.1
Melting Point	°C	
Normal Boiling Point	°C	
Triple Point Pressure	bar	
Triple Point Temperature	°C	-16.75
Water Heat Transfer Coefficient	W/m^2.°K	1

15.2.2 Sulphur Trioxide Coefficients

Parameter	Equation Number	Lower Temp. Limit (°C)	Upper Temp. Limit (°C)	Coefficient A	Coefficient B	Coefficient C	Coefficient D	Coefficient E
Vapour Viscosity	102	24.78	421.04	3.91E-06	0.3845	470.1	0	
Vapour Thermal Conductivity	102	44.75	726.85	1.07	-0.2384	2010	1.28E+06	
Vapour Pressure	101	16.8	217.7	181	-1.21E+04	-22.84	7.24E-17	6
Trimer Coefficients	101	-273.15	-273.15			0	0	0
Surface Tension	106	16.8	217.7	0.1033	1.218	0	0	0
Second Virial Equation Coefficient	104	-27.75	1292.25	0.08512	-80.32	-1.12E+07	-2.99E+18	-9.07E+20
Saturated Liquid Density	105	16.8	217.7	1.497	0.1901	490.9	0.4359	
Octamer Coefficients	101	-273.15	-273.15			0	0	0
Liquid Viscosity	101	16.8	45	-88.79	6401	10.71	0	0
Liquid Thermal Conductivity	100	16.8	208.25	0.9288	-0.00308	2.66E-06	0	0
Liquid Heat Capacity	100	30	30	2.58E+05	0	0	0	0
Ideal Gas Heat Capacity	107	-173.15	1226.85	3.34E+04	4.97E+04	873.2	2.86E+04	393.7

15.3 Propane Constants

CONSTANT	UNITS	VALUE
Acentric Factor		0.1523
Acid Association Flag		Not Modelled
Aerosol Class Number		8
Combustion At		0.9612
Combustion Ct		0.04032
Critical Pressure	bar	42.48
Critical Temperature	°C	96.68
Emissive Power Length Scale	m	2.75
Flammable/Toxic Flag		Flammable
Heat of Combustion	kJ/kmol	2.04E+06
Immediate Ignition Category		Average
Laminar Burning Velocity	m/s	0.464
Lower Flammability Limit	ppm	2.00E+04
Luminous/Smoky Flame Flag		Luminous
Maximum Burn Rate	kg/m2.s	0.12
Maximum Surface Emissive Power	kW/m2	160
Melting Point	°C	-187.7
Molecular Weight		44.1
Normal Boiling Point	°C	-42.04
Pool-Fire Burn-Rate Length	m	2
Reaction with Water Model		None
Reactivity with Atmosphere		Not Strongly Reactive

15.3.1 Propane Coefficients

	Equation Number	Lower Temperature Limit (°C)	Upper Temperature Limit (°C)	Coefficient A	Coefficient B	Coefficient C	Coefficient D	Coefficient E
Vapour Viscosity	102	-187.7	726.9	2.50E-07	0.6861	179.3	-8255	
Vapour Thermal Conductivity	102	-42.04	726.9	-1.12	0.1097	-9835	-7.54E+06	
Vapour Pressure	101	-187.7	96.68	59.08	-3493	-6.067	1.09E-05	2
Trimer Coefficients	101			0	0	0	0	0
Surface Tension	106	-187.7	96.68	0.05092	1.22	0	0	0
Second Virial Equation Coefficient	104	-88.24	1227	0.1127	-99.2	-4.51E+06	3.09E+17	-7.05E+19
Saturated Liquid Density	105	-187.7	96.68	1.376	0.2745	369.8	0.2936	
Octamer Coefficients	101			0	0	0	0	0
Liquid Viscosity	101	-187.7	86.85	-17.16	646.3	1.11	-7.34E-11	4
Liquid Thermal Conductivity	100	-187.7	76.85	0.2676	-0.0006646	2.77E-07	0	0
Liquid Heat Capacity	114	-187.7	86.85	62.98	1.14E+05	633.2	-873.5	0
Ideal-Gas Heat Capacity	107	-73.15	1227	5.19E+04	1.93E+05	1627	1.17E+05	723.6
Hexamer Coefficients	101			0	0	0	0	0
Dimer Coefficients	101			0	0	0	0	0

16 APPENDIX D: REFERENCE DRAWINGS

Drawings relevant to the report are listed in Table 16-1 and attached in this appendix.

Table 16-1: Reference drawings

Drawing No.	Title	Rev
H341232-0000-10-014-0002-001	General Arrangement with Site Photo Layout FEL 3	A
S-02799 P41024	Anglo Platinum Union Section Mortimer SO_2 Abatement Project FEL 3 Process Flow Diagram	1

DRAWING No.	REFERENCE DRAWINGS	DRAWING No.	REFERENCE DRAWINGS	REV No	DATE	REVISIONS	BY / CHK	SL / ENG	REV No	DATE	REVISIONS	BY / CHK	SL / ENG	REV No	DATE	REVISIONS	BY / CHK	SL / ENG

AngloAmerican PLATINUM Ltd

CONSULTANTS DRAWING No H341232-0000-10-014-0001

Anglo American Platinum Ltd VDTE No. UK10020

OPERATIONS UNIT		PROJECTS & ENGINEERING		CONTRACTOR / CONSULTANT	
OPERATIONS MANAGER		MECH ENGINEER		DRAWN	
ENGINEERING MANAGER		ELEC ENGINEER		CHECKED	
SHE MANAGER		STRUCT/CIVIL ENGINEER		DESIGN COORD	
PROCESS		C&I ENGINEER		DISCIPLINE DESIGNER	
SAFETY		PROJECT MANAGER		AREA MANAGER	
PROTECTION SERVICES		ENGINEERING COORD		PROJECT MANAGER	
		LEAD PROC ENGINEER		ENGINEERING MANAGER	
		MINING ENGINEER		PR. ENG / PR TECH	
				NAME	
				REG NUMBER	
				SIGNATURE	
				SCALE	

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PROJECT DESIGN PHASE

FEASIBILITY (FEL 3)

UNION SECTION

MORTIMER SMELTER SO2 ABATEMENT FEL 3

GENRAL AND SITE DEVELOPMENT
GENERAL ARRANGEMENTS
SITE WITH PHOTO
LAYOUT

COMP	SITE	AREA	DISP	DRG. No	SHEET No	ID CODE	REV
I	BC	100	C	123456	01	HA	A

Frame A0.DWG Rev Date: 01 01 12

$TIME$
$FILE$
$DATE$
$USERNAME$

ALL EQUIPMENT TAG NUMBERS TO BE PREFIXED BY 542

Calc No's: 1534208
Layout: L5
PFF: F1
Case: C01_2
Doc: PFD1

Client's DocNo: E98 100 00 017942 01 HA

HALDOR TOPSØE

REV.	DESCRIPTION	DATE	DRAWN	CHECK	APPR.
1	Approved for use	26-Nov-2012	MARM	ABJE	ABJE
0	First Issue	25-Jul-2012	MARM	MOHN	ABJE

Anglo American Platinum
Union Section
Mortimer SO2 Abatement FEL 3

Design Case

Process Flow Diagram

SHEET SIZE
UNIT
NAME C01_2 PFD1

DOCUMENT ID
S-02799 JOB NUMBER
P41012 DOCUMENT NUMBER
1 REV

MARM 2012-11-15 12:16:04

Reference pressure: 90.2 kPa

○ Pressure kPa g
○ Alt Pressure MPa g
Duty GJ/h
Flow kg/h
Flow Nm³/h
Lower Heating Value kJ/kg
Power kWh/h
Temperature °C

STREAMS	* 10 *		* 100 *		* 180 *		* 190 *		* 260 *		* 830 *		* 835 *	
COMP.	Nm³/h	mole %	Nm³/h	mole %	Nm³/h	mole %	Nm³/h	mole %	kg/h	wt %	Nm³/h	mole %	Nm³/h	mole %
CO_2	286	1.10	332	1.25	332	1.27	332	1.30			332	1.30	335	0.97
H_2SO_4		4 ppm			221	0.84		10 ppm	1663	97.00		4 ppm		3 ppm
Inerts	18486	71.10	18871	71.11	18870	72.24	18871	73.94			18871	73.94	25937	74.79
NO_x				2 ppm		2 ppm		2 ppm				2 ppm		2 ppm
O_2	4550	17.50	4577	17.25	4387	16.79	4387	17.19			4387	17.19	6265	18.07
SO_2	390	1.50	390	1.47	10	379 ppm	10	388 ppm			10	388 ppm	10	286 ppm
SO_3				4 ppm	160	0.61								
H_2O	2288	8.80	2367	8.92	2146	8.21	1923	7.53	51	3.00	1921	7.53	2129	6.14
TOTAL	26000	100.00	26537	100.00	26126	100.00	25523	100.00	1714	100.00	25521	100.00	34676	100.00
MOLE WEIGHT	28.55		28.54		28.99		28.17		86.54		28.17		28.31	

Approved

17 APPENDIX E: PADHI LAND-PLANNING TABLES

17.1 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	

17.2 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	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
	caravan sites, camping sites		
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	Principally an outdoor development for use by the general public	Developments where members of the public will

Development Type	Examples	Development Detail and Size	Justification
	Retail: outdoor markets, car boot sales, funfairs Community and adult 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	i.e. developments where people will predominantly be outdoors and not more than 100 people will gather at the facility at any one time (Level 2)	be present (but not resident) 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

17.3 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

17.4 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 a 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
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

18 APPENDIX F: INCIDENT SCENARIOS

18.1 Toxic Emission (Sulphur Dioxide and Sulphur Trioxide)

Scenario No.	Scenario	Component	Duration (min)	Approx. Height of Release (m)	Failure Freq. (m/y)	Approx. Length (m)	Frequency (per annum)
1	**Piping failure at Secondary Gas Cleaning Feed**						
SO2-1	Full-bore pipe failure	SO_2	30	1	1.00E-07	2.00E+01	2.00E-06
SO2-2	10 mm hole	SO_2	30	1	5.00E-07	2.00E+01	1.00E-05
10	**Piping failure at WSA Feed**						
SO2-10	Full-bore pipe failure	SO_2	30	3	1.00E-07	4.00E+01	4.00E-06
SO2-11	10 mm hole	SO_2	30	3	5.00E-07	4.00E+01	2.00E-05
100	**Piping failure at Convertor Feed**						
SO2-100	Full-bore pipe failure	SO_2	30	3	1.00E-07	6.00E+01	6.00E-06
SO2-101	10 mm hole	SO_3	30	3	5.00E-07	6.00E+01	3.00E-05
180	**Piping failure at Convertor/Condenser**						
SO2-180	Full-bore pipe failure	SO_2	30	3	1.00E-07	2.00E+01	2.00E-06
SO2-181	10 mm hole	SO_2	30	3	5.00E-07	2.00E+01	1.00E-05
SO3-180	Full-bore pipe failure	SO_3	30	3	1.00E-07	2.00E+01	2.00E-06
SO3-181	10 mm hole	SO_3	30	3	5.00E-07	2.00E+01	1.00E-05
190	**Piping failure at Condenser**						
SO2-190	1.00E-07	SO_2	30	3	1.00E-07	1.00E+01	1.00E-06
SO2-191	10 mm hole	SO_3	30	3	5.00E-07	1.00E+01	5.00E-06
SO3-190	Full-bore pipe failure	SO_2	30	3	1.00E-07	1.00E+01	1.00E-06
SO3-191	10 mm hole	SO_3	30	3	5.00E-07	1.00E+01	5.00E-06

Scenario No.	Scenario	Component	Duration (min)	Approx. Height of Release (m)	Failure Freq. (m/y)	Approx. Length (m)	Frequency (per annum)
835	**Piping failure at the stack**						
SO2-835	Full-bore pipe failure	SO_2	30	3	1.00E-07	2.00E+01	2.00E-06
SO3-836	10 mm hole	SO_3	30	3	5.00E-07	2.00E+01	1.00E-05

18.2 Fires (LPG Jet Fires)

Scenario N$^{o.}$	Equipment Description	Scenario	Incident	Release Rate (kg/s)	Duration (min)	Event Frequency (per annum/m of pipe)	System Reaction1	System Reaction Pipe length (m)	System Reaction	System Reaction	Probability of Ignition	Total System Event Frequency
LPG-01	Support Burner	Full bore pipe rupture	Jet Fire	1.7	30	1.00E-07	Pipe leng	30		0.5	0.2	3.00E-07

19 APPENDIX G: CONSEQUENCE VALUES FOR INCIDENT SCENARIOS

19.1 Sulphur Dioxide

19.1.1 Distance to AEGL Values for Sulphur Dioxide

Scenario N°.	**Weather Category**	**Conc. (ppm)**	**Max. Distance (m)**	**Max. Width (m)**	**Release Rate (kg/s)**
SO2-1	1.5/D	0.2	14336.0	537.8	0.32
		0.75	4476.0	150.7	0.32
		30.0	45.3	17.9	0.32
	1.5/F	0.2	7371.7	673.2	0.32
		0.75	3172.9	321.6	0.32
		30.0	331.6	40.7	0.32
	5/D	0.2	4007.2	404.5	0.32
		0.75	1844.7	204.2	0.32
		30.0	234.2	29.9	0.32
	9/D	0.2	2858.7	301.7	0.32
		0.75	1340.8	152.8	0.32
		30.0	169.3	22.2	0.32
	5/E	0.2	6405.3	447.8	0.32
		0.75	2874.0	222.0	0.32
		30.0	351.7	32.7	0.32
	3/B	0.2	2570.0	512.2	0.32
		0.75	1220.2	265.0	0.32
		30.0	162.2	40.6	0.32
SO2-10	1.5/D	0.2	35997.4	1485.3	0.32
		0.75	13869.5	784.8	0.32
		30.0	981.7	386.0	0.32
	1.5/F	0.2	8411.0	859.7	0.32
		0.75	3642.0	466.5	0.32
		30.0	354.8	189.6	0.32
	5/D	0.2	4148.8	424.3	0.32
		0.75	1926.4	217.3	0.32
		30.0	246.4	35.9	0.32
	9/D	0.2	2870.1	303.1	0.32
		0.75	1340.2	154.8	0.32
		30.0	168.8	23.3	0.32
	5/E	0.2	6976.9	497.3	0.32

Scenario Nº	**Weather Category**	**Conc. (ppm)**	**Max. Distance (m)**	**Max. Width (m)**	**Release Rate (kg/s)**
		0.75	3185.5	255.4	0.32
		30.0	413.8	46.5	0.32
	3/B	0.2	2676.4	541.5	0.32
		0.75	1282.1	286.6	0.32
		30.0	180.5	53.9	0.32
SO2-100	1.5/D	0.2	204.5	58.6	0.32
		0.75	169.1	50.7	0.32
		30.0	77.5	20.9	0.32
	1.5/F	0.2	5641.1	515.3	0.32
		0.75	2247.6	221.4	0.32
		30.0	107.2	22.7	0.32
	5/D	0.2	3833.4	386.7	0.32
		0.75	1742.1	191.6	0.32
		30.0	203.1	26.7	0.32
	9/D	0.2	2818.6	297.0	0.32
		0.75	1311.0	149.8	0.32
		30.0	161.5	21.5	0.32
	5/E	0.2	5698.3	398.2	0.32
		0.75	2485.0	191.5	0.32
		30.0	253.7	23.8	0.32
	3/B	0.2	2469.2	489.9	0.32
		0.75	1155.6	248.6	0.32
		30.0	139.9	35.0	0.32
SO2-180	1.5/D	0.2	3973.9	208.2	0.009
		0.75	1892.2	109.5	0.009
		30.0	237.4	18.3	0.009
	1.5/F	0.2	1085.7	127.3	0.009
		0.75	529.3	65.4	0.009
		30.0	71.0	9.8	0.009
	5/D	0.2	536.1	65.3	0.009
		0.75	259.5	32.7	0.009
		30.0	34.6	4.7	0.009
	9/D	0.2	387.6	47.9	0.009
		0.75	187.1	23.8	0.009
		30.0	25.2	3.5	0.009
	5/E	0.2	879.7	77.0	0.009
		0.75	426.1	39.4	0.009

Scenario Nº.	Weather Category	Conc. (ppm)	Max. Distance (m)	Max. Width (m)	Release Rate (kg/s)
		30.0	56.8	5.9	0.009
	3/B	0.2	367.9	87.6	0.009
		0.75	180.0	44.4	0.009
		30.0	24.9	6.4	0.009
SO2-190	1.5/D	0.2	3973.9	208.2	0.009
		0.75	1892.2	109.5	0.009
		30.0	237.4	18.3	0.009
	1.5/F	0.2	1085.7	127.3	0.009
		0.75	529.3	65.4	0.009
		30.0	71.0	9.8	0.009
	5/D	0.2	536.1	65.3	0.009
		0.75	259.5	32.7	0.009
		30.0	34.6	4.7	0.009
	9/D	0.2	387.6	47.9	0.009
		0.75	187.1	23.8	0.009
		30.0	25.2	3.5	0.009
	5/E	0.2	879.7	77.0	0.009
		0.75	426.1	39.4	0.009
		30.0	56.8	5.9	0.009
	3/B	0.2	367.9	87.6	0.009
		0.75	180.0	44.4	0.009
		30.0	24.9	6.4	0.009

19.1.2 Distance to 1% Fatality Isopleth for Sulphur Dioxide

Scenario Nº.	Weather Category	Max. Distance (m)	Max. Width (m)	Release Rate (kg/s)
SO2-1	1.5/D	22.1	6.2	0.32
	1.5/F	30.5	7.2	0.32
	5/D	35.6	4.9	0.32
	9/D	24.6	3.4	0.32
	5/E	47.2	4.6	0.32
	3/B	25.3	6.7	0.32
SO2-10	1.5/D	68.2	110.8	0.32
	1.5/F	68.4	55.9	0.32
	5/D	36.4	9.4	0.32
	9/D	22.2	4.1	0.32

Scenario Nº.	Weather Category	Max. Distance (m)	Max. Width (m)	Release Rate (kg/s)
	5/E	57.7	14.6	0.32
	3/B	36.0	18.1	0.32
SO2-100	1.5/D			0.32
	1.5/F			0.32
	5/D	22.4	3.8	0.32
	9/D	19.9	3.1	0.32
	5/E	16.0	3.9	0.32
	3/B	16.5	4.3	0.32
SO2-180	1.5/D	22.3	4.6	0.009
	1.5/F	9.7	1.3	0.009
SO2-190	1.5/D	22.3	4.6	0.009
	1.5/F	9.7	1.3	0.009
SO2-835	1.5/D	22.3	4.6	0.009
	1.5/F	9.7	1.3	0.009

19.2 Sulphur Trioxide

19.2.1 Distance to AEGL Values for Sulphur Dioxide

Scenario Nº.	Weather Category	Conc. (ppm)	Max. Distance (m)	Max. Width (m)	Release Rate (kg/s)
SO3-180	1.5/D	0.2	30704.7	1429.0	0.39
		2.7	6050.4	425.3	0.39
		51.6	789.2	257.5	0.39
	1.5/F	0.2	7440.1	794.8	0.39
		2.7	1825.7	213.7	0.39
		51.6	353.9	55.6	0.39
	5/D	0.2	3511.8	406.1	0.39
		2.7	901.2	106.8	0.39
		51.6	173.6	23.0	0.39
	9/D	0.2	2482.7	298.2	0.39
		2.7	647.8	78.4	0.39
		51.6	123.5	16.9	0.39
	5/E	0.2	5841.0	470.3	0.39
		2.7	1471.8	124.2	0.39
		51.6	290.3	28.0	0.39
	3/B	0.2	2279.9	516.5	0.39

Scenario N^{o.}	Weather Category	Conc. (ppm)	Max. Distance (m)	Max. Width (m)	Release Rate (kg/s)
		2.7	609.1	141.1	0.39
		51.6	122.2	31.8	0.39

19.2.2 Distance to 1% Fatality Isopleth for Sulphur Trioxide

Scenario N^{o.}	Weather Category	Max. Distance (m)	Max. Width (m)	Release Rate (kg/s)
SO3-180	1.5/D	481.9	235.3	0.39
	1.5/F	246.7	42.7	0.39
	5/D	119.9	16.6	0.39
	9/D	85.3	12.0	0.39
	5/E	201.5	19.9	0.39
	3/B	85.9	22.8	0.39

19.3 LPG Jet Fires

Scenario N^{o.}	Weather Category	kW/hr/m^2	Length (m)	Width (m)
LPG-1	1.5/D	4	10.8	13.8
		10	8.2	8.2
		35	5.1	2.1
	1.5/F	4	10.8	13.8
		10	8.2	8.2
		35	5.1	2.1
	5/D	4	11.0	13.5
		10	8.8	7.8
		35	6.0	2.0
	9/D	4	11.1	12.6
		10	9.3	7.0
		35	7.0	1.8
	5/E	4	11.0	13.5
		10	8.8	7.8
		35	6.0	2.0
	3/B	4	10.9	13.7
		10	8.5	8.1
		35	5.5	2.1

20 APPENDIX H: MATERIAL SAFETY DATA SHEETS

20.1 Sulphur Dioxide

Sulphur dioxide is produced as an intermediate component during the manufacture of sulphuric acid, and therefore a generic MSDS is provided.

SULPHUR DIOXIDE (cylinder)	**ICSC:** 0074 Peer-Review Status: 10.10.2006 Validated
Sulphurous oxide Sulphurous anhydride Sulphur oxide	
CAS #: 7446-09-5 RTECS #: WS4550000 UN #: 1079 EC #: 016-011-00-9 EINECS #: 231-195-2	Formula: SO_2 Molecular mass: 64.1

TYPES OF HAZARD / EXPOSURE	ACUTE HAZARDS / SYMPTOMS	PREVENTION	FIRST AID / FIRE-FIGHTING
FIRE	Not combustible. Heating will cause rise in pressure with risk of bursting.		In case of fire in the surroundings, use appropriate extinguishing media.
EXPLOSION			In case of fire: keep cylinder cool by spraying with water. NO direct contact with water. Combat fire from a sheltered position.
EXPOSURE STRICT HYGIENE! IN ALL CASES CONSULT A DOCTOR!			
Inhalation	Cough. Shortness of breath. Sore throat. Laboured breathing. See Notes.	Use ventilation, local exhaust or breathing protection.	Fresh air, rest. Artificial respiration may be needed. Refer for medical attention.
Skin	ON CONTACT WITH LIQUID: FROSTBITE.	Cold-insulating gloves.	ON FROSTBITE: rinse with plenty of water, do NOT remove clothes. Refer for medical attention.

Eyes	Redness. Pain.	Wear safety goggles, face shield or eye protection in combination with breathing protection.	Rinse with plenty of water for several minutes (remove contact lenses if easily possible). Refer for medical attention.
Ingestion			

SPILLAGE DISPOSAL	PACKAGING & LABELLING
Evacuate danger area! Consult an expert! Personal protection: complete protective clothing including self-contained breathing apparatus. Ventilation. NEVER direct water jet on liquid.	Note: 5 **EC Classification** Symbol: T; R: 23-34; S: (1/2)-9-26-36/37/39-45 **UN Classification** UN Hazard Class: 2.3; UN Subsidiary Risks: 8 **GHS Classification** Signal: Warning Contains refrigerated gas; may cause cryogenic burns or injury Toxic if inhaled Causes eye irritation Causes damage to respiratory tract if inhaled Causes damage to the respiratory tract through prolonged or repeated exposure if inhaled Harmful to aquatic life 

EMERGENCY RESPONSE	SAFE STORAGE
Transport Emergency Card: TEC (R)-20S1079 or 20G2TC. NFPA Code: H3; F0; R0.	Ventilation along the floor. Dry.

IMPORTANT DATA	
Physical State; Appearance COLOURLESS GAS OR COMPRESSED LIQUEFIED GAS WITH PUNGENT ODOUR. **Physical dangers** The gas is heavier than air. **Chemical dangers** The solution in water is a medium strong acid. Reacts violently with sodium hydride. Attacks plastic. **Occupational exposure limits** TLV: 2 ppm as TWA; 5 ppm as STEL; A4 (not classifiable as a human carcinogen); (ACGIH 2006). MAK: 0.5 ppm, 1.3 mg/m³; Peak limitation category: I (1); Pregnancy risk group: C; (DFG 2006).	**Routes of exposure** The substance can be absorbed into the body by inhalation. **Inhalation risk** A harmful concentration of this gas in the air will be reached very quickly on loss of containment. **Effects of short-term exposure** Rapid evaporation of the liquid may cause frostbite. The substance is irritating to the eyes and respiratory tract. Inhalation may cause asthma-like reactions. The substance may cause effects on the respiratory tract. This may result in asthma-like reactions, reflex spasm of the larynx and respiratory arrest. The effects may be delayed. Medical observation is indicated. **Effects of long-term or repeated exposure** Repeated or prolonged inhalation may cause asthma.

PHYSICAL PROPERTIES	ENVIRONMENTAL DATA
Boiling point: -10°C Melting point: -75.5°C Relative density (water = 1): 1.4 (liquid, -10°C) Solubility in water, ml/100ml at 25°C: 8.5 Vapour pressure, kPa at 20°C: 330 Relative vapour density (air = 1): 2.25	The substance is harmful to aquatic organisms.

NOTES
Depending on the degree of exposure, periodic medical examination is suggested. The symptoms of asthma often do not become manifest until a few hours have passed and they are aggravated by physical effort. Rest and medical observation are therefore essential. Anyone who has shown symptoms of asthma due to this substance should avoid all further contact. Do NOT spray water on leaking cylinder (to prevent corrosion of cylinder). Turn leaking cylinder with the leak up to prevent escape of gas in liquid state.

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20.2 Sulphur Trioxide

Sulphur trioxide is produced as an intermediate component during the manufacture of sulphuric acid, and therefore a generic MSDS is provided.

SULPHUR TRIOXIDE	**ICSC:** 1202 Peer-Review Status: 10.10.2002 Validated
Sulphuric (acid) anhydride Sulphuric oxide	
CAS #: 7446-11-9 RTECS #: WT4830000 UN #: 1829 EINECS #: 231-197-3	Formula: SO_3 Molecular mass: 80.1

TYPES OF HAZARD / EXPOSURE	ACUTE HAZARDS / SYMPTOMS	PREVENTION	FIRST AID / FIRE-FIGHTING
FIRE	Not combustible. Heating will cause rise in pressure with risk of bursting. Gives off irritating or toxic fumes (or gases) in a fire.	NO contact with bases, combustible substances, reducing agents or water.	NO hydrous agents. NO water. In case of fire in the surroundings, use appropriate extinguishing media.
EXPLOSION	Risk of fire and explosion on contact with bases, combustible substances, reducing agents or water.		In case of fire: keep drums, etc., cool by spraying with water. NO direct contact with water.
EXPOSURE **PREVENT GENERATION OF MISTS! AVOID ALL CONTACT!** **IN ALL CASES CONSULT A DOCTOR!**			
Inhalation	Burning sensation. Cough. Laboured breathing. Sore throat. Wheezing. Shortness of breath.	Use ventilation, local exhaust or breathing protection.	Fresh air, rest. Half-upright position. Refer for medical attention.
Skin	Redness. Serious skin burns. Pain. Blisters.	Protective gloves. Protective clothing.	Remove contaminated clothes. Rinse skin with plenty of water or shower. Refer for medical attention.
Eyes	Redness. Pain. Blurred vision. Severe deep burns.	Wear face shield or eye protection in combination with breathing protection.	First rinse with plenty of water for several minutes (remove contact lenses if easily possible), then

			refer for medical attention.
Ingestion	Abdominal pain. Burning sensation. Nausea. Shock or collapse.	Do not eat, drink, or smoke during work.	Refer for medical attention. Rinse mouth. Do NOT induce vomiting. Give one or two glasses of water to drink.

SPILLAGE DISPOSAL	PACKAGING & LABELLING
Evacuate danger area! Consult an expert! Personal protection: chemical protection suit including self-contained breathing apparatus. Ventilation. NEVER direct water jet on liquid. Do NOT let this chemical enter the environment. Do NOT absorb in saw-dust or other combustible absorbents. Absorb remaining liquid in dry sand or inert absorbent. Then store and dispose of according to local regulations.	Do not transport with food and feedstuffs. Airtight. **EC Classification** **UN Classification** UN Hazard Class: 8; UN Pack Group: I **GHS Classification**

EMERGENCY RESPONSE	SAFE STORAGE
Transport Emergency Card: TEC (R)-80GC1-I-X. NFPA Code: H3; F0; R2.	Store only if stabilized. Separated from food and feedstuffs and incompatible materials. See Chemical Dangers. Dry. Store between 17°C and 25°C.

IMPORTANT DATA	
Physical State; Appearance FUMING HYGROSCOPIC COLOURLESS LIQUID OR COLOURLESS-TO-WHITE CRYSTALS. **Physical dangers** The vapour is heavier than air. See Notes. **Chemical dangers** The substance is a strong oxidant. It reacts violently with combustible and reducing materials and organic compounds. This generates fire and explosion hazard. Reacts violently with water and moist air. This produces sulphuric acid. The solution in water is a strong acid. It reacts violently with bases and is corrosive to metals. This produces flammable/explosive gas (hydrogen, see ICSC 0001). **Occupational exposure limits** TLV (NOT-ESTABLISHED):	**Routes of exposure** The substance can be absorbed into the body by inhalation of its vapour and by ingestion. **Inhalation risk** A harmful contamination of the air will be reached very quickly on evaporation of this substance at 20°C. **Effects of short-term exposure** The substance is corrosive to the eyes, skin and respiratory tract. Corrosive on ingestion. **Effects of long-term or repeated exposure** Repeated or prolonged inhalation of the aerosol may cause effects on the lungs. Repeated or prolonged inhalation of the aerosol may cause effects on the teeth. This may result in tooth erosion. Strong inorganic acid mists containing this substance are carcinogenic to humans.

PHYSICAL PROPERTIES	ENVIRONMENTAL DATA
Boiling point: 45°C Melting point: see Notes Relative density (water = 1): 1.9 Solubility in water: reaction Vapour pressure: see Notes Relative vapour density (air = 1): 2.8 Relative density of the vapour/air-mixture at 20°C (air = 1): 1.2-2	The substance is harmful to aquatic organisms.

NOTES
NEVER pour water into this substance; when dissolving or diluting always add it slowly to the water. When the alpha form melts it takes the gamma form, and vapour pressure rises dramatically with a hazard of explosion. Melting point is 62, 33 and 17°C for alpha, beta and gamma forms. Vapour pressure is 9.7, 45.9 and 57.7 kPa at 25°C for alpha, beta and gamma forms.

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20.3 Sulphuric Acid

SULFURIC ACID		**ICSC:** 0362 Peer-Review Status: 10.02.2000 Validated
Sulfuric Oil of vitriol	acid	100%
CAS #: 7664-93-9 RTECS #: WS5600000 UN #: 1830 EC #: 016-020-00-8 EINECS #: 231-639-5	Formula: Molecular mass: 98.1	H_2SO_4

TYPES OF HAZARD / EXPOSURE	**ACUTE HAZARDS / SYMPTOMS**	**PREVENTION**	**FIRST AID / FIRE FIGHTING**
FIRE	Not combustible. Many reactions may cause fire or explosion. Gives off irritating or toxic fumes (or gases) in a fire.	NO contact with flammables. NO contact with combustible substances.	NO water. In case of fire in the surroundings, use appropriate extinguishing media.
EXPLOSION	Risk of fire and explosion on contact with bases, combustible substances, oxidizing agents, reducing agents or water.		In case of fire: keep drums, etc., cool by spraying with water. NO direct contact with water.
EXPOSURE		**PREVENT GENERATION OF MISTS! AVOID ALL CONTACT!**	**IN ALL CASES CONSULT A DOCTOR!**
Inhalation	Burning sensation. Sore throat. Cough. Laboured breathing. Shortness of breath. Symptoms may be delayed. See Notes.	Use ventilation, local exhaust or breathing protection.	Fresh air, rest. Half-upright position. Artificial respiration may be needed. Refer for medical attention.
Skin	Redness. Pain. Blisters. Serious skin burns.	Protective gloves. Protective clothing.	Remove contaminated clothes. Rinse skin with plenty of water or shower. Refer for medical attention .
Eyes	Redness. Pain. Severe deep burns.	Wear face shield or eye protection in combination	First rinse with plenty of water for several minutes (remove contact lenses if easily possible), then

		with breathing protection.	refer for medical attention.
Ingestion	Abdominal pain. Burning sensation. Shock or collapse.	Do not eat, drink, or smoke during work.	Rinse mouth. Do NOT induce vomiting. Refer for medical attention .

SPILLAGE DISPOSAL	**PACKAGING & LABELLING**
Evacuate danger area! Consult an expert! Personal protection: complete protective clothing including self-contained breathing apparatus. Do NOT let this chemical enter the environment. Do NOT absorb in saw-dust or other combustible absorbents.	Unbreakable packaging. Put breakable packaging into closed unbreakable container. Do not transport with food and feedstuffs. **EC Classification** Symbol: C; R: 35; S: (1/2)-26-30-45; Note: B **UN Classification** UN Hazard Class: 8; UN Pack Group: II **GHS Classification**

EMERGENCY RESPONSE	**SAFE STORAGE**
Transport Emergency Card: TEC (R)-80S1830 or 80GC1-II+III. NFPA Code: H3; F0; R2; W.	Separated from combustible substances, reducing agents, strong oxidants, strong bases, food and feedstuffs and incompatible materials. See Chemical Dangers. Store in stainless steel containers. Store in an area having corrosion resistant concrete floor.

IMPORTANT DATA	
Physical State; Appearance ODOURLESS COLOURLESS OILY HYGROSCOPIC LIQUID. **Physical dangers** No data. **Chemical dangers** The substance is a strong oxidant. It reacts with combustible and reducing materials. The substance is a strong acid. It reacts violently with bases and is corrosive to most common metals forming a flammable/explosive gas (hydrogen - see ICSC 0001). Reacts violently with water and organic materials. This generates heat. See Notes. Decomposes on heating. This produces irritating or toxic fumes (or gases) and sulfur oxides. **Occupational exposure limits** MAK (inhalable fraction): 0.1 mg/m³; Carcinogen category: 4; Peak limitation	**Routes of exposure** The substance can be absorbed into the body by inhalation of its aerosol and by ingestion. **Inhalation risk** Evaporation at 20°C is negligible; a harmful concentration of airborne particles can, however, be reached quickly on spraying. **Effects of short-term exposure** Corrosive. The substance is very corrosive to the eyes, skin and respiratory tract. Corrosive on ingestion. Inhalation of of the aerosol may cause lung oedema. See Notes. **Effects of long-term or repeated exposure** Repeated or prolonged inhalation may cause effects on the lungs and teeth. This may result in tooth erosion. Strong inorganic acid mists containing this substance are carcinogenic to humans.

category: I(1); Pregnancy risk group: C; (DFG 2004).	

PHYSICAL PROPERTIES	ENVIRONMENTAL DATA
Decomposes at 340°C Melting point: 10°C Relative density (water = 1): 1.8 Solubility in water: miscible Vapour pressure, kPa at 146°C: 0.13 Relative vapour density (air = 1): 3.4	The substance is harmful to aquatic organisms.

NOTES

The symptoms of lung oedema often do not become manifest until a few hours have passed and they are aggravated by physical effort.
Rest and medical observation are therefore essential.
NEVER pour water into this substance; when dissolving or diluting always add it slowly to the water.
Other UN numbers: UN1831 Sulfuric acid, fuming, hazard class 8, subsidiary hazard 6.1, pack group I; UN1832 Sulfuric acid, spent, Hazard class 8, Pack group II.
Card has been partly updated in October 2005.
See sections Occupational Exposure Limits, Emergency Response.
Card has been partially updated in January 2008: see Fire fighting.

ADDITIONAL INFORMATION

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20.4 LPG

MATERIAL SAFETY DATA SHEET (MSDS)
LIQUEFIED PETROLEUM GAS AND PROPANE

Please ensure that this MSDS is received by the appropriate person

DATE: March 2017 Version 3

Ref. No.: MS111

1 PRODUCT AND COMPANY IDENTIFICATION

PRODUCT IDENTIFICATION

Product Name:	HANDIGAS (LIQUEFIED PETROLEUM GAS)
Chemical Formula:	C3H8 PLUS C4 H10 PLUS C3 H6
Trade name:	Handigas
Colour Coding:	Plascon Dark Admiralty Grey (SABS 1091 – G.12) body, with a Handigas decal affixed to the cylinder. All cylinders fitted with an internal eductor tube for liquid withdrawal shall be clearly marked with two Yellow (B.49) stripes painted diametrically opposite each other along the length of the cylinder.
Valve:	Brass 5/8 inch BSP left hand female, either single or two-way outlet.
Company Identification:	African Oxygen Limited 23 Webber Street Johannesburg, 2001 Tel. No: (011) 490-0400 Fax. No: (011) 490-0506

EMERGENCY NUMBER 0860 020202 or +27(0) 11 821 3000 (24 hours)

2 COMPOSITION/INFORMATION ON INGREDIENTS

Chemical Name	Butane / Propane / Propylene		
Chemical Family	Aliphatic Hydrocarbon		
CAS NO.	BUTANE	106-97-8	UN NO.1075
	Propane	74-98-6	UN No. 1978
	Propylene	115-07-01	UN No. 1077
UN No.	1075		
ERG No.	115		
Hazchem Warning	2A Flammable gas		

3 HAZARDS IDENTIFICATION

Vapourised liquefied petroleum gas is highly flammable and can form explosive mixtures with air. The vapourised liquid does not support life. It can act as a simple asphyxiant by diluting the concentration of oxygen in the air below the levels necessary to support life. It can act as a simple asphyxiant.

Adverse Health effects

The liquefied petroleum gases are non-toxic. Prolonged inhalation of high concentrations has an anaesthetic effect

Chemical Hazards

Propane and butane (known as extensively in commercial and popular terms as Lpgas or LPG) have an extremely wide range of domestic, industrial, commercial, agricultural and internal combustion engine uses. It is estimated that two gases, un-mixed and in mixtures, have several thousand industrial applications and many more in other fields. Their very broad application stems from their occurrences as hydrocarbons between natural gas and natural gasoline, and from their corresponding properties. As a result of their wide application, misuse could result in serious chemical hazards.

Biological Hazards.

Contact with the liquid phase of liquefied petroleum gases with the skin can result in frostbite.

Vapour Inhalation

As the vapourised liquid act as a simple asphyxiant death may result from errors in judgement, confusion, or loss of consciousness which prevents self-rescue. At low oxygen concentrations, unconsciousness and death may occur in seconds without warning.

Eye Contact	The liquid can cause severe burn-like injuries.
Skin Contact	Contact with the liquid phase can cause severe burn-like injuries.
Ingestion	No known effect

Hazard Category
1

Danger
Extremely flammable gas

4 FIRST AID MEASURES

Prompt medical attention is mandatory in all cases of overexposure to vapourised liquefied petroleum gas. Rescue personnel should be equipped with self-contained breathing apparatus. In the case of frostbite from contact with the liquid phase, place the frost bitten part in warm water, about 40 -42 ℃. If warm water is not available. Or is impractical to use, wrap the affected part gently in blankets. Encourage the patient to exercise the affected part whilst it is being warmend. Do not remove clothing whilst frosted. Conscious persons should be assisted to an uncontaminated area and inhale fresh air. Quick removal from the contaminated area is most important. Unconscious persons should be removed to an uncontaminated area, and given mouth-to-mouth resuscitation and supplemental oxygen.

Eye contact **(with liquid phase)**
Eye contact Immediately flush with large quantities Of tepid water, or with sterile saline solution. Seek medical attention
Skin Contact See above for handling of frostbite
Ingestion No known effect

5 FIRE FIGHTING MEASURES

Extinguish media

Do not extinguish fire unless the leakage can be stopped. DO NOT USE WATER JET. Use dry chemical, CO2 or foam.

Specific Hazards

The rupturing of cylinders or bulk containers due to excessive exposure to fire could result in a BLEVE (Boiling Liquid expanding Vapour Explosion), with disastrous effects. As the flammability limits in the air for the main constituents of liquefied petroleum gas vary between approximately 2 and 11% by vol, extreme care must be taken when handling leaks.

Emergency actions

If possible shut off the source of spillage. Evacuate area. Post notices "No Naked lights – No Smoking". Prevent liquid or vapour from entering sewers, basements and workpits. Keep cylinders or bulk vessels cool by spraying with water if exposed to fire. If tanker has overturned, do not attempt to right or move it. CONTACT THE NEAREST AFROX BRANCH.

Protective Clothing

Self contained breathing apparatus. Safety gloves and shoes, or boots, should be worn when handling containers.

Environmental precautions.

Vapourised liquefied petroleum gas is heavier than air and could form pockets of oxygen-deficient atmosphere in low lying areas.

6 ACCIDENTAL RELEASE MEASURES

Personal Precautions

Do not enter any area where liquefied petroleum gas has been spilled unless tests have shown that it is safe to do so.

Environmental Precautions.

The danger of widespread formation of explosive LPG/Air mixtures should be taken into account. Accidental ignition could result in massive explosion.

Small spills

DO NOT extinguish the fire unless the leakage can be stopped immediately. Once the fire has been extinguished and all spills have been stopped, ventilate the area.

Large spills

Stop the source if it can be done without risk. Contain the leaking liquid, with sand or earth, or disperse with special water/fog spray nozzle. Allow to evaporate. Restrict access to the area until completion of the clean-up procedure. Ventilate the area using forced-draught if necessary. All electrical equipment must be flameproof.

7 HANDLING AND STORAGE

Cylinders containing liquefied petroleum gas should only be handled and stored in the vertical position. Cylinders should never been rolled. Do not allow cylinders to slide or come into contact with sharp edges and they should be handled carefully. Ensure that cylinders are stored away from oxidants. Comply with local legislation..

8 EXPOSURE CONTROLS/PERSONAL PROTECTION

Occupational Exposure Hazards.

As vaporised LPG is a simple asphyxiant, avoid any areas where spillage has taken place.

Engineering control measures.

Engineering control measures are preferred to reduce exposure to Oxygen-depleted atmospheres. General methods include forced-draught ventilation, separate from other exhaust ventilation, separate from other exhaust ventilation systems. Ensure that all electrical equipment is flameproof.

Personal Protection.

Self-contained breathing apparatus should always be worn when entering area where oxygen depletion may have occurred. Safety goggles, gloves and shoes, or boots, should be worn when handling containers.

Skin. Wear loose-fitting overalls, preferably without pockets.

.

9 PHYSICAL AND CHEMICAL PROPERTIES

Physical Data

Specific Volume @ 20°C & 101,325 kPa	471ml/g
Auto ignition temperature	450°C
Relative density (Air=1) @101,325kPa	+-1,75
Flammability in air	2,2-9.5%
Colour – Liquid	Clear
Taste	None
Odour	EthylMercaptan
Specification	SANS 1174

10 STABILITY AND REACTIVITY

Conditions to avoid

The dilution of the oxygen concentration in the atmosphere to levels which cannot support life. The formation of explosive gas/air mixtures.

Incompatible Materials

Any common, commercially available metal may be used with commercial (or higher) grades of liquefied petroleum gases because they are non-corrosive, though installations must be designed to withstand the pressure involved and must comply with all state local regulations**.**

Hazardous Decomposition Products.

The constituents of liquefied petroleum gas are relatively stable. However, on combustion, toxic compositions, typically carbon monoxide, may be formed, depending on conditions.

11 TOXICOLOGICAL INFORMATION

Acute Toxicity	TLV 1000 VPM
Skin & eye contact	No known effect.
Carcinogenicity	Severe cold burns can result in carcinoma

(For Further information see Section3.Adverse Health Effects)

12 ECOLOGICAL INFORMATION

Vapourised liquefied petroleum gas is heavier than air, and can cause pockets of oxygen-depleted atmosphere in low-lying areas. It does not pose a hazard to the ecology, unless the gas/air is ignited.

13 DISPOSAL CONSIDERATIONS

Disposal Methods Disposal of Propane, as with other flammable gases, should be undertaken only by personnel familiar with the gas and the procedures for disposal. Contact the supplier for instructions. In general, should it become necessary to dispose of Propane, the best procedure, as for other flammable gases, is to burn them in suitable burning unit available in the plant. This should be done in accordance with appropriate regulations.

Disposal of packaging The disposal of cylinders must only be handled by the gas supplier.

14 TRANSPORT INFORMATION

ROAD TRANSPORTATION

Road Transportation		
UN No.	1075	
ERG No.	115	
Hazchem warning	2A-Flammable gas	
SEA TRANSPORTATION		
IMDG	1075	
Label	Flammable gas	
AIR TRANSPORTATION		
ICAO/IATA Code	1075	
Class	2.1	
Packaging group		
Packaging instructions	Cargo	200
	Passenger	Forbidden
Maximum Quantity allowed	Cargo	150kg
	Passenger	Forbidden

15 REGULATORY INFORMATION

SUPPLEMENT TO SANS 10234:2008
Edition 1
Annex A Index No. 608-011-00-8

Hazard & Precautionary statement codes

H220	Extremely Flammable Gas
P210	Keep away from heat/sparks/open flames/ hot surfaces – NO SMOKING (Manufacture, supplier or the competent authority to specify ignition sources)
P377	Leaking gas fire: Do not extinguish unless leak can be stopped safely
P381	Eliminate all ignition sources if safe to do so
P403	Store in a well-ventilated place

16 OTHER INFORMATION

Bibliography
Handbook of Compressed Gases - 3rd Edition
Matheson. Matheson Gas Data Book - 6th Edition
Supplement to SANS 10234 – List of classification and labelling of chemicals in accordance with Globally Harmonized System (GHS)

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20.5 Hydrated Lime

	MATERIAL SAFETY DATA SHEET CALCIUM HYDROXIDE	**MSDS nr:** CH001

1. COMPANY AND PRODUCT IDENTIFICATION

Company Information: Bontebok Lime Works (pty) ltd t/a P & B Lime Works
: Swellendam Road, PO Box 2, Bredasdorp, 7280
: www.pandblime.co.za / sales@pandblime.co.za
: 028 424 1157 (tel) / 028 424 1428 (fax)

Product names: Water Purification Lime, Calim, Building Lime (SANS 523), Road Lime (SANS 824), iSikhuseli, Decarb Lime, Nature All, Concrim™, Agricultural Hydrated Lime

Synonyms: Calcium hydrate, Slaked lime, Hydrated lime

Molecular Weight: 74.09

Chemical Formula: $Ca(OH)2$

2. COMPOSITION AND INFORMATION ON HAZARDS

Ingredient	Percentage	Hazardous
Calcium Hydroxide	90%	Yes

3. HAZARDS IDENTIFICATION

DANGER: HARMFUL IF SWALLOWED OR INHALED. CAUSES BURNS TO SKIN AND EYES. CAUSES SEVERE IRRITATION TO RESPIRATORY TRACT

Inhalation: Causes irritation to the respiratory tract. Symptoms may include coughing, shortness of breath. Can cause chemical bronchitis.

Ingestion: Gastric irritant. Ingestion may be followed by severe pain, vomiting, diarrhea, and collapse. If death does not occur in 24 hours, esophageal perforation may occur, as evidenced by fall in blood pressure and severe pain. A narrowing of the esophagus may occur weeks, months, or years after ingestion, making swallowing difficult.

Skin Contact: Corrosive. May cause severe burns and blistering, depending on duration of contact.

Eye Contact: Corrosive. May cause severe irritation and pain. May induce ulcerations of the corneal epithelium. Can cause blindness.

Chronic Exposure: Prolonged or repeated skin contact may produce severe irritation or dermatitis.

Aggravation of existing Conditions: Persons with existing skin problems or impaired respiratory function may be more susceptible to the effects of this substance.

4. FIRST AID MEASURES

Inhalation: If inhaled remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Call a physician immediately.

Ingestion: Do NOT induce vomiting. Give large quantities of water. Never give anything by mouth to an unconscious person. Call a physician immediately.

Skin Contact: In case of contact, wipe off excess material from skin then immediately flush skin with plenty of water for at least 15 minutes. Remove contaminated clothing and shoes. Wash clothing before reuse. Call a physician immediately.

Eye Contact: Check for and remove any contact lenses, immediately flush eyes with gentle but large stream of water for at least 15 minutes, lifting lower and upper eyelids occasionally. Cold water may be used. Call a physician immediately.

5. FIRE FIGHTING MEASURES

Fire: Not considered to be a fire hazard. Alkaline hydroxides boiled with phosphorus yields mixed phosphines which may ignite spontaneously in air.

Explosion: Not considered to be an explosion hazard.

Fire Extinguishing Media: Use any means suitable for extinguishing surrounding fire.

6. ACCIDENTAL RELEASE MEASURES

Ventilate area of leak or spill.
Keep unnecessary and unprotected people away from area of spill.
Wear appropriate personal protective equipment as specified in Section 8.
Spills: Pick up and place in a suitable container for reclamation or disposal, using a method that does not generate dust.
Do not flush caustic residues to the sewer.
Residues from spills can be diluted with water, neutralized with dilute acid such as acetic, hydrochloric or sulfuric.
Absorb neutralized caustic residue on clay, vermiculite or other inert substance and package in a suitable container for disposal.

7. HANDLING AND STORAGE

Keep in a tightly closed container, stored in a cool, dry, ventilated area.
Protect against physical damage. Isolate from incompatible substances.
Containers of this material may be hazardous when empty since they retain product residues (dust, solids); observe all warnings and precautions listed for the product.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

Airborne Exposure Limits:
OSHA Permissible Exposure Limit (PEL): 15 mg/m3 (total dust), 5 mg/m3 (respirable fraction)
ACGIH Threshold Limit Value (TLV): 5 mg/m3

Ventilation System:
A system of local and/or general exhaust is recommended to keep employee exposures below the Airborne Exposure Limits. Local exhaust ventilation is generally preferred because it can control the emissions of the contaminant at its source, preventing dispersion of it into the general work area.

Personal Respirators: If the exposure limit is exceeded and engineering controls are not feasible, a full face piece particulate respirator may be worn for up to 50 times the exposure limit or the maximum use concentration specified by the appropriate regulatory agency or respirator supplier, whichever is lowest. For emergencies or instances where the exposure levels are not known, use a full-face piece positive-pressure, air-supplied respirator. WARNING: Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.

Skin Protection:
Wear impervious protective clothing, as appropriate, to prevent skin contact.

Eye Protection:
Use chemical safety goggles and/or full face shield where dusting or splashing of solutions is possible. Maintain eye wash fountain and quick-drench facilities in work area.

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance: Crystals or powder.

Colour: White

Odor: Odorless.

Solubility: 0.185 g/100 cc water @ 0C.

Specific Gravity: 2.24

pH: 12.4 (saturated solution)

% Volatiles by volume @ 21C (70F): 0

Boiling Point: Decomposes.

Melting Point: 580C (1076F)

Vapor Density (Air=1): No information found.

Vapor Pressure (mm Hg): No information found.

Evaporation Rate (BuAc=1): No information found.

10. STABILITY AND REACTIVITY

Stability: Stable under ordinary conditions of use and storage. Readily absorbs carbon dioxide from air to form calcium carbonate.

Hazardous Decomposition Products: Caustic fumes of calcium oxide form when heated to decomposition (580°C; 1076°F).

Hazardous Polymerization: Will not occur.

Incompatibilities: Violent reactions with maleic anhydride, nitroethane, nitromethane, nitroparaffins, nitropropane, phosphorus. As a strongly alkaline material, it is incompatible with acids.

Conditions to Avoid: Air, dusting, and incompatibles.

11. TOXICOLOGICAL INFORMATION

Routes of Entry: Absorbed through skin. Inhalation. Ingestion.

Toxicity to Animals: Acute oral toxicity (LD50): 7300 mg/kg [Mouse].

Chronic Effects on Humans: Not available.

Other Toxic Effects on Humans:
Extremely hazardous in case of eye contact (irritant) Hazardous in case of skin contact (irritant), of eye contact (corrosive), of ingestion, inhalation Slightly hazardous in case of skin contact (corrosive, permeator).

Special Remarks on Toxicity to Animals: Not available.

Special Remarks on Chronic Effects on Humans:
Mutangenicity: Cytogenic analysis [Rat]: Cell type: Ascities tumor; Dose: 1200 mg/kg

Special Remarks on other Toxic Effects on Humans:
Acute Potential Health Effects:
Skin - Causes skin irritation. Alkalies penetrate skin slowly. The extent of damage depends on the duration of contact.
Eyes - Causes severe irritation of the eyes. Can cause "Lime Burns" of the eye. Clumps may lodge deep in the recesses of the eye, releasing calcium hydroxide over a long period of time. Severe burns of the cornea with possible damage to corneal nerves can occur.
Ingestion - Causes gastrointestinal tract irritation with vomiting, diarrhea, severe pain. Vomit may contain blood and desquamated mucosal lining. May cause delayed gastrointestinal burns and perforation (gastric or esophageal) with severe abdominal pain and rapid fall in blood pressure.
Inhalation - Causes severe irritation of the respiratory tract (nose, throat, lungs), and mucous membranes with coughing, wheezing and/or shortness of breath. Material is destructive to tissue of the mucous membranes and upper respiratory tract.
Chronic Potential Health Effects - Prolonged or repeated skin contact may produce severe irritation or dermatitis.

12. ECOLOGICAL INFORMATION

Environmental Fate:
This material is not expected to significantly bioaccumulate.

Environmental Toxicity:
No information found.

13. DISPOSAL CONSIDERATIONS

Whatever cannot be saved for recovery or recycling should be managed in an appropriate and approved waste facility.
Although not a listed RCRA hazardous waste, this material may exhibit one or more characteristics of a hazardous waste and require appropriate analysis to determine specific disposal requirements.
Processing, use or contamination of this product may change the waste management options.
State and local disposal regulations may differ from federal disposal regulations.
Dispose of container and unused contents in accordance with federal, state and local requirements.

14. TRANSPORT INFORMATION

Not regulated

15. REGULATION AND LEGISLATION

National Environmental Management: Air Quality Act, 39 of 2004 prescribes maximum emission levels of SO_2 and NO_x

Mine Health and Safety Act, 29 of 1996 prescribes the personal protective equipment to be worn

SANS 9001:2008 (ISO 9001:2008) – Quality Management Systems (ISBN 978-0-626-22214-7

SANS 523 (SABS 523) – Lime for use in building (Permit number 7380/10943)

SANS 824 (SABS 824) – Lime for use in soil stabilization (Permit number 7380/10944)

16. DISCLAIMER

P&B LIME WORKS provides the information contained herein in good faith but makes no representation as to its comprehensiveness or accuracy. This document is intended only as a guide to the appropriate precautionary handling of the material by a properly trained person using this product. Individuals receiving the information must exercise their independent judgment in determining its appropriateness for a particular purpose.

21 APPENDIX I: WSP IMPACT ASSESSMENT METHODOLOGY

IMPACT ASSESSMENT METHODOLOGY

The EIA uses a methodological framework developed by WSP | Parsons Brinckerhoff to meet the combined requirements of international best practice and NEMA, Environmental Impact Assessment Regulations, 2014 (GN No. 982) (the “EIA Regulations”).

As required by the EIA Regulations (2014), the determination and assessment of impacts will be based on the following criteria:

- Nature of the Impact
- Significance of the Impact
- Consequence of the Impact
- Extent of the impact
- Duration of the Impact
- Probability if the impact
- Degree to which the impact:
  - can be reversed;
  - may cause irreplaceable loss of resources; and
  - can be avoided, managed or mitigated.

Following international best practice, additional criteria have been included to determine the significant effects. These include the consideration of the following:

- Magnitude: to what extent environmental resources are going to be affected;
- Sensitivity of the resource or receptor (rated as high, medium and low) by considering the importance of the receiving environment (international, national, regional, district and local), rarity of the receiving environment, benefits or services provided by the environmental resources and perception of the resource or receptor); and
- Severity of the impact, measured by the importance of the consequences of change (high, medium, low, negligible) by considering inter alia magnitude, duration, intensity, likelihood, frequency and reversibility of the change.

It should be noted that the definitions given are for guidance only, and not all the definitions will apply to all of the environmental receptors and resources being assessed. Impact significance was assessed with and without mitigation measures in place.

METHODOLOGY

Impacts are assessed in terms of the following criteria:

→ The **nature**, a description of what causes the effect, what will be affected and how it will be affected

NATURE OR TYPE OF IMPACT	DEFINITION
Beneficial / Positive	An impact that is considered to represent an improvement on the baseline or introduces a positive change.
Adverse / Negative	An impact that is considered to represent an adverse change from the baseline, or introduces a new undesirable factor.
Direct	Impacts that arise directly from activities that form an integral part of the Project (e.g. new infrastructure).
Indirect	Impacts that arise indirectly from activities not explicitly forming part of the Project (e.g. noise changes due to changes in road or rail traffic resulting from the operation of Project).
Secondary	Secondary or induced impacts caused by a change in the Project environment (e.g. employment opportunities created by the supply chain requirements).
Cumulative	Impacts are those impacts arising from the combination of multiple impacts from existing projects, the Project and/or future projects.

→ The physical **extent**, wherein it is indicated whether:

SCORE	DESCRIPTION
1	the impact will be limited to the site;
2	the impact will be limited to the local area;
3	the impact will be limited to the region;
4	the impact will be national; or
5	the impact will be international;

→ The **duration**, wherein it is indicated whether the lifetime of the impact will be:

SCORE	DESCRIPTION
1	of a very short duration (0 to 1 years)
2	of a short duration (2 to 5 years)
3	medium term (5–15 years)
4	long term (> 15 years)
5	permanent

- → The **magnitude of impact on ecological processes**, quantified on a scale from 0-10, where a score is assigned:

SCORE	DESCRIPTION
0	small and will have no effect on the environment.
2	minor and will not result in an impact on processes.
4	low and will cause a slight impact on processes.
6	moderate and will result in processes continuing but in a modified way.
8	high (processes are altered to the extent that they temporarily cease).
10	very high and results in complete destruction of patterns and permanent cessation of processes.

- → The **probability of occurrence**, which describes the likelihood of the impact actually occurring. Probability is estimated on a scale where:

SCORE	DESCRIPTION
1	very improbable (probably will not happen.
2	Improbable (some posibility, but low likelihood).
3	probable (distinct possibility).

SCORE	DESCRIPTION
4	highly probable (most likely).
5	definite (impact will occur regardless of any prevention measures).

- the **significance**, which is determined through a synthesis of the characteristics described above (refer formula below) and can be assessed as low, medium or high;
- the **status**, which is 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; and
- the *degree* to which the impact can be mitigated.

The **significance** is determined 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:

OVERALL SCORE	SIGNIFICANCE RATING	DESCRIPTION
< 30 points	Low	where this impact would not have a direct influence on the decision to develop in the area
31-60 points	Medium	where the impact could influence the decision to develop in the area unless it is effectively mitigated
> 60 points	High	where the impact must have an influence on the decision process to develop in the area

The impact significance without mitigation measures will be assessed with the design controls in place. Impacts without mitigation measures in place are not representative of the Project's actual extent of impact, and are included to facilitate understanding of how and why mitigation measures were identified. The residual impact is what remains following the application of mitigation and management measures, and is thus the final level of impact associated with the development of the Project. Residual impacts also serve as the focus of management and monitoring activities during Project implementation to verify that actual impacts are the same as those predicted in this EIA Report.