Sunrise Project

Project Execution Plan Modification

Appendix E

Preliminary Hazard Analysis

PRELIMINARY HAZARD ANALYSIS
FOR THE SUNRISE PROJECT
PROJECT EXECUTION PLAN MODIFICATION,
FIFIELD, NSW

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Sunrise Project PEP Modification -
Preliminary Hazard Analysis

Disclaimer

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Rev	Date	Description	Reviewed By
A	1/06/2021	Draft for Comment	SEM
B	26/6/21	Draft Comments Included	SEM
C	29/6/21	Final Issue	SEM

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EXECUTIVE SUMMARY

The Sunrise Project (the Project) is a nickel, cobalt and scandium open cut mining project situated near the village of Fifield, approximately 350 kilometres (km) west-northwest of Sydney, in New South Wales.

Development Consent (DA 374-11-00) for the Project was issued under Part 4 of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) in 2001.

SRL Ops Pty Ltd owns the rights to develop the Project. SRL Ops Pty Ltd is a wholly owned subsidiary of Sunrise Energy Metals Limited (SEM)[1].

SEM has continued to review and optimise the Project design, construction and operations as part of preparations for Project execution. The outcomes of this review are outlined in the Project Execution Plan.

The Project Execution Plan Modification (the Modification) includes the implementation of Project changes identified in the Project Execution Plan to optimise the construction and operation of the Project. The Project Execution Plan identified a number of changes to the approved mine and processing facility, accommodation camp, rail siding and road transport activities.

Pinnacle Risk Management Pty Ltd has been engaged by SEM to conduct a Preliminary Hazard Analysis (PHA) for the modified Project. Relevant to this PHA, the Modification would include the following changes to the mine and processing facility:

- Revised processing facility area layout including a revised processing plant layout;
- Revised processing plant reagent types, rates and storage volumes (including increased ammonia storage vessels capacity); and
- Reduced sulphuric acid plant stack height from 80 m to 40 m.

The Modification would include a revised rail siding location and layout, and the addition of an ammonium sulphate storage and distribution facility to the rail siding.

This PHA has been prepared to support an application by SEM to modify Development Consent (DA 374-11-00) for the Project, which would be sought under section 4.55(2) of the EP&A Act.

The risks associated with the modified mine and processing facility, and rail siding have been assessed and compared against the NSW Department of Planning (now the NSW Department of Planning, Industry and Environment) risk criteria.

The results are summarised in Table 1 and show compliance with all risk criteria.

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[1] SEM was previously Clean TeQ Holdings Limited (Clean TeQ).

Table 1 - HIPAP 4 Risk Compliance

Description	Risk Criteria	Risk Acceptable?	Comments
Fatality risk to sensitive users, including hospitals, schools, aged care	0.5 x 10^{-6} per year	Y	The facility is to be located in a rural area with no nearby sensitive landusers. Based on the analysis in this PHA, there are no credible fires, explosions or toxic gas releases that can cause fatality to sensitive land users. The estimated maximum individual fatality risk at the site boundary is $1x10^{-6}$/yr
Fatality risk to residential and hotels	1 x 10^{-6} per year	Y	As the estimated maximum individual fatality risk at the site boundary is $1x10^{-6}$/yr then this criterion is satisfied
Fatality risk to commercial areas, including offices, retail centres, warehouses	5 x 10^{-6} per year	Y	As the estimated maximum individual fatality risk at the site boundary is $1x10^{-6}$/yr then this criterion is satisfied
Fatality risk to sporting complexes and active open spaces	10 x 10^{-6} per year	Y	As the estimated maximum individual fatality risk at the site boundary is $1x10^{-6}$/yr then this criterion is satisfied
Fatality risk to be contained within the boundary of an industrial site	50 x 10^{-6} per year	Y	As the estimated maximum individual fatality risk at the site boundary is $1x10^{-6}$/yr then this criterion is satisfied
Injury risk – incident heat flux radiation at residential areas should not exceed 4.7 kW/m^2 at frequencies of more than 50 chances in a million per year or incident explosion overpressure at residential areas should not exceed 7 kPa at frequencies of more than 50 chances in a million per year	50 x 10^{-6} per year	Y	Based on the analysis in this PHA, there are no credible fires or explosions that can cause injury at the closest privately owned residence

Description	Risk Criteria	Risk Acceptable?	Comments
Toxic exposure – Toxic concentrations in residential areas which would be seriously injurious to sensitive members of the community following a relatively short period of exposure	10×10^{-6} per year	Y	The likelihood of causing injury at the closest privately owned residence is approximately 1×10^{-6}/yr, therefore, this criterion is satisfied
Toxic exposure – Toxic concentrations in residential areas which should cause irritation to eyes or throat, coughing or other acute physiological responses in sensitive members of the community	50×10^{-6} per year	Y	The likelihood of causing irritation at the closest privately owned residence is approximately 4×10^{-6}/yr, therefore, this criterion is satisfied
Propagation due to Fire and Explosion – exceed radiant heat levels of 23 kW/m^2 or explosion overpressures of 14 kPa in adjacent industrial facilities	50×10^{-6} per year	Y	The facility has no adjacent industrial facilities, therefore, this criterion is satisfied

Societal risk, area cumulative risk, propagation risk, transport risk and environmental risk are also concluded to be acceptable.

The primary reason for the low risk levels from the modified mine and processing facility and rail siding is the separation distances between the potentially hazardous materials and equipment and the nearest private place of residences and also the site boundaries.

The highest contributors to off-site risk are releases of ammonia, in particular, from transfer operations to the storage vessels, and sulphur dioxide releases from catastrophic equipment failure. It is expected that the design review process followed by the Hazard and Operability (HAZOP) study would help mitigate the risk of releases to acceptable levels. This would include designing to Australian Standard AS2022 for the ammonia storage and handling systems. The following recommendations were made in the approved 2017 PHA and are still valid for the modified design. These recommendations are made to lower the risk associated with releases of ammonia.

1. Ensure that the final design includes means to automatically isolate the ammonia road tanker and storage vessels should a release during a transfer occur (vapour and liquid lines). Actuation should be local as well as remote;

2. Provide closed circuit television (CCTV) coverage of the ammonia transfer area to the plant’s control room;

3. Provide means to isolate the ammonia flow to the plant should a release occur. This should be at each storage vessel;

4. Provide means to suppress an ammonia vapour plume. A plume could occur due to a release from the transfer system, the storage vessels or the plant supply lines. Options include spray deluge for the transfers bay and fire water monitors in the transfer and storage area. The latter can be operated remotely (preferable) or manually (may require the use of a full protective suit with self-contained breathing air). Monitors can be fixed or portable;

5. Provide means for road tanker driveaway protection. This could include interlocks on the vehicles brakes or self-sealing devices in the transfer lines;

6. Include the transfer hoses and couplings (dry-break preferred) in the preventative maintenance system. The transfer hoses would need to be regularly inspected, tested and replaced as per the manufacturer’s recommendations;

7. Provide means for preventing stress corrosion cracking in the ammonia storage vessels and include the vessels in the preventative maintenance system for routine inspections;

8. Provide wind socks at appropriate locations to allow people to decide the best means of escape from an ammonia plume;

9. Provide alternate emergency assembly areas given that an ammonia plume can travel in any direction;

10. Provide means for protection for the ammonia road tanker driver should a release occur, e.g. safehouse;

11. Apply good practice for building design, e.g. design buildings as safehouses should relevant guidelines recommend this. For example, design buildings as per the recommendations in the Chemical Industries Association guideline, “Guidance for the Location and Design of Occupied Buildings on Chemical Manufacturing Sites”;

12. Provide overfill protection on the ammonia storage vessels. This system should be reviewed via a Safety Integrity Level (SIL) analysis; and

13. Provide means to prevent the vapour compressor from overpressuring the vapour return line and/or the road tanker.

GLOSSARY

Al	Aluminium
ANE	Ammonium Nitrate Emulsion
AS	Australian Standard
CCPS	Centre for Chemical Process Safety
CCTV	Closed Circuit Television
cLX	Continuous Resin-In-Column
cRIP	Continuous Resin–in-Pulp
CSX	Cobalt Solvent Extraction
DG	Dangerous Good
DoP	NSW Department of Planning (now the Department of Planning, Industry and Environment)
DPIE	Department of Planning, Industry and Environment
EP&A	Environmental Planning and Assessment (Act)
ERPG	Emergency Response Planning Guidelines
EIV	Emergency Isolation Valve
EN	Eluate Neutralisation
FEL	Front-End Loader
HAZOP	Hazard and Operability Study
HIPAP	Hazardous Industry Planning Advisory Paper
HP	High Pressure
HPAL	High Pressure Acid Leach
HSE	Health and Safety Executive (UK)
IBC	Intermediate Bulk Container
IDLH	Immediately Dangerous to Life and Health
ISX	Impurity Solvent Extraction
LGA	Local Government Area
LP	Low Pressure

Ni	Nickel
NSW	New South Wales
NSX	Nickel Solvent Extraction
PAL	Pressure Acid Leach
PHA	Preliminary Hazard Analysis
PN	Partial Neutralisation
QRA	Quantitative Risk Analysis
ROM	Run of Mine
Sc	Scandium
SEM	Sunrise Energy Metals Limited
SEP	Surface Emissive Power
SEPP	State Environmental Planning Policy
SFARP	So Far As Reasonably Practicable
Si	Silica
SIL	Safety Integrity Level
SMBS	Sodium Metabisulphate
SLOT	Specified Level of Toxicity
SSAN	Security Sensitive Ammonium Nitrate
STEL	Short Term Exposure Limit
SX	Solvent Extraction
TLV	Threshold Limit Value
TN	Tailings Neutralisation
TNT	Trinitrotoluene
TWA	Time Weighted Average

REPORT

1 INTRODUCTION

1.1 BACKGROUND

The Sunrise Project (the Project) is a nickel, cobalt and scandium open cut mining project situated near the village of Fifield, approximately 350 kilometres (km) west-northwest of Sydney, in New South Wales (NSW) (Figure 1).

Development Consent (DA 374-11-00) for the Project was issued under Part 4 of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) in 2001.

The Project includes the establishment and operation of the following:

- Mine and processing facility;
- Limestone quarry;
- Rail siding;
- Borefield, surface water extraction infrastructure and water pipeline;
- Gas pipeline; and
- Associated transport activities and transport infrastructure (e.g. the Fifield Bypass, road and intersection upgrades).

SRL Ops Pty Ltd owns the rights to develop the Project. SRL Ops Pty Ltd is a wholly owned subsidiary of Sunrise Energy Metals Limited (SEM)[2].

SEM has continued to review and optimise the Project design, construction and operations as part of preparations for Project execution. The outcomes of this review are outlined in the Project Execution Plan.

The Project Execution Plan Modification (the Modification) includes the implementation of Project changes identified in the Project Execution Plan to optimise the construction and operation of the Project. The Project Execution Plan identified a number of changes to the approved mine and processing facility, accommodation camp, rail siding and road transport activities.

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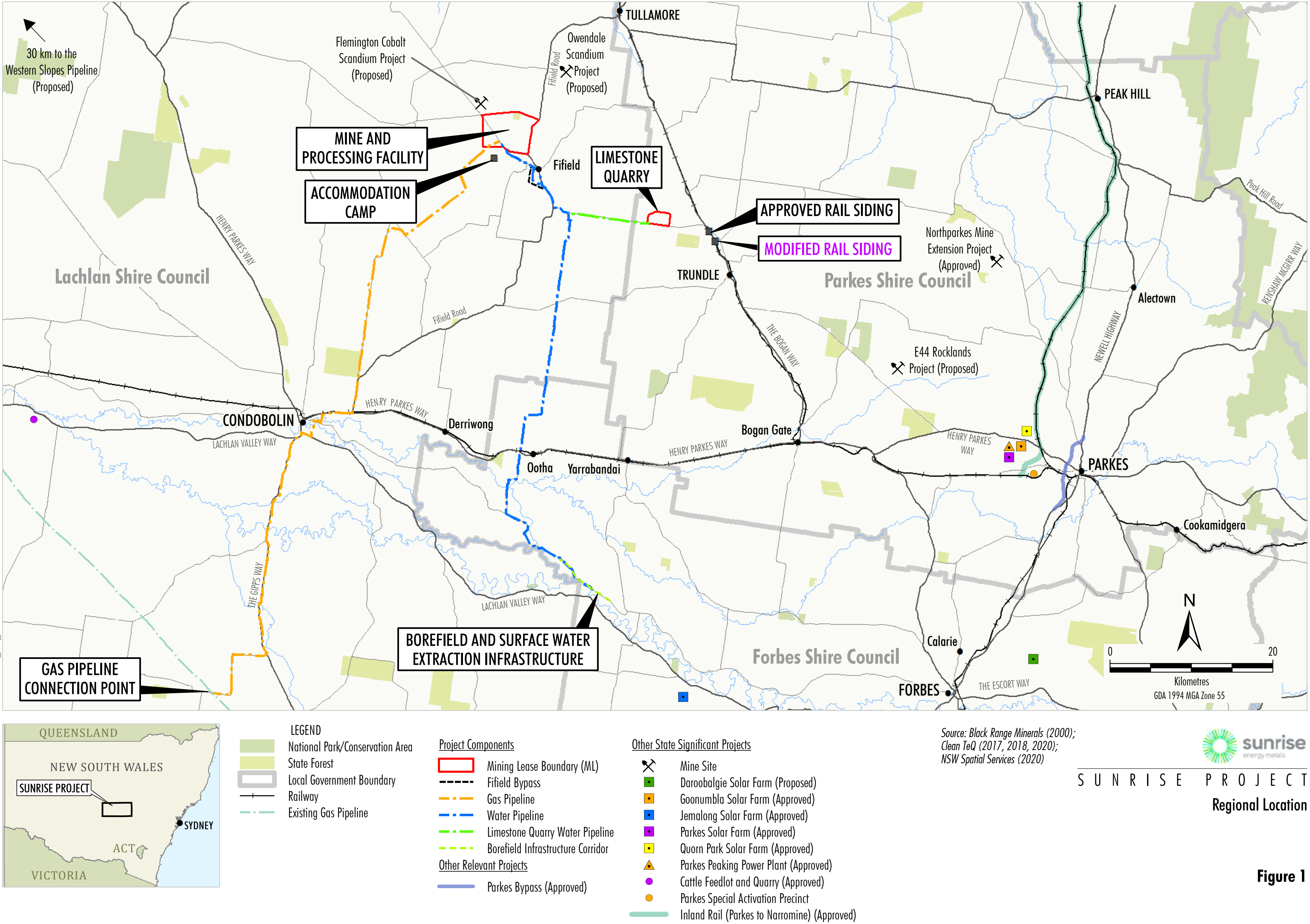
[2] SEM was previously Clean TeQ Holdings Limited (Clean TeQ).



Source: Black Range Minerals (2000); Clean TeQ (2017, 2018, 2020); NSW Spatial Services (2020)

SUNRISE PROJECT

Regional Location

Figure 1

Pinnacle Risk Management Pty Ltd (Pinnacle) has been engaged by SEM to conduct a Preliminary Hazard Analysis (PHA) for the modified mine and processing facility. The original PHA for the Project was completed in 2000 (Ref 1), while the currently approved PHA for the Project was completed in 2017 for Modification 4 (Ref 2).

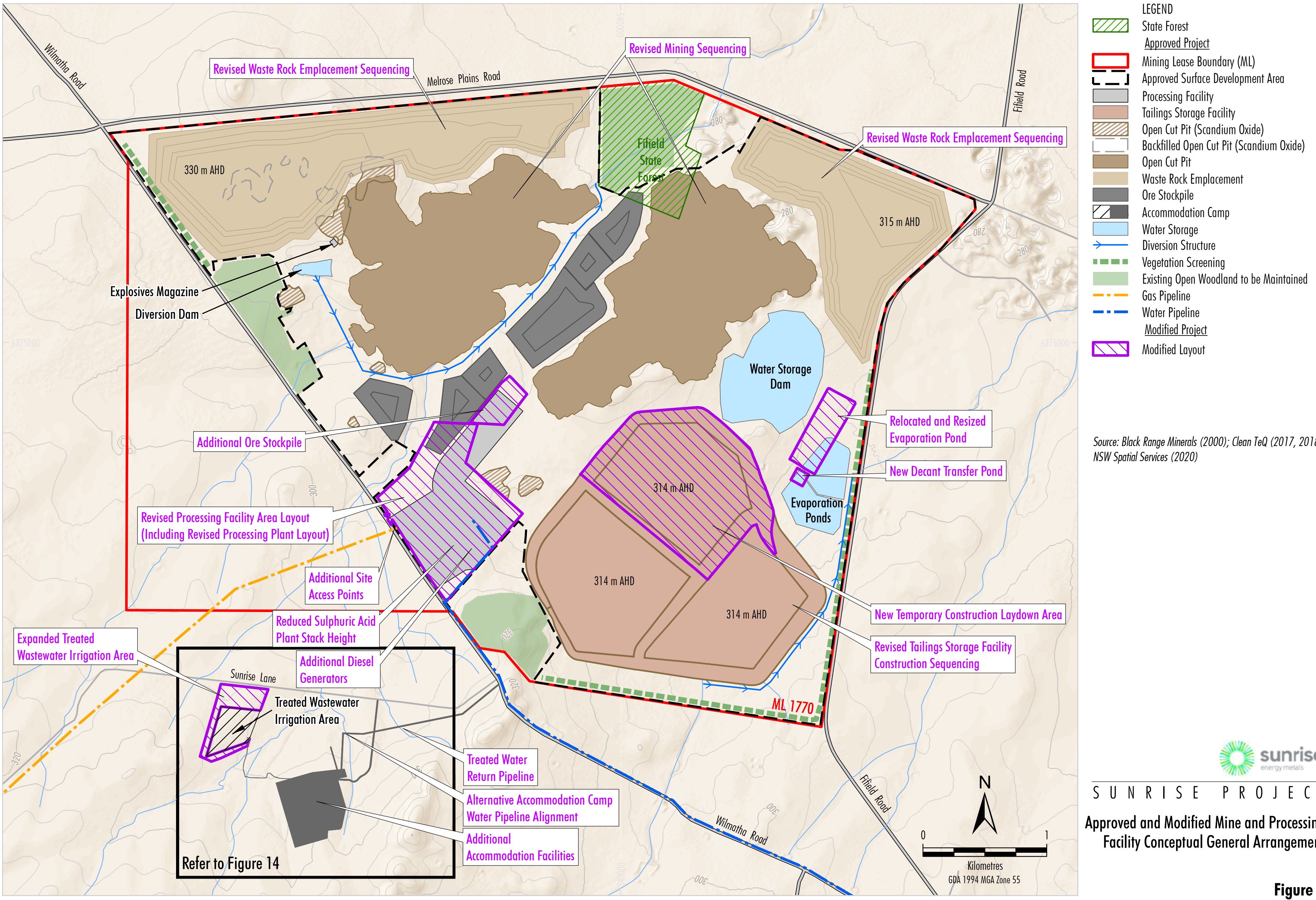
The Modification would include the following changes to the mine and processing facility (Figure 2):

- Revised processing facility area layout including a revised processing plant layout;
- Revised processing plant reagent types, rates and storage volumes (including increased ammonia storage vessels capacity);
- Reduced sulphuric acid plant stack height from 80 metres (m) to 40 m; and
- Increased number of diesel-powered backup generators (and associated stacks) from one to four.

Also, the Modification would include a revised rail siding location and layout, and the addition of an ammonium sulphate storage and distribution facility to the rail siding (Figure 3 and Figure 4).

This PHA has been prepared to support an application by SEM to modify Development Consent (DA 374-11-00) for the Project, which would be sought under section 4.55(2) of the EP&A Act.

This PHA has been prepared in accordance with the guidelines published by the NSW Department of Planning (DoP) (now the NSW Department of Planning, Industry and Environment [DPIE]) *Hazardous Industry Planning Advisory Paper (HIPAP) No 6* (Ref 3).



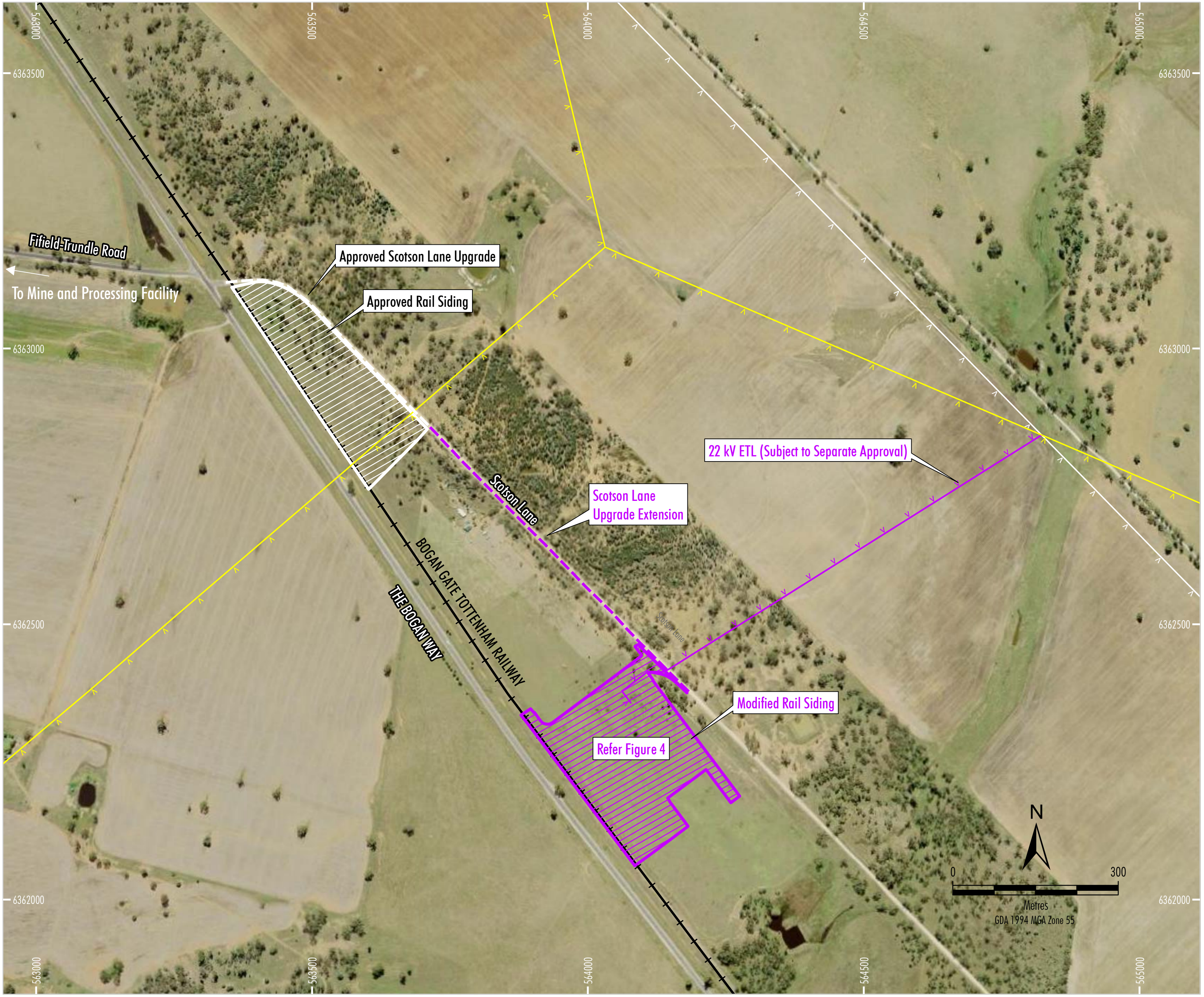
Source: Black Range Minerals (2000); Clean TeQ (2017, 2018, 2020); NSW Spatial Services (2020)

CTL-20-08 MOD 7_PHA_202B

SUNRISE PROJECT

Approved and Modified Mine and Processing Facility Conceptual General Arrangement

Figure 2



LEGEND

- ┿ Railway
- ▬ Existing 11 kV Electricity Transmission Line
- ▬ Existing 22 kV Electricity Transmission Line

Approved Project

- ▨ Surface Development Area
- ╌ Scotson Lane Upgrade

Modified Project

- ▨ Surface Development Area
- ╌ Scotson Lane Upgrade Extension
- ⌄ 22 kV Electricity Transmission Line (Subject to Separate Approval)

Source: Black Range Minerals (2000);
Clean Teq (2020, 2021); NSW Spatial Services (2020, 2021).

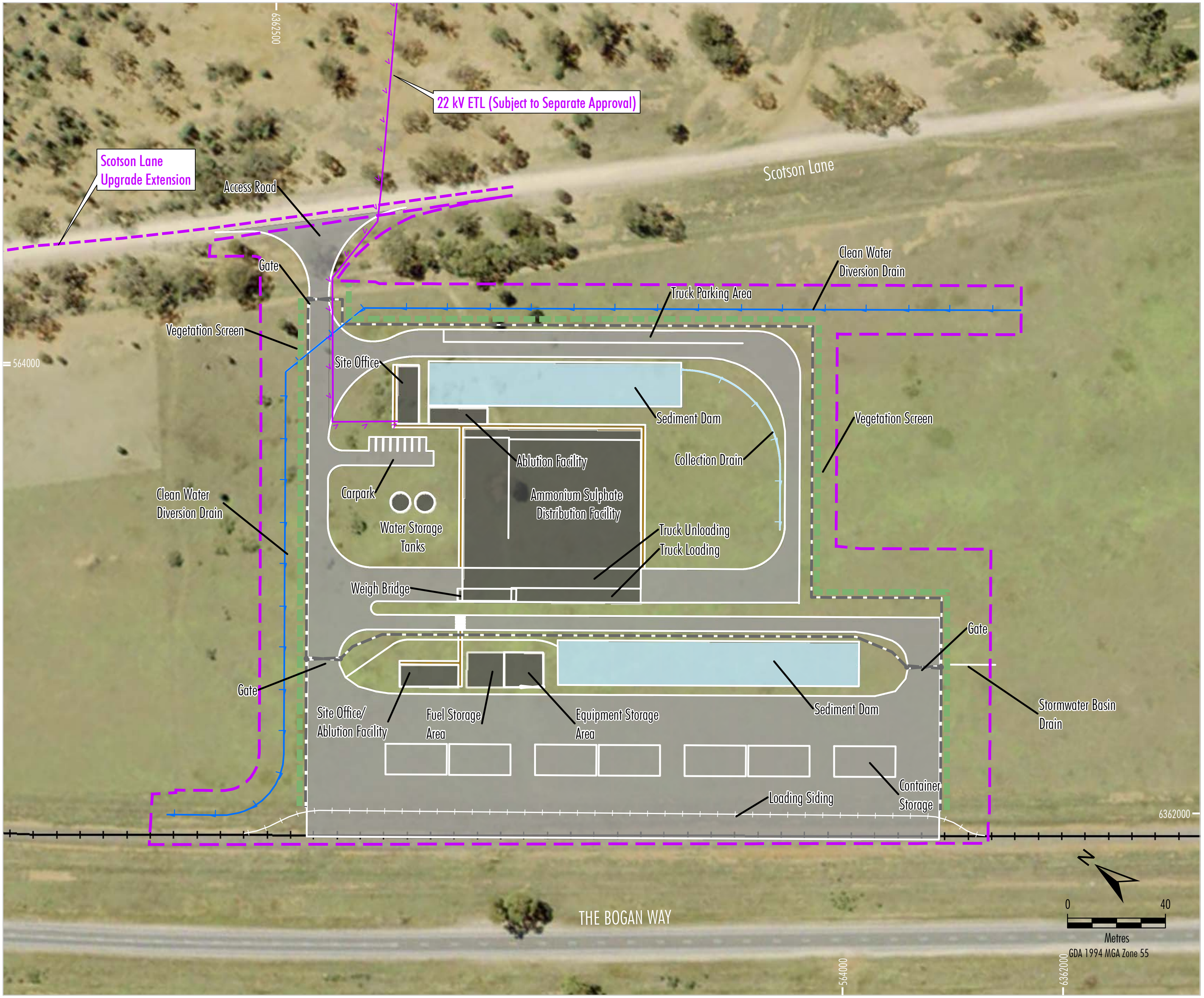
Orthophoto: © NSW Department of Finance, Services & Innovation (2021)

SUNRISE PROJECT

Approved and Modified Rail Siding Location

Figure 3

CTL-20-08 MOD 7_PHA_203A



LEGEND

—+— Railway

Modified Project

▭ Surface Development Area

- - Scotson Lane Upgrade Extension

v v 22 kV Electricity Transmission Line (Subject to Separate Approval)

Source: Black Range Minerals (2000); NSW Spatial Services (2020); Clean Teq (2017, 2018, 2020).
Orthophoto: © NSW Department of Finance, Services & Innovation (2020)

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SUNRISE PROJECT

Modified Rail Siding General Arrangement

Figure 4

CTL-20-08 MOD 7_PHA_204A

1.2 OBJECTIVES

The main aims of this PHA study are to:

- Identify the credible, potential hazardous events associated with the Modification (including the modified mine and processing facility and modified rail siding);
- Evaluate the level of risk associated with the identified potential hazardous events to surrounding land users and compare the calculated risk levels with the risk criteria published by the DoP in HIPAP No 4 (Ref 4);
- Review the adequacy of the proposed safeguards to prevent and mitigate the potential hazardous events; and
- Where necessary, submit recommendations to SEM to ensure that the modified Project is operated and maintained at acceptable levels of process safety and effective safety management systems are used.

1.3 SCOPE

This PHA assesses the credible, potential hazardous events and corresponding risks associated with the modified mine and processing facility and modified rail siding, with the potential for off-site impacts only.

Given the significant separation distances between the potentially hazardous materials and equipment at the modified mine and processing facility and rail siding to adjacent land users then only the events that have the potential for off-site impacts are analysed in detail in this PHA. This approach is consistent with the methodology used in the original and approved PHAs (Refs 1 and 2).

The transport of more hazardous materials, e.g. ammonia, are included in this PHA.

Given the Modification does not involve any changes to the limestone quarry, borefield, surface water extraction infrastructure and water pipeline, or the gas pipeline that are relevant to this PHA, the risks associated with these components of the Project have not been reassessed.

1.4 METHODOLOGY

In accordance with the approach recommended by the DoP in HIPAP No 6 (Ref 3), the underlying methodology of the PHA is risk-based, that is, the risk of a particular potentially hazardous event is assessed as the outcome of its consequences and likelihood.

The PHA has been conducted as follows:

- Initially, the relevant components of the revised processing facility area and rail siding were reviewed to identify credible, potential hazardous events, their causes and consequences. Proposed safeguards were also included in this review;
- As the potential hazardous events are located at a significant distance from other sensitive land users, the consequences of the potential hazardous events that could have off-site impact were estimated;
- Included in the analysis is the risk of propagation within the mine and processing facility and modified rail siding; and
- If adverse off-site impacts could occur, assess the risk levels to check if they are within the criteria in HIPAP No 4 (Ref 4).

1.5 RISK CRITERIA

The assessment of risks to both the public as well as to operating personnel from a potentially hazardous development requires the application of the basic steps outlined in Section 1.4. As per the NSW State Environmental Planning Policy (SEPP) 33 (Ref 5) and HIPAP No 6 (Ref 3), the chosen analysis technique should be commensurate with the nature of the risks involved.

The typical risk analysis methodology attempts to take account of all credible hazardous situations that may arise from the operation of processing plants etc. Specific incidents, identified by a variety of techniques, are assessed in terms of consequences and likelihood.

Having assembled data on the credible incidents, risk analysis requires the following general approach for individual incidents (which are then summated for all potential recognised incidents to get cumulative risk):

Risk = Likelihood x Consequence

For quantitative risk analysis (QRA) and hazard analysis, the consequences of an incident are calculated using standard correlations and probit-type methods which assess the effect of fire radiation, explosion overpressure and toxicity to an individual, depending on the type of hazard.

In this PHA, however, the approach adopted to assess the risk of the identified hazardous events is scenario based risk assessment. The reason for this approach is the limited hazardous events with the potential for off-site harm, i.e. there are generous separation distances involved to sensitive receptors.

Therefore, appropriate analysis of credible scenarios is performed in this PHA. Typically, the consequences of the potential events with off-site impact are assessed first. For the events which do not contribute to off-site risk (as determined by the risk criteria in HIPAP No 4 (Ref 4), no further risk analysis is warranted. When the consequence of an event does have the potential to impact people off-site, the likelihood and hence risk is then analysed as required.

The DoP risk criteria applying to developments are summarised in Table 2 below (from Ref 4).

Table 2 – Risk Criteria, New Plants

Description	Risk Criteria
Fatality risk to sensitive users, including hospitals, schools, aged care	0.5 x 10^{-6} per year
Fatality risk to residential and hotels	1 x 10^{-6} per year
Fatality risk to commercial areas, including offices, retail centres, warehouses	5 x 10^{-6} per year
Fatality risk to sporting complexes and active open spaces	10 x 10^{-6} per year
Fatality risk to be contained within the boundary of an industrial site	50 x 10^{-6} per year
Injury risk – incident heat flux radiation at residential areas should not exceed 4.7 kW/m^2 at frequencies of more than 50chances in a million per year or incident explosion overpressure at residential areas should not exceed 7 kPa at frequencies of more than 50chances in a million per year	50 x 10^{-6} per year
Toxic exposure - Toxic concentrations in residential areas which would be seriously injurious to sensitive members of the community following a relatively short period of exposure	10 x 10^{-6} per year
Toxic exposure - Toxic concentrations in residential areas which should cause irritation to eyes or throat, coughing or other acute physiological responses in sensitive members of the community	50 x 10^{-6} per year
Propagation due to Fire and Explosion – exceed radiant heat levels of 23 kW/m^2 or explosion overpressures of 14 kPa in adjacent industrial facilities	50 x 10^{-6} per year

2 PROJECT DESCRIPTION

The Project includes the establishment and operation of the following:

- Mine and processing facility;
- Limestone quarry;
- Rail siding;
- Borefield, surface water extraction infrastructure and water pipeline;
- Gas pipeline; and
- Associated transport activities and transport infrastructure (e.g. the Fifield Bypass, road and intersection upgrades).

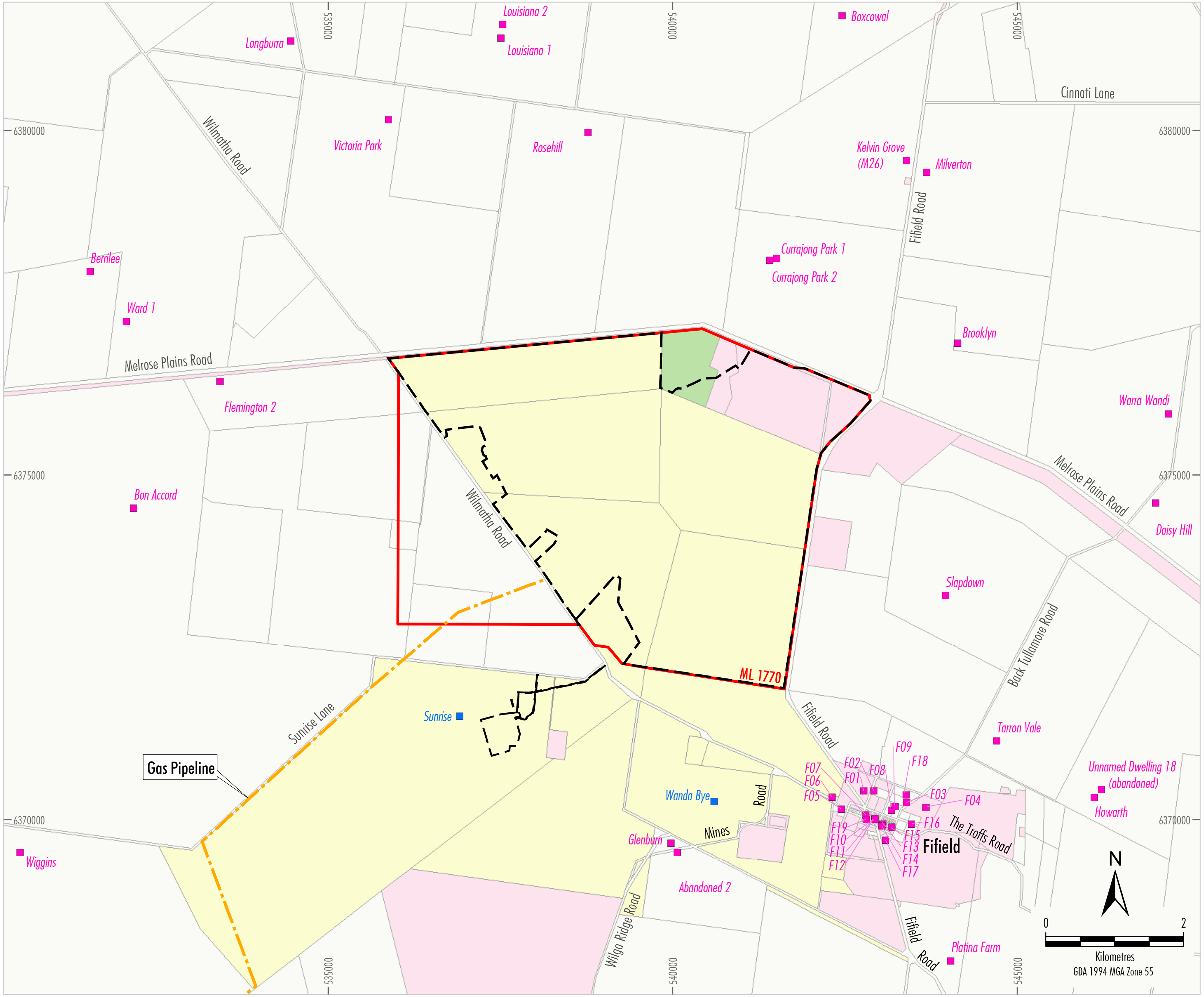
Land use surrounding the modified mine and processing facility, as well as the modified rail siding, is largely agricultural and is dominated by sheep farming and cropping.

The mine and processing facility is located approximately 4.5 km north-west of the village of Fifield in the Lachlan Shire Local Government Area (LGA) in the Central Western Region of NSW (Figure 1). The modified rail siding is located on the Bogan Gate Tottenham Railway approximately 25 km south-east of the mine and processing facility in the Parkes Shire LGA (Figure 1).

Both the mine and processing facility and modified rail siding are accessible by road. There are no ecologically sensitive areas (e.g. National Parks or wetlands) in the immediate vicinity of the mine and processing facility or modified rail siding.

Locations of the nearest dwellings from the processing facility are (Figure 5):

- ‘Sunrise’ approximately 2.6 km south-west (SEM owned);
- ‘Wanda Bye’ approximately 2.6 km south (SEM owned);
- ‘Slapdown’ approximately 4.6 km east;
- ‘Currajong Park 1 and 2’ approximately 5.8 km north-east; and
- ‘Flemington’ approximately 6.8 km north-west.



LEGEND
🟥 Mining Lease Boundary (ML)
▭ Approved Surface Development Area
— · — Gas Pipeline
▨ Sunrise Energy Metals Owned Land
▨ Crown Land
🟩 Fifield State Forest
☐ Private Landholder
■ Mine-owned Dwelling
■ Private Dwelling

Source: Black Range Minerals (2000); NSW Department of Industry (2017); NSW Land & Property Information (2017)

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S U N R I S E   P R O J E C T

Mine and Processing Facility
Land Ownership

Figure 5

CTL-20-08 MOD 7_PHA_205B

The distance of impact to residential areas is taken as 4.6 km, i.e to the 'Slapdown' dwelling, as this is the closest privately-owned dwelling to the processing facility, and the percentage of the wind direction from the west is relatively higher than some other directions.

Locations of the nearest dwellings from the modified rail siding are (Figure 6):

- An SEM-owned property approximately 350 m north-west;
- 'Glen Rock' approximately 1.1 km west; and
- 'Ballenrae West' approximately 1.3 km east.

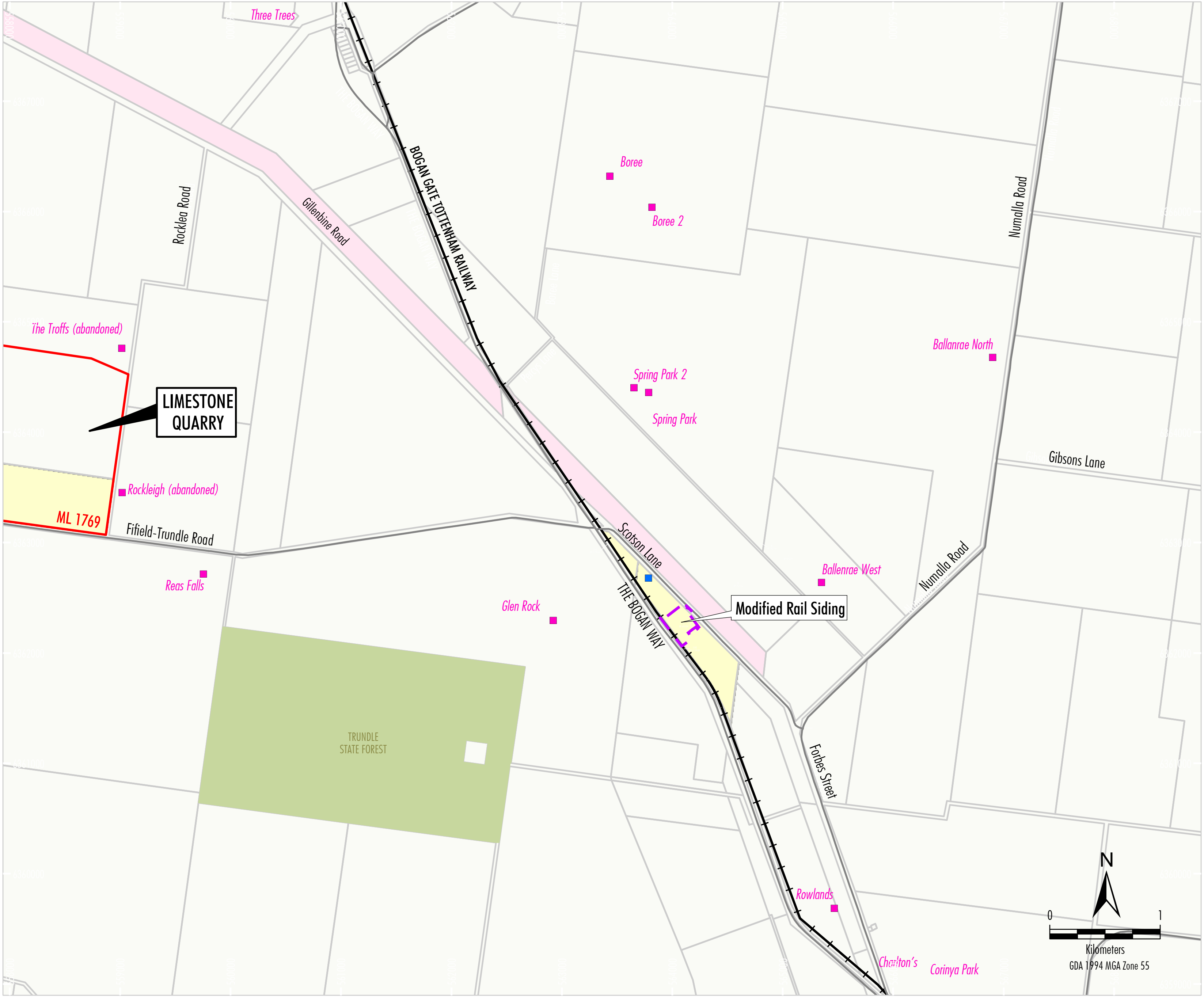
The distance of impact to residential areas is taken as 1.1 km, i.e to the 'Glen Rock' dwelling, as this is the closest privately-owned dwelling to the modified rail siding.

Security of the mine and processing facility and modified rail siding would be achieved by a number of means. This includes security fencing, site personnel and where necessary security patrols by an external security company (including weekends and night patrols). Both the modified mine and processing facility and modified rail siding would operate 24 hours per day, 7 days per week.

At the modified mine and processing facility, there would be approximately 180 people on site during day shifts and 60 people on site during night shifts. At the modified rail siding, there would be approximately 6 people on site during day shift and 4 people on site during night shifts.

There are no natural hazards for either the mine and processing facility or modified rail siding that are considered high risk.

A detailed layout drawing showing the proposed location of the mine and processing facility components is provided on Figure 7.



LEGEND

- ┼─┼ Railway
- ▭ Mining Lease Boundary (ML)
- 🟨 Sunrise Energy Metals Owned Land
- ▭ Crown Land
- ▭ Private Landholder
- ■ Mine-owned Dwelling
- ■ Private Dwelling

Modified Project

- ⌐ ¬ Surface Development Area

Source: Black Range Minerals (2000); NSW Spatial Services (2020); Clean Teq (2017, 2018, 2020).
Orthophoto: © NSW Department of Finance, Services & Innovation (2020)

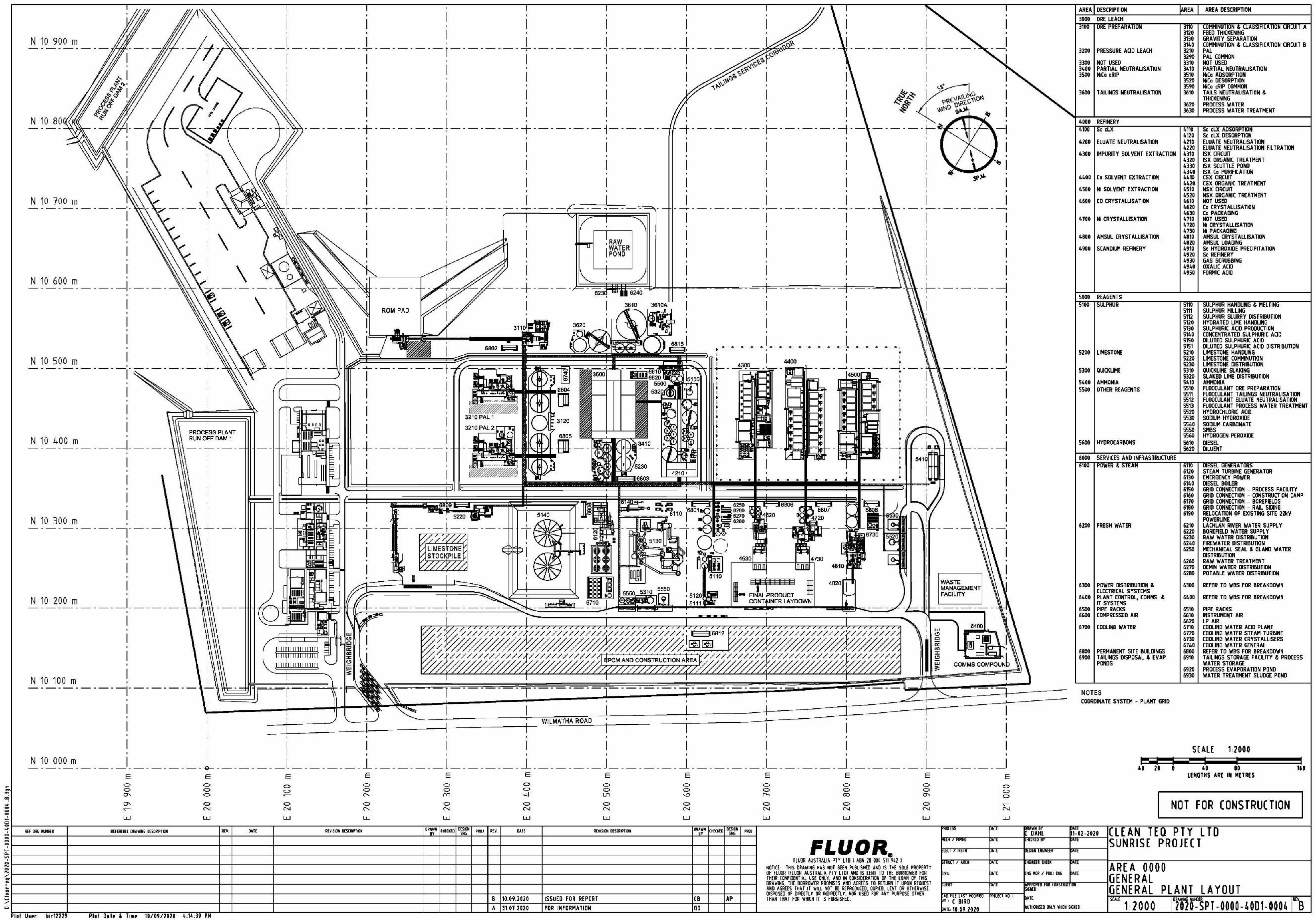
SUNRISE PROJECT

Rail Siding
Land Ownership

Figure 6

CTL-20-08 MOD 7_PHA_206B

Figure 7 - Mine and Processing Facility Components



AREA	DESCRIPTION	AREA	AREA DESCRIPTION
3000	ORE LEACH		
3100	ORE PREPARATION	3110	COMMINUTION & CLASSIFICATION CIRCUIT A
		3120	FEED THICKENING
		3130	GRAVITY SEPARATION
		3140	COMMINUTION & CLASSIFICATION CIRCUIT B
3200	PRESSURE ACID LEACH	3210	PAL
		3290	PAL COMMON
3300	NOT USED	3310	NOT USED
3400	PARTIAL NEUTRALISATION	3410	PARTIAL NEUTRALISATION
3500	NiCo cRIP	3510	NiCo ADSORPTION
		3520	NiCo DESORPTION
		3590	NiCo cRIP COMMON
3600	TAILINGS NEUTRALISATION	3610	TAILS NEUTRALISATION & THICKENING
		3620	PROCESS WATER
		3630	PROCESS WATER TREATMENT
4000	REFINERY		
4100	Sc cLX	4110	Sc cLX ADSORPTION
		4120	Sc cLX DESORPTION
4200	ELUATE NEUTRALISATION	4210	ELUATE NEUTRALISATION
		4220	ELUATE NEUTRALISATION FILTRATION
4300	IMPURITY SOLVENT EXTRACTION	4310	ISX CIRCUIT
		4320	ISX ORGANIC TREATMENT
		4330	ISX SCUTTLE POND
		4340	ISX Co PURIFICATION
4400	Co SOLVENT EXTRACTION	4410	CSX CIRCUIT
		4420	CSX ORGANIC TREATMENT
4500	Ni SOLVENT EXTRACTION	4510	NSX CIRCUIT
		4520	NSX ORGANIC TREATMENT
4600	CO CRYSTALLISATION	4610	NOT USED
		4620	Co CRYSTALLISATION
		4630	Co PACKAGING
4700	Ni CRYSTALLISATION	4710	NOT USED
		4720	Ni CRYSTALLISATION
		4730	Ni PACKAGING
4800	AMSUL CRYSTALLISATION	4810	AMSUL CRYSTALLISATION
		4820	AMSUL LOADING
4900	SCANDIUM REFINERY	4910	Sc HYDROXIDE PRECIPITATION
		4920	Sc REFINERY
		4930	GAS SCRUBBING
		4940	OXALIC ACID
		4950	FORMIC ACID
5000	REAGENTS		
5100	SULPHUR	5110	SULPHUR HANDLING & MELTING
		5111	SULPHUR MILLING
		5112	SULPHUR SLURRY DISTRIBUTION
		5120	HYDRATED LIME HANDLING
		5130	SULPHURIC ACID PRODUCTION
		5140	CONCENTRATED SULPHURIC ACID
		5150	DILUTED SULPHURIC ACID
		5151	DILUTED SULPHURIC ACID DISTRIBUTION
5200	LIMESTONE	5210	LIMESTONE HANDLING
		5220	LIMESTONE COMMINUTION
		5230	LIMESTONE DISTRIBUTION
5300	QUICKLIME	5310	QUICKLIME SLAKING
		5320	SLAKED LIME DISTRIBUTION
5400	AMMONIA	5410	AMMONIA
5500	OTHER REAGENTS	5510	FLOCCULANT ORE PREPARATION
		5511	FLOCCULANT TAILINGS NEUTRALISATION
		5512	FLOCCULANT ELUATE NEUTRALISATION
		5513	FLOCCULANT PROCESS WATER TREATMENT
		5520	HYDROCHLORIC ACID
		5530	SODIUM HYDROXIDE
		5540	SODIUM CARBONATE
		5550	SMBS
		5560	HYDROGEN PEROXIDE
5600	HYDROCARBONS	5610	DIESEL
		5620	DILUENT
6000	SERVICES AND INFRASTRUCTURE		
6100	POWER & STEAM	6110	DIESEL GENERATORS
		6120	STEAM TURBINE GENERATOR
		6130	EMERGENCY POWER
		6140	DIESEL BOILER
		6150	GRID CONNECTION - PROCESS FACILITY
		6160	GRID CONNECTION - CONSTRUCTION CAMP
		6170	GRID CONNECTION - BOREFIELDS
		6180	GRID CONNECTION - RAIL SIDING
		6190	RELOCATION OF EXISTING SITE 22kV POWERLINE
6200	FRESH WATER	6210	LACHLAN RIVER WATER SUPPLY
		6220	BOREFIELD WATER SUPPLY
		6230	RAW WATER DISTRIBUTION
		6240	FIREWATER DISTRIBUTION
		6250	MECHANICAL SEAL & GLAND WATER DISTRIBUTION
		6260	RAW WATER TREATMENT
		6270	DEMIN WATER DISTRIBUTION
		6280	POTABLE WATER DISTRIBUTION
6300	POWER DISTRIBUTION & ELECTRICAL SYSTEMS	6300	REFER TO WBS FOR BREAKDOWN
6400	PLANT CONTROL, COMMS. & IT SYSTEMS	6400	REFER TO WBS FOR BREAKDOWN
6500	PIPE RACKS	6510	PIPE RACKS
6600	COMPRESSED AIR	6610	INSTRUMENT AIR
		6620	LP AIR
6700	COOLING WATER	6710	COOLING WATER ACID PLANT
		6720	COOLING WATER STEAM TURBINE
		6730	COOLING WATER CRYSTALLISERS
		6740	COOLING WATER GENERAL
6800	PERMANENT SITE BUILDINGS	6800	REFER TO WBS FOR BREAKDOWN
6900	TAILINGS DISPOSAL & EVAP. PONDS	6910	TAILINGS STORAGE FACILITY & PROCESS WATER STORAGE
		6920	PROCESS EVAPORATION POND
		6930	WATER TREATMENT SLUDGE POND

REV.	DATE	REVISION DESCRIPTION	DRAWN BY	CHECKED	DESIGN ENG	PROJ
B	10.09.2020	ISSUED FOR REPORT	CB		AP	
A	31.07.2020	FOR INFORMATION	GD			

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3 PROCESS DESCRIPTION

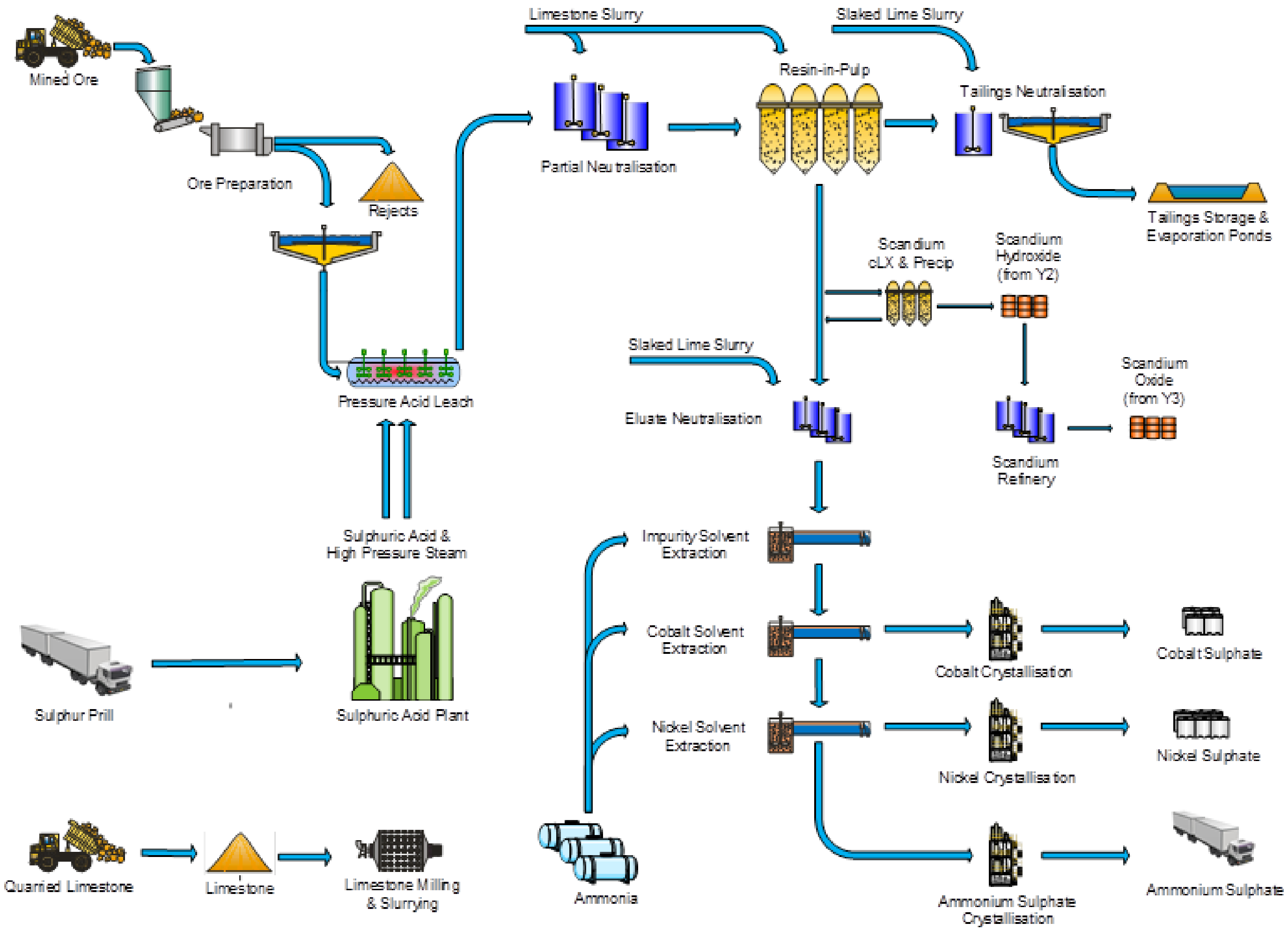
3.1 OVERALL PROCESS DESCRIPTION

The following process description is from the Sunrise Project Execution Plan Phase Report (Ref 6). It is an update of that presented in the previous PHA (Ref 2). Further details can be obtained in Ref 6. A process schematic flow sheet is shown in Figure 8.

The processing plant comprises four main areas and numerous sub-areas as listed below.

- Area 3000 Ore Leach
    - Sub-area 3100 Ore Preparation
    - Sub-area 3200 Pressure Acid Leach
    - Sub-area 3400 Partial Neutralisation (PN)
    - Sub-area 3500 NiCo cRIP (Nickel Cobalt Continuous Resin in Pulp)
    - Sub-area 3600 Tailings Neutralisation (TN)
- Area 4000 Refinery
    - Sub-area 4100 Sc cLX (Scandium Continuous Liquid Ion Exchange)
    - Sub-area 4200 Eluate Neutralisation (EN)
    - Sub-area 4300 Impurity Solvent Extraction (ISX)
    - Sub-area 4400 Co Solvent Extraction (CSX)
    - Sub-area 4500 Ni Solvent Extraction (NSX)
    - Sub-area 4600 Co Crystallisation
    - Sub-area 4700 Ni Crystallisation
    - Sub-area 4800 Amsul (ammonium sulphate) Crystallisation
    - Sub-area 4900 Scandium Refinery

Figure 8 – Schematic Process Flow Sheet



- Area 5000 Reagents
    - Sub-area 5100 Sulphur
    - Sub-area 5200 Limestone
    - Sub-area 5300 Quicklime
    - Sub-area 5400 Ammonia
    - Sub-area 5500 Other Reagents
    - Sub-area 5600 Hydrocarbons
- Area 6000 Services and Infrastructure
    - Sub-area 6100 Power and Steam
    - Sub-area 6200 Fresh Water
    - Sub-area 6600 Air Supply
    - Sub-area 6700 Cooling Water
    - Sub-area 6900 Tailings Disposal and Evaporation Ponds

The processing plant has a nameplate capacity of 2.5 Mtpa of solids fed to the leach autoclaves. The processing facility is designed to produce a maximum of 30 ktpa of contained nickel (Ni) and cobalt (Co) in the form of battery grade nickel sulphate hexahydrate and cobalt sulphate heptahydrate. The scandium recovery circuit is designed to produce a scandium hydroxide product at a rate of 30 tpa of contained scandium oxide equivalent. A scandium refinery to produce 20 tpa of high purity scandium oxide from a portion of this scandium hydroxide will be operated from Year 3 onwards. Ammonium sulphate, commonly used as an agricultural fertilizer, is produced as a by-product of the refining process at a rate of approximately 70 ktpa. Notwithstanding the above, is noted that the Project is approved to produce 40 tpa of nickel and cobalt metal sulphates, 100 ktpa of ammonium sulphate and 180 tpa of scandium oxide.

Ore is mined from the open pits and hauled to the adjacent processing plant. Ore is primarily directly tipped into the Run-of-Mine (ROM) bin, however can be deposited to a ROM stockpile if direct tipping is not available. The ROM stockpile is serviced by a front-end-loader (FEL) and used to supplement direct tipped ore if there is an interruption such as poor weather or mechanical issues.

The ore preparation circuit is designed to process high grade, low silica goethite ore (Silica:Aluminium [Si:Al] < 2.65) for the first 4 years of operation using a combination of crushing and closed circuit ball milling (wet screen classification) to achieve the desired particle size distribution without appreciable mass rejection.

Feed blends rich in silica (silicified goethite, Si:Al > 2.65) are amenable to beneficiation by rejecting a competent, coarse grained barren component. A second ore preparation circuit will be constructed in year 4 to process this ore using a combination of crushing, open circuit wet scrubbing and size classification using vibrating wet screens to selectively reject coarse, low grade components of the ore and advance a beneficiated slurry to the existing ball mill circuit.

The classified slurry is then dewatered in paste thickeners before entering the 18-hour pressure acid leach (PAL) feed surge tanks. The ore preparation circuit is operated at elevated temperature by recirculating a stream of water that is heated in the downstream leach circuits using low pressure (LP) flash steam. This configuration reduces the quantity of high pressure (HP) steam required for autoclave temperature control. The ore preparation circuit is designed with redundancy, surge and catchup capacity to allow for regular planned maintenance to be performed without compromising downstream production.

The two parallel, identical PAL trains lie at the core of the processing facility and represent the asset which has the highest impact on the plant availability. Upstream of PAL the plant has been designed to ensure that slurry is always available for leaching when the autoclaves are in operation. Similarly, the downstream circuits have been designed to ensure leached slurry can always be received for processing when the autoclaves are in operation.

Preheated slurry from the ore preparation circuit is pumped through two direct contact steam heaters, using steam recovered from the flash circuit as the heating medium, before entering the six-compartment, mechanically agitated horizontal autoclave. Leaching of the slurry is undertaken at high temperature (250°C) to reduce iron and aluminium solubility, thereby reducing leach acid consumption which is the primary contributor to reagent operating costs. Leached slurry is discharged through a three-stage flash pressure reduction system and pumped to the partial neutralisation circuit. LP steam recovered from the final flash vessel is used to heat water for use in Ore preparation as previously described.

The partial neutralisation (PN) circuit is the physical and chemical link between the upstream leach circuit and the downstream continuous resin-in-pulp (cRIP) circuit. In cRIP, soluble nickel and cobalt are extracted from the slurry using an ion exchange resin. When nickel and cobalt are extracted, any soluble iron, aluminium and chromium present will also be extracted to a large extent and this impurity transfer incurs significant operating cost and also occupies production capacity otherwise reserved for nickel and cobalt. Fortunately, iron, aluminium and chromium can be selectively precipitated from the slurry by raising the slurry pH. This must be performed carefully (to avoid precipitating a significant quantity of nickel and cobalt which will occur if pH is raised too high) and quickly (to avoid adsorption of nickel and cobalt on the precipitated solids which increases with ageing time). The PN circuit is designed to address these challenges.

The PN circuit consists of two co-current stages of neutralisation separated by a surge tank. Each stage comprises several mechanically agitated tanks configured in series. Limestone slurry is added to the tanks for the purpose of acid neutralisation (pH control). The first PN stage is designed to achieve addition of ~80% of total limestone demand, which is consumed quickly and without the need for particularly close control of the final pH.

A six-hour PN surge tank separates the two PN stages and is the major slurry surge point between the leach circuit and the resin-in-pulp (cRIP) circuit used for primary recovery of nickel-cobalt-scandium from the leached slurry. This permits the downstream circuits (PN stage 2, cRIP) to be controlled at a slower rate of change relative to the leach circuit. This mode of operation is conducive to achieving high recoveries as a result of tight control of the PN stage 2 pH (low Ni-Co precipitation losses) as well as steady cRIP operation (high soluble Ni-Co recovery).

The second stage of PN receives the remaining ~20% of limestone to reduce remaining iron, aluminium and chromium to optimum levels for the downstream cRIP circuit.

The cRIP circuit adsorbs the value metals from the advancing slurry using ion exchange. cRIP is divided into two parallel trains, each with an adsorption and desorption circuit. The resin adsorbs the value metals (Nickel, Cobalt, Scandium) from the slurry preferentially over the majority of the impurities (Manganese, Magnesium), discharging the spent pulp from the circuit to the tailings neutralisation circuit for disposal. The loaded resin is washed to remove entrained pulp before being contacted with dilute sulphuric acid (eluant) to desorb (elute) all loaded metals, thereby creating a relatively concentrated stream of nickel and cobalt containing minor impurities (eluate). Eluate is stored in a 12-hour surge tank providing the primary process break between the upstream large-volume slurry processing areas and the downstream low-volume liquor processing areas. Eluted resin is recirculated to adsorption.

Spent pulp, and other waste streams from the processing plant, are neutralised using slaked lime in the tailings neutralisation circuit before being thickened in the tailings thickener to reduce the contained water content to only that required for pumping/transfer purposes. Densified slurry from the tailings neutralisation area is pumped to the tailings storage facility for final deposition.

Process water, the combination of tailings thickener overflow and water recovered from the tailings dam, is entirely re-used within the process. Some are used directly for the preparation of limestone slurry and for treatment in the process water treatment plant (if required) to remove magnesium, manganese and sulphate to levels suitable for re-use in the Ore Prep (and downstream PAL) circuit. Ore Prep make-up water is supplemented by raw water imported from offsite. The balance is further clarified to remove suspended solids with the resulting *clean* process water used in the cRIP circuit for washing of loaded resin.

Eluate produced within the cRIP area is a relatively concentrated stream of liquor containing nickel, cobalt and scandium (as value metals), together with small but significant levels of iron, aluminium, chromium, copper, zinc, manganese, magnesium and calcium. These elements are sequentially separated in a series of unit operations that together encompass the Refinery section of Sunrise.

The first refining unit operation is for recovery of scandium. This is an optional process in that selective scandium removal is not required to facilitate nickel-cobalt production. Consequently, scandium is recovered from only a portion of the eluate (20%), with the balance of the eluate proceeding directly to the downstream eluate neutralisation area. Scandium recovery will commence only at the start of Year 2.

Scandium is recovered from the eluate using an ion exchange process. Scandium is adsorbed onto a scandium-selective resin, which is then washed and eluted using sodium carbonate; eluted resin is returned to adsorption. The scandium-rich eluate is heated to selectively precipitate contained iron, then sodium hydroxide is added to precipitate a scandium hydroxide product which is washed, partially dewatered and stored in Intermediate Bulk Containers (IBCs) for further processing. Refining of the scandium hydroxide to a higher purity (for example, scandium oxide) will take place from Year 3 onwards.

All eluate, whether treated for scandium or not, is processed through the eluate neutralisation (EN) circuit. Here a two-stage counter-current precipitation process is used to selectively remove iron, aluminium and chromium impurities while retaining nickel and cobalt in the liquor phase for downstream recovery. Slaked lime slurry is used as the precipitation agent. Precipitated impurities are dewatered and washed then recycled to the upstream partial neutralisation circuit for recovery of any co-precipitated and/or soluble nickel-cobalt. The two-stage configuration avoids recirculating a high proportion of nickel-cobalt across the cRIP circuit, thereby conserving operating costs.

Each EN stage comprises several mechanically agitated tanks configured in series followed by a thickener to effect solid-liquid separation. Slaked lime slurry is added to the tanks for the purpose of acid neutralisation (pH control). The EN stage 1 precipitate (comprising gypsum, iron- and aluminium-hydroxides) is thickened, then dewatered and washed in a pressure filter, then re-pulped and returned to the upstream PN circuit. The EN stage 2 precipitate (comprising gypsum, iron- and aluminium-hydroxides, together with nickel- and cobalt hydroxides) is thickened and recycled to the first EN stage 1 reactor for nickel-cobalt redissolution.

The liquor discharged from the EN stage 2 thickener is clarified in a polishing filter before entering a 12-hour surge tank which, together with the eluate surge tank, provides surge volume ahead of the three sequential solvent extraction (SX) circuits. This ensures, as far as practicable, SX operation with low rates of change in feed flow and composition which is conducive to achieving the high metal separation extents demanded by the nickel and cobalt product purity specifications, as well as low levels of internal metal recirculation within the SX areas which drive operating costs.

Each SX circuit uses a specific organic solvent to selectively extract certain metals, leaving others behind in the liquor phase for further processing. The organic extractant type and the metals targeted for extraction in each SX circuit are:

1. Impurity SX (ISX): Phosphoric acid (e.g. Di-(2-ethylhexyl) phosphoric acid); zinc, calcium, copper, manganese
2. Cobalt SX (CSX): Phosphonic acid (e.g. Cyanex 272); cobalt (plus remaining zinc, copper, manganese)
3. Nickel SX (NSX): Carboxylic acid (e.g. Versatic 10); nickel.

All SX circuits use mixer-settlers for aqueous-organic contacting in a counter-current configuration. Gaseous anhydrous ammonia is used for pH control in the extraction stages and dilute sulphuric acid used for scrubbing and stripping solutions. All aqueous exit streams are treated for organic removal to both minimise the cost associated with organic reagent make-up and also to prevent cross-contamination of extractants between adjacent circuits.

ISX produces a strip product liquor that is neutralised with lime slurry and discharged into an evaporation pond.

CSX strip product liquor, rich in cobalt, is returned to the cobalt purification section of the ISX circuit for final scavenging of impurities. This purified strip product is advanced to the cobalt crystallisation circuit.

NSX strip product liquor, rich in nickel, is advanced directly to the nickel crystallisation circuit.

Cobalt and nickel crystallisation and packaging circuits have a similar design configuration. Crystalliser feed liquor is collected from upstream in three twelve-hour surge tanks before being pumped into the crystallisers. In addition to providing surge capacity, the three feed tanks enable blending and, if necessary, quarantining of feed solutions. The dry crystalliser products are conveyed to the eight-hour silo's in the respective packaging plant. The product crystals are withdrawn from the silo's and packaged into sealed 1m^3 bulk bags and loaded into shipping containers for dispatch to customers. Process condensate from the crystallisers is used for strip and scrub liquor make-up in the respective SX circuits. Residual mother liquor is purged to the feed tanks of the respective solvent extraction circuits to provide an outlet for chloride. The crystallisers are designed to run on a continuous basis while the packaging plants are designed to run for 12 hours per day.

NSX raffinate is advanced to a single twenty-four-hour amsul crystalliser feed tank which provides a surge point between the solvent extraction and amsul crystalliser circuits. The amsul crystalliser recovers high quality water from the NSX raffinate for re-use as cRIP eluant make-up) while providing an outlet for the ammonium sulphate produced during SX extraction. The ammonium sulphate crystals, which require a crystalliser specifically designed to meet the large crystal size demanded by the amsul market, are transported from the crystalliser circuit to the storage and distribution shed. . Amsul is reclaimed in bulk from the sheds stockpiles and transported by truck to the storage and distribution facility at the rail siding for sale to local markets.

All rainfall collected within the designated perimeter of the processing plant is considered potentially contaminated and therefore fully contained and returned directly to the processing plant. Within bunded areas, rainfall is collected and returned to the process via drains and sump pumps. Water collected outside of the bunded areas, such as rainfall on roads, is contained within the processing plant drainage system and directed to one of two lined processing plant runoff dams via a series of spoon drains and culverts. Each of the two processing plant runoff dams have a duty and standby set of pumps, and appropriate instrumentation for automatic operation, to pump the water from the dams directly to the process water tank for use in the processing plant.

3.2 RAIL SIDING

The Modification would include the following changes to the approved rail siding (Figure 3 and Figure 4):

- Revised rail siding location and layout;
- Addition of an ammonium sulphate storage and distribution facility to the rail siding;
- Extension of the Scotson Lane upgrade; and
- Addition of a 22 kV electrical transmission line (subject to separate approval) to the rail siding power supply.

Consistent with the approved rail siding, the modified rail siding will serve as a loading and unloading point for the consumables transported by rail and as the export point for the nickel, cobalt, scandium and ammonium sulphate product. As described above, the modified rail siding would also include the addition of an ammonium sulphate storage and distribution facility which would facilitate the supply of ammonium sulphate (a fertiliser) to agricultural operations in the region.

Activities at the rail siding would include train loading and unloading (by forklift), container stacking, and truck loading and unloading. The modified rail siding would consist of the following main components:

- Loading siding[3];
- Site access point and internal roads;
- Truck parking, loading and unloading hardstand areas and weighbridge;
- Container storage hardstand areas;
- Ammonium sulphate storage and distribution facility;

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[3] The loading siding may not be required depending on other rail operations on the Tottenham to Bogan Gate Railway.

- Site offices, ablution facilities, sewage system and car parking;
- Equipment and fuel storage areas;
- Water storage tanks;
- Lighting and telecommunications infrastructure;
- Sediment dams, clean water diversions, runoff collection drains and other water management equipment and structures;
- Landscaping (including vegetation screen) and perimeter security fencing; and
- Other associated minor infrastructure, plant, equipment and activities.

The Bogan Gate Tottenham Railway is infrequently used for grain transport. Depending on future rail operations on the Bogan Gate Tottenham Railway, the Project trains may therefore be able to be loaded/unloaded on the main line. If this is the case, the loading siding would not be constructed and train loading/unloading would occur on the main line. The requirement for the loading siding would be determined in consultation with John Holland (or the relevant rail network operator at the time).

The modified rail siding perimeter would be fenced. Trucks would run from the siding to the mine and processing facility on a campaign basis when trains arrive.

3.3 TRANSPORT

The various aspects of transport associated with the Project are:

- Rail transportation of bulk materials to, and from, the modified rail siding using containers;
- Road transport of limestone from the limestone quarry or third party suppliers to the mine and processing facility;
- Road transport of bulk materials, chemicals, reagents and goods to the mine and processing facility;
- On-site transport and storage requirements; and
- Export of product from site.

The rail system would be used primarily for the receival of sulphur and export of product, plus receival of other reagents and supplies.

The bulk chemicals likely to be transported to the mine and processing facility by road tankers are diluent, diesel, caustic soda, liquid nitrogen, quicklime, anhydrous ammonia, hydrogen peroxide, hydrated lime, sulphuric acid (for startup), hydrochloric acid, ammonium nitrate and flocculant. Waste oil from the effluent separator would be transported from the mine and processing facility by road tanker. The majority of the packaged chemicals (e.g. acids, bases and reagents in bulkiboxes, and chemicals and catalysts supplied in drums, bulkabags or cylinders) are to be transported by road.

The mine and processing facility is accessible by the existing local road network. The local road network would be upgraded in accordance with the conditions of Development Consent DA 374-11-00 and Voluntary Planning Agreement with the Lachlan Shire Council, Parkes Shire Council and Forbes Shire Council. Nickel, cobalt and scandium product would be exported from the site in containers via road to the rail siding and via rail transport to a suitable port (e.g. Port Botany or Newcastle). Bulk ammonium sulphate by-product would be transported by road to the ammonium sulphate storage and distribution facility located near the rail siding area for storage and distribution to users.

The sulphur transport capacity would be a 350,000 tonne per annum operation involving bulk transport by ship to Newcastle and then by rail and road to the site.

Up to a total of 990,000 tonnes of limestone would be transported by road to the mine and processing facility, with up to 790,000 tonnes from the limestone quarry and up to 560,000 tonnes from a third party supplier.

The above process description is very similar to that presented in the previous, approved PHA (Ref 2). With regards to major hazards, the events with the potential for adverse off-site impacts from the mine site are the same as previously analysed, i.e. releases of sulphur dioxide (from the sulphuric acid plant) and ammonia, failures associated with the natural gas pipeline and an incident involving explosives (including the ammonium nitrate emulsion). The other potential hazardous events, e.g. fires (such as pool fires in the solvent extraction areas), dust explosions (e.g. sulphur or ammonium sulphate) and corrosive liquids releases, do not pose credible off-site impacts given the separation distances between the potentially hazardous materials and equipment and the nearest private place of residences and also the site boundaries. For example, the closest plant equipment to the nearest site boundary around the processing plant is approximately 110 m away.

4 HAZARD IDENTIFICATION

4.1 HAZARDOUS MATERIALS

The hazardous materials involved with the Modification are shown in Table 3. Given the large separation distances from the location of these materials to the nearest place of residence to the modified processing facility (4.6 km to the nearest privately owned property) then the materials with the potential for off-site impact are:

- Natural gas due to failure of the natural gas supply pipeline with subsequent ignition. This can occur anywhere along the pipeline;
- Incident involving the explosives storages where the explosives detonate; and
- Ammonia and sulphur oxides due to a large release and dispersion downwind.

The potential for offsite impact at the rail siding is negligible given the materials.

4.1.1 Natural Gas

Natural gas is a Class 2.1 Dangerous Good (DG) (flammable gas). It is a colourless hydrocarbon fluid mainly composed of the following hydrocarbons:

- Methane (typically 88.5% or higher);
- Ethane (typically 8%);
- Propane (typically 0.2%);
- Carbon dioxide (typically 2%); and
- Nitrogen (typically 1.3%).

For a typical natural gas, the TLV (threshold limit value) is approximately 1,000 parts per million (ppm) and the STEL (short term exposure limit) is 30,000 ppm (i.e. approaching 5 vol% which is the lower explosive limit).

The hydrocarbons are not considered to represent a significant environmental threat. Their hazard potential derives solely from the fact that they are flammable materials. To enable ready leak detection, natural gas is normally odorised with mercaptans (sulphur containing hydrocarbons).

The flammability range is typically 5% to 15% by volume in air. The vapours are lighter than air and will normally disperse safely if not confined and/or ignited. Natural gas ignition can lead to jet fires, flash fires or vapour cloud explosions.

Products of combustion include carbon monoxide and carbon dioxide.

Table 3 - Hazardous Materials Summary

Material	Plant Area	Description	Typical Annual Consumption	Storage Amount
Processing Plant Raw Materials				
Sulphur Prills	5110	Prilled solids. Transported in closed containers by rail and road. Full container storage provided on site with primary site sulphur storage as molten sulphur.	286,226 t	300 t
Sulphuric Acid (98.5%)	5140	Product of the sulphuric acid plant; stored in two tanks prior to use in various process areas (predominantly area 3200).	N/A	45,000 t
Hydrated Lime ($Ca(OH)_2$)	5120	Powder. Transported to site in road tankers and stored in a closed silo.	458 t	50 t
Quicklime (CaO)	5310	Powder. Transported to site in road tankers and stored in a closed silo.	46,424 t	403 t
Anhydrous Ammonia	5410	Liquid. Transported to site in pressurised road tankers and stored in bullets.	24,978 t	415 t
Flocculant (Ore Preparation)	5510	Powder. Transported to site in road tankers and stored in closed silos.	470 t	60 t
Flocculant (Eluate Neutralisation)	5510	Powder. Transported to site in road tankers and stored in closed silos.		
Flocculant (Tailings)	5510	Powder. Transported to site in road tankers and stored in closed silos.		
Flocculant (Process Water Treatment)	5510	Powder. Transported to site in road tankers and stored in closed silos.		
Hydrochloric Acid (32%)	5520	Liquid. Transported to site in road tankers and stored in a tank.	690 t	233 t (203 m^3)

Material	Plant Area	Description	Typical Annual Consumption	Storage Amount
Diluent -Shell Shellsol D70 or equivalent	5620	Liquid. Transported to site in road tankers and stored in a tank.	254 t (317 m^3)	48 t (60 m^3)
Sodium Metabisulphate (SMBS)	5550	Powder. Transported to site in road tankers and stored in a closed silo.	1,291 t	371 t
Resin	3500/4100	Resin delivered in 1 te bulkabags	497 t	100 t
Extractant, ISX	4310	Liquid. Transported to site in IBC's which are stored in the warehouse until use.	75 t (82 m^3)	15 t (16 m^3)
Extractant, CSX	4410	Liquid. Transported to site in IBC's which are stored in the warehouse until use.		
Extractant, NSX	4510	Liquid. Transported to site in IBC's which are stored in the warehouse until use.		
Caustic (NaOH)	5530	Liquid. Transported to site in road tankers and stored in a tank.	1,033 t	119 t (78 m^3)
Soda Ash (Na_2CO_3)	5540	Powder. Transported to site in road tankers and stored in a closed silo.	1,291 t	17 t
Hydrogen Peroxide (70%)	5560	Liquid. Transported to site in road tankers and stored in a tank.	657 t	83 t (64 m^3)
Diesel Fuel (All Users)	5610	Liquid. Transported to site in road tankers and stored in a tank.	9,869 m^3	1,000 m^3 (1,000 kL)
Mine				
Mining Explosives	Explosive's magazine	Solid AN precursor transported to site by road and stored prior to mixing as emulsion	-	Stored in secure magazine at site

Material	Plant Area	Description	Typical Annual Consumption	Storage Amount
'In-Process' Fluids				**Estimates Only**
Molten Sulphur	5130	Sulphur is melted and filtered. Clean molten sulphur is stored in two tanks prior to use in the sulphuric acid plant.	N/A	10,000 t
Sulphur Dioxide and Sulphur Trioxide (SO_2/SO_3)	5130	SO_2 and SO_3 are intermediates in the production of sulphuric acid. SO_2 is produced by burning sulphur and is catalytically converted to SO_3. SO_3 is absorbed in weak acid to produce stronger acid. Low level SO_2/SO_3 atmospheric emissions (<250 ppm) leave the acid plant stack.	-	No storage, however, large volumes exist within the acid plant
Slaked Lime Slurry	5320	Quicklime is slaked and the slurry product is stored in two tanks prior to use in Areas 3600 and 4200.	N/A	150 t (384 m^3 slurry)
HPAL Process Slurry	3200	Acidic process slurry (40 g/L free acid) at high temperature (250°C) and pressure.	-	2 x 718 m^3 autoclaves plus other piping, heaters and flash vessels
Partial Neutralisation Slurry	3410	Partially neutralised slurry (pH<4) at atmospheric temperature and pressure.	-	6 x 0.5 ML tanks
Tailings Slurry	3600	Neutralised process slurry (pH ~6) at atmospheric temperature and pressure.	-	Multiple large process tanks
cRIP Slurry	3500	Partially neutralised slurry (pH <4) at atmospheric temperature and pressure.	-	Estimate ~20 ML of process tankage
cRIP Eluate	4100	Partially neutralised pregnant liquor (pH ~2) at atmospheric temperature and pressure.	-	Multiple large process tanks
Neutralised Eluate	4200	Neutralised pregnant liquor (pH ~6) at atmospheric temperature and pressure.	-	Multiple large process tanks

Material	Plant Area	Description	Typical Annual Consumption	Storage Amount
Various Solvent Extraction Process Fluids	4300-4900	SX organic phases (combustible). SX aqueous phases (acidic).	-	Multiple large process tanks
Rail Siding				
Sulphur Prills	7170	Prilled solids. Transported in closed containers by rail and stored temporarily prior to road transport to plant. Full container storage provided at rail siding.	286,226 t	2400 (up to 120 full containers) t
Ammonium Sulphate	7170	Inorganic and odourless sulphate salt. Transported by truck from the processing facility to the rail siding and stockpiled in an enclosed shed.	-	30,000 t

4.1.2 Explosives (Ammonium Nitrate Emulsion)

Ammonium nitrate emulsion (ANE) is a Dangerous Good (DG) 5.1, Packing Group II, liquid (a creamy emulsion that supports combustion of other materials). A typical composition for ANE is:

- Ammonium nitrate > 60%;
- Fuels (diesel) < 10%;
- Mineral oil, hydrocarbon solvent, petroleum < 10%;
- Water 5 to 30%; and
- Non-hazardous materials < 30%.

ANE will support combustion of other materials and increase the intensity of a fire. It will decompose on heating emitting irritating white fumes (ammonium nitrate). Brown fumes indicate the presence of toxic oxides of nitrogen, e.g. nitrogen dioxide.

A major fire may involve a risk of explosion, in particular, if the ANE is confined and contaminated. An adjacent detonation may also involve the risk of explosion (i.e. sympathetic detonation). Heating can cause expansion or decomposition of the material which can lead to the containers exploding.

When molten, ANE may decompose violently due to shock or pressure.

ANE is insoluble in water, however, open fires can be fought by applying water spray.

This material is classified as Security Sensitive Ammonium Nitrate (SSAN). Within Australia, all persons who have unsupervised access to Security Sensitive Ammonium Nitrate require security clearances. The issuing of security clearances is controlled and issued through the local Government authorities. The checks include a criminal history check and a politically motivated violence check.

4.1.3 Ammonia

Anhydrous ammonia is toxic and flammable (DG Class 2.3 toxic gas). It is a gas at normal temperature and pressure but may be liquefied under moderate pressure (630 kPag at 15°C) or at temperatures below -33°C at atmospheric pressure.

At low concentrations in air, ammonia vapour irritates the eyes, nose and throat. Ammonia is very soluble in water, therefore as it enters the body, it is readily absorbed. Irritation is immediate and local to the point of entry. Inhalation of high concentrations produces a sensation of suffocation and quickly causes burning of the respiratory tract and may result in death.

Anhydrous liquid ammonia causes severe burns on contact with the skin and if swallowed, it will cause very severe corrosion in the mouth, throat and stomach. Severe eye damage may result from direct contact with the liquid or exposure to high gas concentrations. Long term disability is mainly due to corneal and respiratory injuries.

The exposure limits for ammonia are summarised in Table 4.

Table 4 - Ammonia Exposure Limits

Material	Odour Threshold	Exposure Limit (ppm)		IDLH (ppm)	Injury mechanism
		TWA	STEL		
Ammonia	5 to 53 ppm	25	35	300	Irritant

Note: IDLH is Immediately Dangerous to Life and Health

Ammonia is flammable in air in a concentration range of 16 - 25% by volume but it does not readily ignite (the minimum ignition energy is 100 mJ, compared with 0.29 mJ for methane). Ignition is therefore difficult and the probability of an explosion in the open air is low. The auto-ignition temperature of ammonia is 651°C (relatively high compared to hydrocarbon materials).

Ammonia decomposes into flammable hydrogen gas at approximately 450°C.

Given the difficulty of ignition, the relatively narrow flammability range and typical operating conditions, ammonia storage and distribution installations are not generally regarded as significant fire or unconfined explosion hazards.

Water spray can be used to absorb vapour releases but should not be sprayed on pools of liquid ammonia as this will cause the liquid to rapidly vaporise (ammonia dissolves exothermically in water). If water is used for vapour absorption, a minimum of 100 volumes of water must be available for each volume of ammonia.

The transport of liquefied ammonia in a tank or bulk container made of quenched and tempered steel is prohibited unless the liquefied ammonia contains not less than 0.2wt% water. Stress corrosion cracking can occur due to the presence of stress and oxygen (even at low ppm), if water is not present for these materials of construction.

4.1.4 Sulphur Oxides

Sulphur dioxide and sulphur trioxide would be produced within the sulphuric acid plant at the mine and processing facility. In the sulphuric acid plant, sulphur dioxide is formed by the combustion of sulphur in a burner. The sulphur dioxide is catalytically converted to sulphur trioxide in a fixed bed reactor. The sulphur trioxide is absorbed in weak acid to produce sulphuric acid.

Both gases are toxic but non-combustible.

Sulphur dioxide is a colourless gas with a characteristic pungent and suffocating odour. The TWA (Time Weighted Average – concentration) is 2 ppm and the STEL is 5 ppm. Repeated exposure to the gas (>10 ppm) may cause lung effects including constriction and inflammation of the lungs and reduced lung function. The IDLH (immediately dangerous to life and health) is 100 ppm. Sulphur dioxide is an air contaminant and a constituent of smog. As the gas is heavier than air, it can accumulate in low points such as sumps and pits. In the presence of moisture, sulphur dioxide will form sulphurous acid (H_2SO_3) which is corrosive.

Sulphur trioxide, if released, will react with water in the atmosphere and form a white visible cloud. The mist is likely to contain submicron droplets which remain airborne until they absorb additional water and rain out or are deposited onto surfaces. With regard to the effects of the acid mist formed, a LC_{50} (lethal concentration for 50% mortality) of 60 mg/m^3 for a 60 minute exposure is typical of most reported data.

4.2 POTENTIAL HAZARDOUS INCIDENTS REVIEW

In accordance with the requirements of HIPAP No 6, (Ref 3), it is necessary to identify hazardous events associated with the facility's operations. As recommended in HIPAP No 6, the PHA focuses on "atypical and abnormal events and conditions. It is not intended to apply to continuous or normal operating emissions to air or water".

In keeping with the principles of risk assessments, credible hazardous events with ***the potential for off-site effects*** have been identified. That is, local events with limited impact or "slips, trips and falls" type events are not included nor are non-credible situations such as an aircraft crash occurring at the same time as an earthquake.

Given that the nearest place of residence is approximately 4.6 km away and the mine and processing facility boundary is at least 150 m from the hazardous materials, only a limited number of potential hazardous events can have off-site impact. This was the basis for the original approved PHA in 2000 (Ref 1) and the revised PHA in 2017 (Ref 2). As examples, large pool fires in the solvent extraction area have the following distances to various levels of radiant heat.

Table 5 - Pool Fire Scenarios

Pool Fire Scenario	SEP (kW/m^2)	Distance to Specified Radiant Heat Level (m)		
		23 kW/m^2	12.6 kW/m^2	4.7 kW/m^2
10 m diameter pool fire	56	4	9	19
50 m diameter pool fire	20		3	36

"SEP" is the surface emissive power (i.e. the radiant heat level of the flames).

From Table 5, there will be no adverse radiant heat impact from pool fires at the site's boundary. Therefore, these events do not contribute to the off-site risk criteria shown in Table 2 and can be ignored in this analysis (consistent with the methodology in the approved PHAs from 2000 and 2017, Refs 1 and 2, respectively).

Similarly for jet fires, Ref 1 included various jet fire scenarios with estimated flame lengths up to 30 m. As with pool fires, no adverse off-site impact is expected given the separation distance to the site’s boundary.

The potential for offsite impact at the rail siding is negligible given the materials.

In preparation for the PHA conducted in 2000, a one day hazardous event identification exercise was conducted. It is from this study, the subsequent assessments conducted in 2017 and the assessment for this report that the potential hazardous events for off-site impact have been determined.

These potential hazardous events are summarised in the following Hazard Identification Word Diagram (Table 6). This diagram presents the causes and consequences of the events, together with major preventative and protective features that are to be included as part of the design.

Table 6 - Hazard Identification Word Diagram

Event Number	Hazardous Event	Causes	Consequences	Proposed Safeguards - Prevention Detection Mitigation
1	Loss of containment from the natural gas pipeline	External interference, e.g. pipe damaged by excavation activities. Corrosion. Exceeding the maximum allowable operating pressure. Weld failure. Ground movement or ground erosion by water	Potential for failure of the natural gas line and a jet fire, flash fire and/or explosion (if the gas is confined) if ignited. This can cause injury to people, and damage to property and the environment	Pipeline designed to AS2885 including signage along the pipeline route. This includes aspects associated with pipeline such as design and construction, welding, operation and maintenance, and field pressure testing. The pipeline would be buried deep to lower the risk of third party damage and recorded for Dial-Before-You-Dig purposes. Pressure monitoring for leak detection
2	Decomposition of the Ammonium Nitrate Emulsion (ANE)	ANE subjected to heat, confinement and impurities. Sympathetic detonation	Potential for the ANE to explode. This can cause injury to people, and damage to property and the environment	ANE would be delivered and stored in precursor form and only mixed at point of use. All explosives handling will be compliant to the relevant Australian Standards and by trained personnel

Event Number	Hazardous Event	Causes	Consequences	Proposed Safeguards - Prevention Detection Mitigation
3	Large loss of containment of ammonia. The ammonia tanks are larger than the previously approved tanks, therefore, ammonia releases are re-assessed in this PHA	Ammonia tank failure, e.g. due to stress corrosion cracking. Catastrophic failure of a large pipe or transfer hose conveying liquid ammonia	Release of ammonia which is both a toxic and flammable hazard. The ammonia would disperse downwind with the potential to impact people. At high concentrations, ammonia can also cause corrosive impact to vegetation	Tanks designed to AS2022. See the recommendations in this PHA for further safeguarding
4	Release of sulphur dioxide or sulphur trioxide. There are changes to the approved sulphuric acid plant, i.e. site location and stack height, therefore, sulphur oxides releases are re-assessed in this PHA	Fugitive emissions from vessel holding hot molten sulphur. Leak or rupture at acid plant due to mechanical failure or impact, e.g. suction seals, valves, blower, piping, vessel or heat exchanger, transport or cranage accident. Loss of absorption in acid plant absorption tower, e.g. loss of reflux liquid	Release of sulphur dioxide or sulphur trioxide at ground level or through the stack. Toxic gases are dispersed downwind. Acute effects only (no long term effects). Corrosion of nearby structures	Regular maintenance. Computer control and monitoring of the acid plant. Stack emissions monitoring. Operator training and surveillance. Automatic shutdown of plant on upset conditions. Sulphur dioxide monitors located throughout the plant. Mechanical protection of the plant from vehicles, e.g. bollards, walls. Appropriate materials of construction. Visual indication of release (visible white plume for a sulphur trioxide release)

5 HAZARDOUS EVENTS ASSESSMENT

5.1 NATURAL GAS SUPPLY PIPELINE FAILURE

The natural gas pipeline was assessed in the 2000 PHA (Ref 1) and subsequently approved. The following pipeline assessment has not been changed as part of this PHA; it is included for completeness only.

Natural gas would be supplied to the site from a lateral of the Moomba to Sydney gas pipeline. The majority of the pipeline run would be within the road reserve. It would be laid underground and setback a minimum safety distance from all residences in accordance with Australian Standard AS2885 (Pipelines – Gas and Liquid Petroleum).

The pipe route has been selected to avoid sensitive areas, thereby taking public safety into consideration. This includes routing the pipe around the outskirts of Condobolin.

The major hazards associated with the pipe are loss of containment from leaks (e.g. due to mechanical damage) leading to fires (jet and flash) and explosions.

To reduce the likelihood of these events from occurring, the pipe is to be laid in accordance with the relevant standards and codes (e.g. AS2885). Measures recommended in this standard to reduce the likelihood of loss of containment include burial to avoid damage from hostile events (e.g. sabotage), corrosion protection features (e.g. corrosion allowance on wall thickness, approved material of construction and cathodic protection), flow monitoring (by computer controls) and fracture control plans (including means of isolation), signage, deep burial and large wall thickness to protect against common digging activities (e.g. ploughing, digging and fence post drilling), and minimisation of joints (and hence potential leak points and hazardous areas for electrical equipment selection).

Given that the natural gas pipe is to be run to avoid sensitive areas and would be installed with mitigation features as detailed in such standards as AS2885, acceptable levels of risk result would be attained.

Data for pipeline failure is available from a number of sources but one of the most recent, comparable data sets is from the United Kingdom's Health and Safety Executive (HSE) (Ref 7).

The HSE have researched pipeline releases in the United Kingdom over a 45 year period and determined a current failure rate of approximately 2.8×10^{-5}/year.km. This is for small, medium and large releases. Note the HSE data assumes the pipelines are in use 100% of the time.

The probability of ignition of flammable gas releases is dependent on the size of the release but is reported (Cox, Lees and Ang, Ref 8) as being from 1 to 30% depending on the size of the leak. As a conservative assumption, a 30% probability of ignition is taken for a leak of natural gas.

Therefore, the likelihood of a release and ignition is:

$$L = 2.8\text{x}10^{-5}/\text{yr.km} \text{ x } 0.3 = 8.4\text{x}10^{-6}/\text{yr.km or } 8.4\text{x}10^{-9}/\text{yr.m}$$

The results from ignition include a jet fire, a flash fire and/or an explosion if the natural gas is confined.

The above low likelihood for a release and ignition supports the anecdotal evidence in Australia that gas and liquid lines built to the Australian Standards, e.g. AS2885, have a low failure rate. The low likelihood of releases and ignition plus construction to recognised codes confirms that the SFARP (So Far As Reasonably Practicable) principle is met.

5.2 EXPLOSIVES

Explosives at the limestone quarry were assessed and approved in the 2000 PHA (Ref 1). The following explosives assessment has not been changed as part of this PHA; it is included for completeness only.

> *Explosives will be used at the limestone quarry. The use of explosives shall be as per standard mining and regulatory practice, e.g. detonators stored separately to explosive charges, purpose built storage facilities, static protection facilities and strict procedural control enacted by well trained personnel. Historically, these practices have proven to be adequate in avoiding unplanned explosions with off-site impacts. As such, the risk of a spurious explosion involving the explosives stored on the limestone quarry site is deemed to be acceptable. This judgement is based on the assumption that the quarry site will have a quality safety management system in place and in use for the life of the facility.*

Explosives at the mine and processing facility were assessed and approved in the 2017 PHA (Ref 2). Similarly to the limestone explosives, they will be stored and used as per the requirements of the Australian Standards. The following explosives assessment has not been changed as part of this PHA; it is included for completeness only.

> *If explosives are to be used at the mine and processing facility, initial information provides the following:*
>
> *Type: Ammonium nitrate emulsion (ANE)*
>
> *Quantity: Approximately 25 tes*
>
> *Whilst storage and use as per the Australian Standards provides risk assurance for explosives, there are ways for it to decompose, e.g. impurities and heat whilst confined.*

The trinitrotoluene (TNT) equivalence for ANE is approximately 0.8. For 25 tes ANE, the equivalent mass of TNT is 20 te. Using the TNT explosion model, the distances to selected explosion overpressures are shown in Table 7.

Given the distance to the nearest site boundary from the explosive storage area is approximately 920 m then the criteria shown in Table 2 are satisfied.

Table 7 - Explosive Overpressures

Explosion Scenario	Distance to Specified Overpressure Level, m		
	21 kPa	14 kPa	7 kPa
25 te ANE	206	265	410

For information, the consequences of various levels of overpressure generated from explosions are shown in Table 8 (Ref 4).

Table 8 - Effects of Explosion Overpressures

Overpressure kPa	Effect
3.5	90% glass breakage No fatality and very low probability of injury
7	Damage to internal partitions and joinery but can be repaired Probability of injury is 10%. No fatality
14	Houses uninhabitable and badly cracked
21	Reinforced structures distort Storage tanks fail 20% chance of fatality to a person in a building
35	Houses uninhabitable Trucks and plant items overturned Threshold of eardrum damage 50% chance of fatality for a person in a building and 15% chance of fatality for a person in the open
70	Threshold of lung damage 100% chance of fatality for a person in a building or in the open Complete demolition of houses

5.3 TOXIC GAS RELEASES

As identified in Section 4, large releases of sulphur oxides and ammonia have the potential to impact people off-site. The 2000 PHA (Ref 1) assessed releases of sulphur oxides and hydrogen sulphide. The latter is no longer part of the processing plant's design and hence is not included in this report.

The 2000 PHA toxic gas modelling basis is included in Appendix A for information. This methodology is still relevant and is used in this revised PHA.

The DoP risk criteria of importance for this rural site are:

- Irritation, injury and fatality risk at a place of residence. The nearest place of residence is the 'Slapdown' house located 4.6 km from the processing plant. Note that HIPAP No 4 defines the one in a million criterion assuming that residents would be at their place of residence (taken to be the house) and exposed to the risk 24 hours a day and continuously day after day for the whole year; and
- Fatality risk to be contained within the boundary of an industrial site, i.e. no more than 50×10^{-6}/yr.

As the processing areas where the hazardous materials are stored and handled are a significant distance from the site's boundary and the nearest place of residence, e.g. the ammonia storage is 262 m from the nearest site boundary, then only the releases that have the potential to cause irritation, injury and/or fatality at these locations are assessed (consistent with the 2000 PHA approach).

Meteorological Data

The meteorological data used in this PHA comprises an updated set of five dominant weather/wind combinations (Pasquill stability category / wind speed) for the area and has been used as the basis for all dispersion calculations. This is based on 2016 data with hourly measurements for 365 days.

The probability of the relevant combined weather/wind category and wind direction (data is split into 8 directions) is used in the calculation of toxic impact at the nearest place of residence ('Slapdown') and the nearest site boundary.

The meteorological data used for this risk assessment, sourced from the Condobolin Bureau of Meteorology weather station, is shown in Table 9.

Slapdown is chosen preferentially to Fifield given the low probabilities of wind from the north-west that could cause a plume to travel towards Fifield, i.e. the risk of potential plumes is higher for westerly winds that blow towards Slapdown.

Table 9 - Stability Class / Wind Speed

Wind Direction	Stability Class / Wind Speed (m/s)					
	Percentages:					
	D5.9	D2.4	E5.8	E2	F2	
N	4.5	3.1	2.4	2.9	5.0	
NE	2.7	2.4	2.5	2.7	2.9	
E	1.9	3.4	1.2	3.9	2.3	
SE	1.3	3.0	0.4	2.0	1.0	
S	1.6	3.2	0.8	1.8	1.0	
SW	5.5	3.9	2.8	3.1	2.7	
W	4.4	3.5	1.7	3.3	2.6	
NW	1.5	1.8	0.5	1.5	1.4	
Totals:	23.4	24.2	12.4	21.3	18.7	100

5.3.1 Sulphur Oxides Releases

Releases of sulphur oxides were assessed in the 2000 PHA (Ref 1). The following is an update of this work.

Sulphuric acid would be produced in a double adsorption style, sulphur burning acid plant. After the burner, the sulphur dioxide is reacted over a fixed bed catalyst system to form sulphur trioxide. The sulphur trioxide is absorbed in acid to form the required 98 wt% sulphuric acid. Overhead gases from the absorber are vented to atmosphere.

These types of plants run at low pressure (typically 24 kPag after the burner) and hence there exists a low driving force for releases. Gas stream temperatures of 80ºC or higher are normal.

Sulphur trioxide is present in the process from the reactor to the absorption tower. Any releases from these areas (including failure of absorption reflux flow) would immediately form white clouds as the sulphur trioxide readily forms sulphuric acid when combined with atmospheric moisture. The sulphuric acid mist generated becomes a dense cloud which partly rains out on to the ground and other surfaces.

This strong affinity of sulphur trioxide with water makes accurate modelling of sulphur trioxide clouds difficult, particularly over large distances such as that to the nearest place of residence. The approach taken in this analysis is to model releases of sulphur dioxide to determine the significant effects, if any, at the nearest place of residence and site boundary. Depending on these results, off-site effects of sulphur trioxide releases can be surmised. Whilst sulphur dioxide also reacts with atmospheric moisture, the reaction is not as fast as that of sulphur trioxide and is not taken into account in the modelling of releases.

The composition of the sulphur dioxide stream varies from plant to plant (e.g. depending on the sulphur sources), and, of course, within each plant. In this study, a composition of 18vol% sulphur dioxide in air is used (typical maximum value).

Release scenarios were only performed for the cases where the plant was kept operating. Once the plant is stopped, the low pressure in the equipment minimises the flowrate of further releases.

Release conditions are summarised as follows:

Plant rate (gas stream after burner)	65 kg/s
Sulphur dioxide rate	25 kg/s
Pressure	24 kPag
Temperature (approximate)	80^{o}C
Release height (approximate pipe rack level)	10 m

Given this temperature, the density of the sulphur dioxide stream when it is released to atmospheric pressure was calculated to be 1.22 kg/m^3. As this is approximately the same as air at 15^{o}C (1.23 kg/m^3), the plume is treated as having neutral buoyancy and it is modelled by using the Gaussian neutral gas dispersion correlations. The simulations involving large releases are based on a release duration of one minute (at full plant rate). Large releases would become known (visual, noise and smell as well as process monitoring alarms and trips) soon after the catastrophic failure, hence it is realistic to assume shutdown within one minute. For the smaller releases (from 50 mm holes or smaller), release durations of 15 minutes are modelled (to determine the worst case effect distances). This time allows for operator intervention to manually control and/or stop the leak.

Toxic Impact of Sulphur Dioxide

The toxicity effects of sulphur dioxide are summarised in Table 10.

Table 10 - Effects of Sulphur Dioxide

Exposure Level (ppm)	Duration (minutes)	Effects
0.3	60	ERPG 1
3		ERPG 2
25		ERPG 3

The three ERPG (emergency response planning guidelines) tiers are defined as follows:

- **ERPG-3** is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.
- **ERPG-2** is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action.
- **ERPG-1** is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing more than mild, transient adverse health effects or without perceiving a clearly defined objectionable odour.

Given the above definitions, ERPG 1 (0.3 ppm) and 2 (3 ppm) are taken as the limits for irritation and injury, respectively.

One level of fatal toxicity used by the United Kingdom HSE (Health and Safety Executive) in relation to the provision of land use planning advice is termed the Specified Level of Toxicity (SLOT). The HSE has defined the SLOT as:

- Severe distress to almost everyone in the area;
- Substantial fraction of exposed population requiring medical attention;
- Some people seriously injured, requiring prolonged treatment; and
- Highly susceptible people possibly being killed.

The SLOT value for sulphur dioxide is 4.655×10^6 ppm^2.min. Hence, for a 1 minute exposure, the required average concentration is 2,160 ppm, or for a 15 minute exposure, the required average concentration is 560 ppm. The SLOT values are used to determine if fatality at the nearest place of residence and site boundary from a release is possible.

Sulphur Dioxide Release Cases Modelled

The following scenarios involving sulphur dioxide releases were modelled for the five dominant stability classes and wind speeds in Table 9. Concentrations at the nearest place of residence and site boundary are calculated.

1. Catastrophic vessel failures or full pipe fractures. The release rate is modelled as full plant rate for one minute.
2. Piping and vessels failures corresponding to the various hole sizes discussed in Appendix A (15 minutes duration).

The results for Scenario 1 above are shown in Table 11. Whilst there is a plantation across the road from the releases, the modelling is performed based on parkland and bushes given the land use beyond the plantation.

The distances used in the modelling have been measured from the sulphuric acid plant to the nearest residential dwelling (i.e. Slapdown) and the nearest property boundary.

Table 11 – Sulphur Dioxide Release Modelling – Catastrophic Failures

Stability Class / Wind Speed	Concentration (ppm) at Nearest Residence (4.6 km)	Concentration (ppm) at Nearest Boundary (150` m)
D5.9	3	2,500
D2.4	3	6,100
E5.8	8	3,200
E2	8	9,200
F2	24	5,100

Given the results in Table 11, irritation and injury (but not fatality) are possible at the nearest place of residence and also fatality at the nearest site's boundary due to catastrophic equipment failures. The corresponding risks are analysed in Section 6 of this PHA.

The results for Scenario 2 above are shown in Table 12.

Table 12 – Sulphur Dioxide Hole Release Modelling

Stability Class / Wind Speed	50 mm Hole (0.2 kg/s)	
	Concentration (ppm) at Nearest Residence (4.6 km)	Concentration (ppm) at Nearest Boundary (150 m)
D5.9	0.1	20
D2.4	0.2	50
E5.8	0.2	25
E2	0.6	74
F2	2	39

The flowrates from 25 mm diameter or smaller holes are too low to impact people at the locations of interest.

Given the results in Table 12 then irritation (but not injury or fatality) is possible at the nearest place of residence due to releases through a 50 mm hole (for the E2 and F2 conditions). The corresponding risks are analysed in Section 6 of this PHA.

The concentrations at the nearest site boundary are not expected to cause fatality.

From the 2000 PHA (Ref 1), with regard to sulphur trioxide releases, it was discussed previously that sulphur trioxide reacts readily with atmospheric moisture to form sulphuric acid which, being a dense mist, rains out significantly on to the ground and nearby structures. Given the predicted low sulphur dioxide levels from releases from 50 mm holes (or less) would only just cause impact at the nearest place of residence, it can be surmised that sulphur trioxide releases from these size holes are unlikely to have any significant off-site impacts. However, for a worst case release at full plant rates involving the sulphur trioxide steam, off-site effects can certainly be expected at the nearest site boundary and are conservatively modelled as sulphur dioxide releases.

5.3.2 Ammonia Releases

Releases of ammonia were not assessed in the 2000 PHA (Ref 1) as ammonia storage and handling was not part of the original design.

Anhydrous ammonia is to be delivered by road tanker and would be transferred to the two anhydrous ammonia storage bullets (208 te capacity each).

Vapour from the bullets passes through the Compressor Knockout Vessels, the Ammonia Unloading Compressors and then back into the ammonia road tanker, i.e. so that liquid ammonia can be transferred into the bullets.

The liquid discharge from the bullets passes through a vaporiser before being distributed to the process at a rate of approximately 1 kg/s (corresponds to approximately 25,000 te/year).

Losses of containment of ammonia can therefore be from:

- Road tanker transfers;
- The storage bullets; and
- Piping including the vaporiser.

It is estimated that an average three ammonia deliveries per day would take place.

Ammonia is normally a heavy gas when modelled due to cooling when flashed (with the formation of mist) and also absorption of water from the atmosphere. Therefore, it is modelled with the heavy gas model (SLAB) within Effects.

Toxic Impact of Ammonia

The toxicity effects of ammonia are summarised in Table 13.

Table 13 - Effects of Ammonia

Exposure Level (ppm)	Duration (minutes)	Effects
25	60	ERPG 1
150		ERPG 2
1,500		ERPG 3

The above exposure limits are quite conservative given the following information from the Australian Standard (AS2022) for ammonia (Ref 9):

Up to 100 ppm – no adverse effect for the average worker with no deliberate exposure for long periods permitted.

400 ppm – immediate nose and throat irritation with no serious effect after 30 minutes to one hour.

700 ppm – immediate eye irritation with no serious effect after 30 minutes to one hour.

1,700 ppm – convulsive coughing, severe eye, nose, and throat irritation; could be fatal after 30 minutes.

2,000-5,000 ppm – convulsive coughing, severe eye, nose, and throat irritation; could be fatal after 15 minutes.

Over 5,000 ppm – respiratory spasm, rapid asphyxia and fatal within minutes.

To be consistent with the sulphur oxides modelling, ERPG 1 (25 ppm) and 2 (150 ppm) are taken as the limits for irritation and injury.

The SLOT value for ammonia is $3.78\text{x}10^8$ ppm^2.min. Hence, for a 1 minute exposure, the required average concentration is 19,440 ppm, or for a 15 minute exposure, the required average concentration is 5,020 ppm. The SLOT values are used to determine if fatality at the nearest place of residence and site boundary from a release is possible.

Ammonia Release Cases Modelled

The following scenarios involving ammonia releases were modelled for the five dominant stability classes and wind speeds in Table 9. Concentrations at the nearest place of residence (i.e. Slapdown) and the site boundary are calculated. The location at the site boundary is the nearest point to the sulphuric acid plant (i.e. the Wilmatha Road boundary) so that cumulative risk can be estimated at this location. The modelling was also performed at the nearest site boundary to the ammonia storage area. The risk results were identical.

1. Catastrophic storage bullet failures. The release quantity is taken as 208 te per bullet, i.e. worst case as the bullets are assumed to be full.

2. Liquid releases from piping, transfer hose and vessel failures corresponding to the various hole sizes discussed in Appendix A (15 minutes duration).

3. Vapour releases from piping, transfer hose and vessel failures corresponding to the various hole sizes discussed in Appendix A (15 minutes duration).

Scenario 1 – Catastrophic Bullet Failure:

The results for Scenario 1 above are shown in Table 14. The modelling is performed based on regular large obstacles as the ammonia plume travels first through the plant and then through the plantation across the road.

Table 14 – Ammonia Release Modelling – Catastrophic Failures

Stability Class / Wind Speed	Concentration (ppm) at Nearest Residence (4.6 km)	Concentration (ppm) at the Boundary (425 m)
D5.9	1,600	79,000
D2.4	1.3	49,000
E5.8	2,600	90,000
E2	-	52,000
F2	-	65,000

Note: The distances used in the modelling have been measured from the ammonia storage and handling area to the nearest residential dwelling (i.e. Slapdown) and the nearest property boundary opposite the sulphuric acid plant (to estimate the maximum cumulative risk).

For the E2 and F2 conditions, the vapour would layer and be largely held by the plant structures and surrounding plantation without dispersing as far as the other weather / wind combinations. This has been observed with historical releases of liquid ammonia.

Given the results in Table 14 then irritation and injury (but not fatality) are possible at the nearest place of residence due to catastrophic storage bullet failures. Also, the concentrations predicted at the nearest site boundary are sufficiently high to cause fatality.

The corresponding risks are analysed in Section 6 of this PHA.

It is noted that historical releases of ammonia (including the 7,000 te release in Lithuania in 1989) have not resulted in fatalities beyond 200 m. Hence, the modelling results are very conservative.

Scenario 2 – Liquid Releases:

The results for Scenario 2 are shown in Table 15 and Table 16.

Table 15 – Ammonia (Liquid) 50 mm Hole Release Modelling

Stability Class (Wind Speed [m/s])	50 mm Hole (rate = 36 kg/s)	
	Concentration (ppm) at Nearest Residence (4.6 km)	Concentration (ppm) at the Boundary (425 m)
D5.9	110	3,500
D2.4	23	4,900
E5.8	200	5,600
E2	-	7,000
F2	-	12,000

This rate, i.e. 36 kg/s, is equivalent to 130 te/hr. Whilst this would exceed the transfer rate into the bullets, the results would be indicative for liquid releases from the transfer hose or bullets.

Table 16 – Ammonia (Liquid) 25 mm Hole Release Modelling

Stability Class / Wind Speed	25 mm Hole (rate = 9.3 kg/s)	
	Concentration (ppm) at Nearest Residence (4.6 km)	Concentration (ppm) at the Boundary (425 m)
D5.9	29	980
D2.4	16	2,000
E5.8	52	1,870
E2	-	2,300
F2	-	5,860

As above, for the E2 and F2 conditions, the vapour would layer and be largely held by the plant structures and surrounding plantation without dispersing as far as the other weather / wind combinations. This has been observed with historical releases of liquid ammonia.

Given the results shown in Table 15 and Table 16 then irritation and injury (but not fatality) are possible at the nearest place of residence due to liquid ammonia releases. There is a risk of fatality at the site boundary for some weather / wind combinations.

The corresponding risks are analysed in Section 6 of this PHA.

Scenario 3 – Vapour Releases:

The design plant vapour ammonia rate is up to 1 kg/s. This rate is modelled to determine the potential consequential impacts. This rate is also indicative of the vapour flow to the road tankers when performing transfers.

The results for Scenario 3 are shown in Table 17.

Table 17 – Ammonia Vapour Release Modelling

Stability Class / Wind Speed	Rate = 1 kg/s	
	Concentration (ppm) at Nearest Residence (4.6 km)	Concentration (ppm) at the Boundary (425 m)
D5.9	2	90
D2.4	4	220
E5.8	4	190
E2	11	560
F2	36	1,450

The plant design ammonia vapour rate does not result in concentrations at the boundary sufficient to result in fatality. Irritation impact at the nearest place of residence is possible for F2 condition only.

The corresponding risks are analysed in Section 6 of this PHA.

5.4 TRANSPORT INCIDENTS

5.4.1 Road

Road transport was assessed in the 2017 PHA (Ref 2). The following is an update of this assessment.

Chemicals transported by road would, where relevant, be transported in accordance with the Australian Code for the Transport of Dangerous Goods by Road and Rail (Ref 10).

The expected frequency and quantity of deliveries of the main Dangerous Goods to the site is given in Table 18.

Hazardous materials that are less frequently delivered include flocculant, diluent, hydrochloric acid, extractant, hydrogen peroxide and explosives (typically one or less deliveries per week).

Table 18 – Bulk Chemicals Road Transport Frequencies

Material Transported	Nominal Site Delivery Frequency	Nominal Annual Consumption
Ammonia	2.3 B Doubles (35 t each) per day	24,978 t
Caustic	5 road tankers (20 t each) per month	1,033 t
Diluent	1 road tanker (25 t each) per month	254 t
Hydrochloric Acid	3 road tankers (20 t each) per month	690 t
Hydrogen Peroxide	3 road tankers (20 t each) per month	657 t

Materials such as limestone, hydrated lime, soda ash, diesel, SMBS, the nickel, cobalt and scandium products, ammonium sulphate and quicklime are not classified as dangerous goods for transport by road and rail and therefore are relatively safe to transport in bulk form (subject to road and rail usage regulations). Shellsol and diesel are both combustible liquids. The transport of these types of materials in approved road tankers throughout Australia is commonplace and of low risk.

The packaged chemicals delivered by road transport in IBCs (intermediate bulk containers), drums, bulk bags or cylinders, again, would be transported in accordance with the Australian Code for the Transport of Dangerous Goods by Road and Rail. The main usage of these chemicals is for dosing systems, shutdown replacements and topping up storages. The small packaged volumes with low usage rates pose minimal transport risks due to loss of containment. Mitigation of risks is also provided by the proposed use of approved transport companies through their safety management systems and emergency response plans.

Hydrochloric acid is a corrosive liquid. Hydrogen peroxide is an oxidising material and also a corrosive fluid. If these materials are involved in a traffic accident, the primary risk to people, the environment and property is the corrosive nature of the fluids (including vapours). It is possible for fires to result from hydrogen peroxide releases as it will oxidise combustible material (mostly due to the water evaporating which allows the hydrogen peroxide to dry / concentrate with subsequent ignition).

From a review of incidents involving ammonium nitrate, the outcomes of a truck accident whilst carrying ammonium nitrate are as follows:

1. Release of the solid ammonium nitrate without harmful effect (it is a commonly used fertiliser). In this case, the ammonium nitrate will be swept-up and recovered;

2. Release of the solid ammonium nitrate and combustion of other materials (it is an oxidising agent). It is possible for the ammonium nitrate to be involved in a fire without a subsequent explosion, however, toxic gases will be emitted;

3. Release of the solid ammonium nitrate to waterways thereby increasing the water's nitrogen content and hence environmental impact; and

4. Heating whilst confined (with or without contamination) with a subsequent explosion.

The main road transport hazard is ammonia. If a road tanker carrying ammonia is involved in an accident and the vessel integrity is lost then there is the potential for serious injury and fatality for people involved in the accident or those nearby.

Causes for road tanker accidents are summarised in Table 19 (Ref 11).

Table 19 – Causes for Road Tanker Accidents

Human Error	Equipment Failures	System or Procedural Failures	External Events
• driver impairment, e.g. alcohol or drugs • speeding • driver overtired • driver exceeding safe working hours • en-route inspection • contamination • overfilling • other vehicle's driver • taking tight turns/ramps too quickly (overturns) • unsecured loads	• non-dedicated trailer • rail road crossing guard failure • leaking valve • leaking fitting • brake failure • relief device failure • tyre failure • soft shoulder • overpressure • material defect • steering failure • sloshing • high centre of gravity • corrosion • bad weld • excessive grade • poor intersection design • road chamber/width • suspension system • tyre fire caused by friction, brakes overheating or exploding tyres give sparks due to metal in the rubber) • fuel tank fire (diesel)	• driver incentives to work longer hours • driver training • carrier selection • container specification • route selection • emergency response training • speed enforcement • driver rest periods • maintenance • inspection • time of the day restrictions	• vandalism/sabotage • rain • fog/visibility • wind • flood/washout • fire at rest area/parking areas • earthquake • existing accident • animals on road

A detailed analysis of heavy vehicle risks in NSW was performed for the Cowal Gold Project (Ref 12). This study found the following typical heavy vehicle accident rates for similar road routes:

> 0.016 - 2.96 Heavy Vehicle Accidents/Annual Million km of Heavy Vehicle Travel

This data compares well with reported data, e.g. the Centre for Chemical Process Safety (CCPS) guidelines (Ref 11) quote a figure of approximately 2 accidents/year (for all causes) per 10^6 miles, i.e. $1.2 \text{x} 10^{-6}$ accidents per kilometre per year.

In the event of an accident involving a heavy vehicle, the carried goods may or may not be released. The probability of release is dependent on factors such as speed, shipping conditions (i.e. pressurised versus non-pressurised), inadequate load securing, and strength and integrity of the container.

Various studies of release probabilities from heavy vehicles involved in an accident have been undertaken. The Guidelines for Chemical Transportation Risk Analysis (CCPS, 1995, Ref 11) indicates that the release probability for various road types is between 5 and 10% (i.e. approximately one heavy vehicle accident in every 10 to 20 would result in a release of the material). The probability of fatality then has to be taken into account but this would depend on factors such as the leak size, i.e. the probability of fatality could be any value from 0 to 1.

Given the history of road tanker transport in NSW, compliance with the Australian Dangerous Goods Code (an indicator of achieving SFARP (so far as reasonably practicable)) and the above representative data then the risk of an accident involving a vehicle transporting a hazardous material such as ammonia to the site resulting in a release of material is therefore relatively low.

5.4.2 Rail

The following is an updated rail assessment from the 2017 PHA (Ref 2).

For this development, rail transport primarily concerns the movement of sulphur from the stockpile in Newcastle, NSW, to the modified rail siding. The proposed number of return train trips per week is approximately three. To avoid congestion in the Sydney rail network as well as steep grades in the crossing of the Blue Mountains (i.e. minimise the likelihood of an accident), it is proposed that trains to and from the site use a route via Muswellbrook, Ulan, Dubbo, Narromine and Parkes to Bogan Gate.

The significant hazards are the potential for the sulphur to catch alight and emit toxic fumes (e.g. sulphur dioxide). The sulphur could catch alight due to ignition whilst in transit (e.g. arson, lightning strike or static) or due to an accident involving the train.

Radiant heat effects due to burning sulphur are localised only. Any loss of containment during transport would be responded to as per the proposed emergency response plans for the site to avoid contamination of waterways etc.

Sulphur is classified as a flammable solid (4.1), Packing Group III (minor danger only). It is routinely transported in bulk around the world. Separation from non-compatible materials and elimination of ignition sources are the major measures taken to avoid incident.

Protection features for the bulk transport of sulphur by rail to the proposed siding include minimal dust in the bulk sulphur (prilled form), proposed water sprays at all transfer points, local fire brigades (for water application), electrics (such as motors) rated for the hazardous area zones, separation from non-compatible materials and static protection. Small fires can be smothered with sand or even with additional sulphur. The sulphur remains within the shipping containers until it is discharged into a hopper at the site.

Given the proposed protective features associated with the rail transport of sulphur, the low likelihood of ignition of sulphur within the containers and the accepted risk of transport of bulk sulphur by road or rail throughout Australia and the world, the overall risk of an incident involving sulphur with significant consequences during rail transport is considered low. No further analysis (i.e. quantification of risks) of the transport of bulk sulphur to this site is deemed necessary.

The product metals are likely to be transported from the site by road. The nickel and cobalt sulphates and scandium oxide products would be stored and transported in bulkabags in containers, not as a bulk product.

The product metals would also be transported from the modified rail siding by rail (the bulkabags would be within containers).

The Modification would allow ammonium sulphate to also be transported from the modified rail siding by truck. Ammonium sulphate will be transported in bulk via rail or trucks.

An average of three trains per week (six train movements per week), with a maximum of two trains per day, is approved at the rail siding.

5.5 NATURAL AND OTHER EXTERNAL HAZARDOUS EVENTS

The site has been assessed with regard to exposure to the following external hazards:

Subsidence

Burst dam

Storm and high winds

Flood

Lightning

Vermin/insect infestation

Landslide

Earthquake

Rising water courses

Storm water runoff

Forest fire

Security

Given the current proposed location of the project components, there are no obvious significant hazards amongst this list that could result in on-site events leading to serious off-site impacts.

6 RISK ANALYSIS

6.1 HIPAP 4 RISK CRITERIA

As discussed and analysed in Section 5.3, the DoP risk criteria of importance for this rural site are:

- Irritation, injury and fatality risk at a place of residence; and
- Fatality risk to be contained within the boundary of an industrial site, i.e. no more than 50x10^{-6}/yr.

Given there are a minimal number of materials and events that can cause off-site impact, the updated analysis in this PHA was done on the same basis as the previous PHAs (Refs 1 and 2). That is, model the sulphur dioxide and ammonia release cases for the five dominant stability class / wind directions to determine which events can contribute to off-site risk. The results are shown in Section 5.3.

These results are then analysed using event likelihoods (United Kingdom HSE 2012 data used, Ref 14), probits, the probability of use (e.g. transfer hoses) and the probability that the stability class / wind direction exists. The analysis is shown in Appendix B along with further explanation of the assumptions and data sources. The total estimated risks at the nearest place of residence and the site boundary are compared to the HIPAP 4 risk criteria (Ref 4) in Table 20.

Table 20 – Comparison to HIPAP 4 Risk Criteria

Risk Type	HIPAP No 4 Criteria	Estimated Risk or Likelihood	Comments
Irritation	50x10^{-6}/yr	4x10^{-6}/yr	Compliant
Injury	10x10^{-6}/yr	1x10^{-6}/yr	Compliant
Fatality	50x10^{-6}/yr	1x10^{-6}/yr	Compliant

The assessment was done on a conservative use of stability class / wind direction data. The above estimated risk values are likely to be conservatively high.

Given the separation distance between the processing plant and both the nearest place of residence and site boundary then all other risk criteria are satisfied.

6.2 CUMULATIVE AND PROPAGATION RISK

Given the rural location, the generous separation distances and that significant consequential impacts largely remain on-site then it is reasonable to conclude that the modified development does not make a significant contribution to the existing cumulative risk in the area.

There is the potential for on-site propagation events, e.g. a diluent fire causing another loss of containment. However, as shown in this report, the separation distances mitigate the impacts from the potential hazardous events, either occurring in isolation or due to propagation from other events, and that the off-site risk is acceptable.

6.3 SOCIETAL RISK

Societal risk results are usually presented as F-N curves which show the frequency of events (F) resulting in N or more fatalities. To determine societal risk, it is necessary to quantify the population within each zone of risk surrounding a facility. By combining the results for different risk levels, a societal risk curve can be produced.

Societal risk is normally calculated where the 1 per million per year (pmpy) contour (or calculated risk level) approaches closely to residential areas or sensitive land uses or when events with very large consequence distances are being assessed. Hence, the potential exists for multiple fatalities as a result of a single accident.

In this study, there is a risk of fatality at the nearest site boundary, however, the surrounding area is rural with the nearest place of residence being 4.6 km from the processing plant. At this location, there is no estimated risk of fatality. Therefore, societal risk at residential and other types of land users is acceptable.

6.4 RISK TO THE BIOPHYSICAL ENVIRONMENT

The main concern for risk to the biophysical environment is generally with effects on whole systems or populations. Whereas any adverse effect on the environment is obviously undesirable, to have an incident with such consequences requires exposure of a sensitive area to either large effect, short term releases or smaller effect, long term releases. For this site, the latter includes seepage from the tailings storage facility and continuous gas emissions, e.g. from the stacks. These events are assessed separately within the Environmental Assessment for the Modification and are not included here.

Given the limited number of events (large effect, short term releases) that can occur at this site with off-site impacts and the rural nature of the surrounding area, the risk to people and other biological groups (animals and plants) is low. This has been shown by analysis summary in Section 6.1.

In summary, whilst off-site effects can be expected if a major release were to occur, there are no identified whole systems or populations which are at unacceptable levels of risk due to the potentially hazardous events reviewed in this PHA.

For completeness, risks to the biophysical environment due to significant loss of containment events are summarised below.

6.4.1 Escape of Materials to Atmosphere

The potential events that could lead to the escape of significant quantities of harmful materials to the atmosphere (and the effects / mitigation features available) are summarised as follows:

1. Dust release from stockpiles (water sprays and dust suppressant to be used);
2. Ammonia releases (analysis as per Section 5.3.2 of this PHA). See the recommendations in this study;
3. Products of combustion from fires (hydrocarbon fires typically generate carbon dioxide, soot and water which readily disperse due to buoyancy of the plume);
4. Sulphur oxide releases (including sulphuric acid mist) from the sulphuric acid plant (generally, containment is within process piping and equipment and startup emissions etc are dispersed via the plant stack – 40 m high) or from sulphur fires (sulphur fires are slow burning, easy to detect and typically smothered to extinguish); and
5. Loss of containment of process gases, e.g. hydrogen and natural gas (if released, these types of gases readily disperse due to their low molecular weights).

6.4.2 Escape of Materials to Soil or Waterways

The potential events that could lead to the escape of significant quantities of harmful materials to the soil or waterways (and the effects / mitigation features available) are summarised as follows:

1. Loss of containment of acidic liquids or other hazardous liquid within the process or storage areas (all areas bunded to contain spills, disposal of spills on an as needs basis);
2. Loss of containment of hazardous liquids outside of bunded areas (site stormwater and effluent systems route all flow to the treatment plant area, thereby minimising the chance of harmful soil or waterways effects);
3. Rupture of the tailings pipe (high integrity pipe design, instrumentation and visual inspection to be used to monitor flow problems); and
4. Loss of containment from the tailings storage facility, water storage dam or evaporation pond (conformance to dam safety regulations including routine monitoring of dam’s structural condition).

7 CONCLUSION AND RECOMMENDATIONS

The risks associated with the modified mine and processing facility, and rail siding have been assessed and compared against the NSW Department of Planning (now the NSW Department of Planning, Industry and Environment) risk criteria.

The results are summarised in Table 21 and show compliance with all risk criteria.

Societal risk, area cumulative risk, propagation risk, transport risk and environmental risk are also concluded to be acceptable.

The primary reason for the low risk levels from the modified mine and processing facility and rail siding is the separation distances between the potentially hazardous materials and equipment and the nearest private place of residences and also the site boundaries.

The highest contributors to off-site risk are releases of ammonia, in particular, from transfer operations to the storage vessels, and sulphur dioxide releases from catastrophic equipment failure. It is expected that the design review process followed by the Hazard and Operability (HAZOP) study would help mitigate the risk of releases to acceptable levels. This would include designing to Australian Standard AS2022 for the ammonia storage and handling systems. The following recommendations were made in the approved 2017 PHA and are still valid for the modified design. These recommendations are made to lower the risk associated with releases of ammonia.

1. Ensure that the final design includes means to automatically isolate the ammonia road tanker and storage vessels should a release during a transfer occur (vapour and liquid lines). Actuation should be local as well as remote;

2. Provide closed circuit television (CCTV) coverage of the ammonia transfer area to the plant’s control room;

3. Provide means to isolate the ammonia flow to the plant should a release occur. This should be at each storage vessel;

4. Provide means to suppress an ammonia vapour plume. A plume could occur due to a release from the transfer system, the storage vessels or the plant supply lines. Options include spray deluge for the transfers bay and fire water monitors in the transfer and storage area. The latter can be operated remotely (preferable) or manually (may require the use of a full protective suit with self-contained breathing air). Monitors can be fixed or portable;

5. Provide means for road tanker driveaway protection. This could include interlocks on the vehicles brakes or self-sealing devices in the transfer lines;

6. Include the transfer hoses and couplings (dry-break preferred) in the preventative maintenance system. The transfer hoses would need to be regularly inspected, tested and replaced as per the manufacturer’s recommendations;

7. Provide means for preventing stress corrosion cracking in the ammonia storage vessels and include the vessels in the preventative maintenance system for routine inspections;

8. Provide wind socks at appropriate locations to allow people to decide the best means of escape from an ammonia plume;

9. Provide alternate emergency assembly areas given that an ammonia plume can travel in any direction;

10. Provide means for protection for the ammonia road tanker driver should a release occur, e.g. safehouse;

11. Apply good practice for building design, e.g. design buildings as safehouses should relevant guidelines recommend this. For example, design buildings as per the recommendations in the Chemical Industries Association guideline, "Guidance for the Location and Design of Occupied Buildings on Chemical Manufacturing Sites";

12. Provide overfill protection on the ammonia storage vessels. This system should be reviewed via a Safety Integrity Level (SIL) analysis; and

13. Provide means to prevent the vapour compressor from overpressuring the vapour return line and/or the road tanker.

Table 21 - HIPAP 4 Risk Compliance

Description	Risk Criteria	Risk Acceptable?	Comments
Fatality risk to sensitive users, including hospitals, schools, aged care	0.5 x 10^{-6} per year	Y	The facility is to be located in a rural area with no nearby sensitive landusers. Based on the analysis in this PHA, there are no credible fires, explosions or toxic gas releases that can cause fatality to sensitive land users. The estimated maximum individual fatality risk at the site boundary is 1×10^{-6}/yr
Fatality risk to residential and hotels	1 x 10^{-6} per year	Y	As the estimated maximum individual fatality risk at the site boundary is 1×10^{-6}/yr then this criterion is satisfied
Fatality risk to commercial areas, including offices, retail centres, warehouses	5 x 10^{-6} per year	Y	As the estimated maximum individual fatality risk at the site boundary is 1×10^{-6}/yr then this criterion is satisfied
Fatality risk to sporting complexes and active open spaces	10 x 10^{-6} per year	Y	As the estimated maximum individual fatality risk at the site boundary is 1×10^{-6}/yr then this criterion is satisfied
Fatality risk to be contained within the boundary of an industrial site	50 x 10^{-6} per year	Y	As the estimated maximum individual fatality risk at the site boundary is 1×10^{-6}/yr then this criterion is satisfied
Injury risk – incident heat flux radiation at residential areas should not exceed 4.7 kW/m^2 at frequencies of more than 50 chances in a million per year or incident explosion overpressure at residential areas should not exceed 7 kPa at frequencies of more than 50 chances in a million per year	50 x 10^{-6} per year	Y	Based on the analysis in this PHA, there are no credible fires or explosions that can cause injury at the closest privately owned residence

Description	Risk Criteria	Risk Acceptable?	Comments
Toxic exposure – Toxic concentrations in residential areas which would be seriously injurious to sensitive members of the community following a relatively short period of exposure	10 x 10^{-6} per year	Y	The likelihood of causing injury at the closest privately owned residence is approximately 1x10^{-6}/yr, therefore, this criterion is satisfied
Toxic exposure – Toxic concentrations in residential areas which should cause irritation to eyes or throat, coughing or other acute physiological responses in sensitive members of the community	50 x 10^{-6} per year	Y	The likelihood of causing irritation at the closest privately owned residence is approximately 4x10^{-6}/yr, therefore, this criterion is satisfied
Propagation due to Fire and Explosion – exceed radiant heat levels of 23 kW/m^2 or explosion overpressures of 14 kPa in adjacent industrial facilities	50 x 10^{-6} per year	Y	The facility has no adjacent industrial facilities, therefore, this criterion is satisfied

8 APPENDIX A - 2000 PHA TOXIC GAS MODELLING BASIS

Appendix A - 2000 PHA Toxic Gas Modelling Basis

Given these large distances to the nearest place of residence, the assessment approach taken in this PHA is to analyse all incidents that may have an effect (e.g. irritation, injury and/or fatality) at this location as well as at the site's nearest boundary (for fatality risk). This approach is taken as the majority of identified incidents have no effect over such a large distance, e.g. a diluent pool fire would have no thermal effects at distances of approximately 150 metres and hence rigorous analysis is unnecessary. This approach would allow detailed assessment of, and hence draw attention to, the significant hazardous events. This approach would also aid in the determination of plant design requirements to mitigate the risks from these significant hazardous incidents as well as influence the plant's safety management systems and emergency response plans.

The consequence calculations in this PHA were carried out using commercially available risk assessment software, TNO's Effects (Ref 13). The consequence models used within Effects are well known and are fully documented in the TNO Yellow Book (Ref 13).

Essentially, for each scenario defined by the analyst (e.g. those events considered significant and likely to have an impact at the nearest place of residence and boundary), an appropriate release rate is calculated by using established equations within Effects. Data pertinent to the release conditions, including the initial state of the material, is included in the calculations.

Once the release conditions and rate have been determined, the likely outcomes (e.g. toxic gas release) are modelled. The results from these simulations (e.g. plume concentrations from toxic gas releases) are used to determine the effect on people, property and/or the environment.

The scenarios identified in Section 4 are the basis of the risk assessment. The significant events that involve fires, explosions and toxic gas releases are analysed further in this PHA. The basis for each analysis is given in the corresponding section to define the conditions of release for each event. This also includes assumptions made for each scenario.

Release Sources

For gas or liquid release scenarios, piping failures have been analysed using four failure cases. These are full pipe fracture, 50 mm, 13 mm, and 3 mm holes. Gasket failure is likely to result in a gap equivalent to the area between two flange bolts and is included in the analysis where relevant. This is considered equivalent to a 13 mm diameter hole size. Vessel failures have been analysed as catastrophic rupture and leaks of 50 mm, 25 mm, 13 mm and 6 mm. These generic failure cases are comparable to those used in a number of published risk assessment studies and described in Lees (Refs 14 and 15).

Release Rates

Release rates were calculated for each release scenario using standard equations based on hole size, pressure, temperature and material state (i.e. gas or liquid). Where the calculated release rate was greater than the maximum possible process rate (for example, if the flow was limited by the sulphur burning rate), the release rate was specified as equal to the limiting production rate. The maximum release inventory was also limited to the contents of the plant equipment plus the amount lost over the duration of the leak (variable depending on the leak rate).

Release Duration

The assumed time taken to stop and control a release is based on a credible estimate of a release scenario rather than always taking a worst case approach (in accordance with quantitative risk analysis principles).

For any scenarios where automatic shutdown of the plant occurs on detection of the hazardous event, a release duration of 1 minute has been chosen. This is consistent with the reported methodologies in Lees (Ref 15) and the approach taken within the Orica ISORIS risk assessment package (Ref 16). Also, if any worst case events occur (e.g. catastrophic rupture within the sulphuric acid plant where large visible clouds may occur, e.g. for sulphur trioxide, along with numerous alarms and trips) which are immediately obvious to the operators (24 hour manning), a release duration of one minute has been chosen.

For smaller leak scenarios which rely on manual response to stop and control the release (i.e. where operator intervention is required to stop the leak, usually by shutting down production or closing valves), release duration of between 6 and 30 minutes can be expected. The duration depends on the means to alert the operators of the release (e.g. process alarms) as well as the closeness of the release to the operators (i.e. smell, sight and/or noise may indicate a release if the operator is nearby). In this assessment, release duration for small leaks is assessed individually as described in the appropriate section.

Given that the plants are to be designed to the latest design standards which would include comprehensive monitoring via programmable electronic systems, it can be expected that sufficient alarms and trips would exist to warn the operators of significant abnormal plant behaviour. This expectation can be verified in the Final Hazard Analysis and HAZOP studies if the project goes ahead. As such, the nominated release durations are judged to be achievable.

As a further means to mitigate the release duration (and hence release quantity), it is proposed to install emergency isolation valves (EIVs) on the inlets and outlets of all equipment processing the more hazardous materials (e.g. the ammonia storage vessels). Once a plant trip is initiated, these EIVs would shut, thereby boxing in sections of pipework and equipment. Hence, the amount released and the release duration are minimised.

For the sulphuric acid plant, shutting the plant down quickly stops releases as these plants run at low pressure (typically up to 24 kPag). Hence, there is little driving force for losses once the plant is stopped.

For any processing plant, once the plant is stopped, the maximum amount released (and hence maximum duration) is limited by depressurising to atmospheric pressure if a pipe or vessel failure has occurred.

9 APPENDIX B - RISK ANALYSIS

Appendix B - Risk Analysis

The risk analysis performed for this PHA is shown Table 22.

The notes associated with the calculations and shown in the table are:

Note 1. Liquid ammonia lines estimated to be approximately 50 m, i.e. from road tankers to bullets and to the vaporiser.

Note 2. Includes the ammonia vapour supply line as well as the vapour line back to the road tankers.

Note 3. United Kingdom HSE data used for all likelihoods.

This failure rate includes catastrophic failures as well as 50 mm holes.

Note 4. Same basis as the 2000 PHA (Ref 1.

Note 5. Transfer failure rate is (United Kingdom HSE data):

0.2×10^{-6}/operation x 3 transfers per day x 340 days per year = 2×10^{-4}/yr

Note: Allowance for shutdowns and other periods taken to be 25 days.

Note 6. Holes can occur in the pipework and vessels.

Note 7. Holes and failures can occur in the pipework and vessels plus transfer hose failures.

Note 8. Probits for sulphur dioxide and ammonia (from Ref 17):

$$Y = a + b\ln(tC^n)$$

where

- Y = probit value
- C = concentration of the toxic gas in ppm
- t = duration of exposure in minutes
- tC^n is referred to as the *Toxic Load*
- a, b, n are constants (unique for each gas)

Chemical	a	b	n
Ammonia	-9.82	0.71	2.0
Sulphur dioxide	-23.70	1.14	3.7

Note 9. The widths of the plumes are estimated to relatively narrow at the nearest place of residence. This results in a narrow angle for the plume (i.e. in the 'Y' direction) and hence the wind direction that can cause impact. The angle of the plume is increased to 5^o to allow for modelling inaccuracies. The probability that the wind is blowing towards the nearest residence is then taken to be (5/45) times the values for wind blowing from the west. Outside of this arc, the plume is not expected at the place of residence.

Table 22 – Risk Analysis

Scenario	Stability Class Wind Speed	Pipe Length, m	Pipe Failure Likelihood, times/yr.m	Probability of System in Use	Vessels Failure Likelihood, times/yr	Number of Vessels	Transfer Hose Failure Likelihood, times/yr	Event Likelihood, times/yr	Probit Value	Probability of Fatality	Probability of Wind Direction from the Northeast	Probability of Wind Direction from the West	Contribution to the Following Risks:		
													Irritation	Injury	Fatality
						Note 4:			Note 8:		Note 9:	Note 9:			
Sulphur Dioxide - Catastrophic Failures	D5.9				4.00E-06	8		3.20E-05	9	1	0.003	0.005	1.60E-07	1.60E-07	9.60E-08
	D2.4				4.00E-06	8		3.20E-05	13	1	0.003	0.004	1.28E-07	1.28E-07	9.60E-08
	E5.8				4.00E-06	8		3.20E-05	10	1	0.003	0.002	6.40E-08	6.40E-08	9.60E-08
	E2				4.00E-06	8		3.20E-05	15	1	0.003	0.004	1.28E-07	1.28E-07	9.60E-08
	F2				4.00E-06	8		3.20E-05	12	1	0.003	0.003	9.60E-08	9.60E-08	9.60E-08
		Note 4:	Note 3:					Note 6:							
Sulphur Dioxide - 50 mm Holes	E2	500	1.40E-07		5.00E-06	8		1.10E-04				0.004	4.40E-07		
	F2	500	1.40E-07		5.00E-06	8		1.10E-04				0.003	3.30E-07		
Ammonia - Catastrophic Failures	D5.9				4.00E-06	2		8.00E-06	6	0.85	0.003	0.005	4.00E-08	4.00E-08	2.04E-08
	D2.4				4.00E-06	2		8.00E-06	6	0.85	0.003				2.04E-08
	E5.8				4.00E-06	2		8.00E-06	6	0.85	0.003	0.002	1.60E-08	1.60E-08	2.04E-08
	E2				4.00E-06	2		8.00E-06	6	0.85	0.003				2.04E-08
	F2				4.00E-06	2		8.00E-06	6	0.85	0.003				2.04E-08
		Note 1:					Note 5:	Note 7:							
Ammonia (liquid) - 50 mm Holes	D5.9	50	5.00E-07	0.08	5.00E-06	2	2.00E-04	2.12E-04	2	0.01	0.003	0.005	1.06E-06		6.36E-09
	D2.4	50	5.00E-07	0.08	5.00E-06	2	2.00E-04	2.12E-04	2	0.01	0.003	0.004			6.36E-09
	E5.8	50	5.00E-07	0.08	5.00E-06	2	2.00E-04	2.12E-04	2	0.01	0.003	0.002	4.24E-07	4.24E-07	6.36E-09
	E2	50	5.00E-07	0.08	5.00E-06	2	2.00E-04	2.12E-04	3	0.025	0.003	0.004			1.59E-08
	F2	50	5.00E-07	0.08	5.00E-06	2	2.00E-04	2.12E-04	4	0.15	0.003	0.003			9.54E-08
		Note 1:													
Ammonia (liquid) - 25 mm Holes	D5.9	50	5.00E-07	0.08	5.00E-06	2		1.21E-05	0		0.003	0.005	6.04E-08		
	E5.8	50	5.00E-07	0.08	5.00E-06	2		1.21E-05	1		0.003	0.002	2.42E-08		
	F2	50	5.00E-07	0.08	5.00E-06	2		1.21E-05	2	0.01	0.003	0.003			3.63E-10
		Note 2:	Note 3:				Note 5:								
Ammonia Vapour Releases	F2	150	6.00E-07		5.00E-06	2	2.00E-04	3.00E-04				0.003	9.00E-07		
TOTALS:													3.87E-06	1.06E-06	7.13E-07

10 REFERENCES

1 SHE Pacific Pty Ltd, *Preliminary Hazard Assessment for the Syerston Nickel – Cobalt Project, Fifield, NSW*, 15 September 2000

2 Pinnacle Risk Management Pty Ltd, *Preliminary Hazard Analysis for the Syerston Project Modification 4, Fifield, NSW*, 26 October 2017

3 NSW Department of Planning, *Hazardous Industry Planning Advisory Paper No 6 – Hazard Analysis,* January 2011

4 NSW Department of Planning, *Hazardous Industry Planning Advisory Paper No 4 – Risk Criteria for Land Use Safety Planning,* January 2011

5 NSW Department of Planning, *Hazardous and Offensive Development Application Guidelines, Applying SEPP 33*, January 2011

6 Clean TeQ, *Clean TeQ Sunrise Project Execution Plan Phase Report, Chapter 8 of 27, Metallurgical Processing*

7 United Kingdom Health and Safety Executive, *Major Hazard Safety Performance Indicators in Great Britain's Onshore Gas and Pipelines Industry*, Annual Report 2007/08

8 Cox, Lees and Ang, Classification of Hazardous Locations, 2000

9 Standards Australia AS2022 *The Storage and Handling of Anhydrous Ammonia*, 2003

10 National Transport Commission, *Australian Code for Transport of Dangerous Goods,* 2020

11 Centre for Chemical Process Safety (CCPS*), Guidelines for Chemical Transportation Risk Analysis*, 1995

12 Resource Strategies, *Cowal Gold Project, Transport of Hazardous Materials Study*, June 2010

13 TNO, *Yellow Book, Methods for the Calculation of the Physical Effects of the Escape of Dangerous Material, CPR 14E, Parts 1 and 2*, Committee for the Prevention of Disasters, 3rd Edition, 1997

14 United Kingdom Health and Safety Executive, *Failure Rate and Event Data for use within Risk Assessments,* 28/06/2012

15 Lees, F. P., *Loss Prevention in the Process Industries*, Third Edition

16 SHE Pacific, *ISORIS Suite of Programs for the Calculation of the Effects of Fires and Explosions*

17 Planager / Pinnacle Risk Management, *HAZAN Course Notes*, 2017

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