

Appendix G

Hazard and risk assessment

Blast Furnace No. 6 Reline Project

Hazard and Risk Report

BlueScope Steel (AIS) Pty Ltd

7 March 2022

→ The Power of Commitment






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Executive summary

BlueScope Steel (AIS) Pty Ltd's (BlueScope) Port Kembla Steelworks operation in NSW includes two blast furnaces. No. 5 Blast Furnace (5BF) is currently operating, while No. 6 Blast Furnace (6BF) is currently in care and maintenance. 5BF is expected to continue to produce (molten) iron on a continuous basis until it reaches the end of its operational life at some stage between 2026 and 2030. BlueScope is proposing a move of iron manufacture from 5BF to 6BF, after 5BF ceases operation. 6BF last produced iron in 2011, at which point it was taken out of service and placed into care and maintenance. To prepare 6BF to become operational again, major maintenance works are required (the project). The project aims to return 6BF to service through a reline process that will be carried out while 5BF continues to operate. GHD Pty Ltd (GHD) was commissioned by BlueScope to prepare a preliminary risk screening in accordance with *State Environment Planning Policy No. 33 - Hazardous and Offensive Development* (SEPP 33).

The results of the dangerous goods and transport screening indicate that the project does not exceed any of the SEPP 33 thresholds for operation but storage of explosives during construction exceeds the SEPP 33 threshold. Given the use of explosives during construction of the project it has been considered 'potentially hazardous' and a Preliminary Hazard Analysis (PHA) has been prepared. It is considered that there is potential for moderately serious harm, and a Level 2 PHA is appropriate. A Level 2 PHA uses a semi-quantitative approach based on comprehensive hazard identification to demonstrate that the activity does not pose a significant risk.

Assessments of the air quality, and noise and vibration impact of the project have been completed as part of the EIS, as the development is 'potentially offensive'. The results from the air quality and noise and vibration assessments indicate that if appropriate control measures are in place during construction and operation, the project will minimise the impact of the relevant amenity criteria. Over the lifecycle of the project, and with safeguards, the project is not expected to release a significant quantity of pollutant emissions and is not considered to be an 'offensive industry'.

A qualitative hazard identification study was completed as a systematic way to identify any potential offsite impacts, during construction and operation. The hazard identification study identified the following hazards with the potential for offsite impact, all of which can be suitably controlled:

- Fire/explosion from the natural gas supply
- Fire/explosion from self-generated gas (coke ovens gas)
- Explosion from molten metal and water
- Discharge of toxic dust and/or fumes (blast furnace gas and coke ovens gas)
- Use/handling of explosives

Of these impacts, three were considered serious enough that further semi-quantitative analysis was warranted, specifically internal furnace molten metal explosions, coke ovens gas leaks and ignition, and fuel gas leaks and ignition. The assessment showed that there was no off-site impact and that the risk complies to HIPAP 4 risk criteria.

The hazard identification study demonstrates that the project could be designed, constructed and operated in a manner that will meet relevant regulations, standards and policies.

It is recommended that the following controls be implemented that incorporate practices that will prevent risk scenarios occurring through:

- Inspection and maintenance regime for the gas reducing station, the coke ovens gas and the blast furnace gas pipework and associated fittings
- Separation, or tightly controlled usage, of water around the furnace areas, including procedures/training regarding the expectations for management of water leaks
- Furnace design to avoid inadvertent water leakage into the furnace
- Inspection and maintenance regime for furnace closed water systems
- Bollards or equivalent to protect ground level fuel gas infrastructure such as the natural gas reducing station
- Explosives stored at least 90 metres from the site boundary

It is important to note that any new equipment should have procedures developed for safe operation. This is particularly important for the operation of any new fixed or mobile machinery to prevent injury to people.

Any changes to the assumptions used in this report should result in a review of the PHA and update as required.

This report is subject to, and must be read in conjunction with, the limitations set out in Section 1.3 and the assumptions and qualifications contained throughout the report.

Contents

1.	Introduction	1
1.1	Background and project overview	1
1.2	Purpose of this report	1
1.3	Limitations	1
2.	Legislative and policy context	3
2.1	Applying SEPP 33: Hazardous and Offensive Development Application Guidelines	3
2.2	Hazardous Industry Planning Advisory Paper No 4 – Risk Criteria for Land Use Safety Planning	3
2.3	Hazardous Industry Planning Advisory Paper No 6 – Guidelines for Hazard Analysis	3
2.4	Multi-Level Risk Assessment	3
2.5	Secretary’s environmental assessment requirements	3
3.	Methodology	5
3.1	Approach to assessment	5
3.1.1	SEPP 33 screening	5
3.1.2	Hazard identification	5
3.1.3	Preliminary Hazard Analysis	5
4.	Existing environment	7
4.1	Project area	11
5.	Preliminary risk screening and emissions	13
5.1	Dangerous goods storage	13
5.1.1	Construction	13
5.1.2	Operation	14
5.2	Transport screening	16
5.2.1	Construction of the project	16
5.2.2	Operation of project	16
5.3	Summary of risk screening results	16
5.4	Amenity overview	16
5.4.1	Air quality assessment	16
5.4.2	Noise and vibration impact assessment	16
5.5	Summary of emissions results	17
6.	Preliminary hazard analysis	18
6.1	Hazard identification	18
6.2	Hazardous materials	20
6.2.1	Natural gas	20
6.2.2	Molten metal	21
6.2.3	Explosives	21
6.2.4	Blast furnace gas	21
6.2.5	Coke ovens gas	21
6.3	Hazard scenarios	22
6.4	Consequence determination	22
6.4.1	Assumptions	22
6.4.2	Results	23
6.5	Likelihood estimation	24
6.6	Risk assessment	24

7. Recommendations	25
7.1 Explosives management	25
7.2 Emergency management	25
8. Conclusions	26
9. References	27

Table index

Table 2.1	Hazard and risk SEARs	4
Table 5.1	Construction chemicals	13
Table 5.2	Construction chemical threshold comparison	14
Table 5.3	Operational chemicals	14
Table 5.4	Operation chemical threshold comparison	15
Table 6.1	Hazard identification list	19
Table 6.2	Conditions for textbook calculations	22
Table 6.3	Conditions for PHAST modelling	23
Table 6.4	Summary of heat radiation consequences	23
Table 6.5	Summary of overpressure consequences	23
Table 6.6	On-site jet fire frequencies	24
Table 6.7	On-site explosion frequencies	24
Table 6.8	Risk criteria compliance	24

Figure index

Figure 3.1	SEPP 33 screening process	6
Figure 4.1	Regional location	8
Figure 4.2	Site layout	9
Figure 4.3	Key features	10
Figure 4.4	Project Area	12
Figure 6.1	PHA process	18

Appendices

Appendix A	Consequence Calculation Summary
Appendix B	PHAST Consequence Modelling Summary
Appendix C	Frequency Calculation Summary

Terms and abbreviations

Abbreviation	Description
ADG	Australian Dangerous Goods Code
AS	Australian Standard
AS/NZS	Australian and New Zealand Standard
bar	Measurement of atmospheric pressure
BF	Blast Furnace
BFG	Blast Furnace Gas
°C	Degrees Celsius
CBD	Central Business District
COG	Coke Ovens Gas
CSSI	Critical State Significant Infrastructure
DG	Dangerous Good
DPIE	Department of Planning, Industry and Environment
EIS	Environmental Impact Statement
EP&A	Environmental Planning and Assessment
GHD	GHD Pty Ltd
HIPAP	Hazardous Industry Planning Advisory Paper
K	Kelvin
kg	Kilograms
km	Kilometres
kPag	Kilopascals gauge
kW/m ²	Kilowatts per meters squared
LGA	Local Government Area
LPG	Liquid Propane Gas
m	Metres
mm	Millimetres
MPag	Mega Pascals gauge
MSDS	Material Safety Data Sheet
NSW	New South Wales
PHA	Preliminary Hazard Analysis
PHAST	Process Hazard Analysis Software Tool
PKSW	Port Kembla Steelworks
PPE	Personal Protective Equipment
SEPP 33	State Environment Planning Policy Number 33
SWMS	Safe Work Method Statement
UN	United Nations

1. Introduction

1.1 Background and project overview

BlueScope Steel (AIS) Pty Ltd's (BlueScope) Port Kembla Steelworks (PKSW) operation in NSW includes two blast furnaces. No. 5 Blast Furnace (5BF) is currently operating, while No. 6 Blast Furnace (6BF) is currently in care and maintenance.

5BF is expected to continue to produce (molten) iron on a continuous basis until it reaches the end of its operational life at some stage between 2026 and 2030. BlueScope is proposing a move of iron manufacture from 5BF to 6BF, after 5BF ceases operation.

6BF last produced iron in 2011, at which point it was taken out of service and placed into care and maintenance. To prepare 6BF to become operational again, major maintenance works are required (the project). The project aims to return 6BF to service through a relining process that will be carried out while 5BF continues to operate.

The project has been declared critical state significant infrastructure (CSSI) in accordance with section 5.13 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) and Schedule 5 of the *State Environmental Planning Policy (State and Regional Development) 2011* (SRD SEPP).

1.2 Purpose of this report

GHD Pty Ltd (GHD) was commissioned by BlueScope to prepare a preliminary risk screening in accordance with *State Environment Planning Policy No. 33 - Hazardous and Offensive Development* (SEPP 33). This report will support the preparation of an Environmental Impact Statement (EIS) under the EP&A Act for the project.

This report addresses the relevant criteria in the NSW Secretary's Environmental Assessment Requirements (SEARs) for the project issued in July 2021 (as outlined in section 2.5) and assesses the potential hazards and risks of the project under SEPP 33.

As such, this report focuses on the impact of potential hazards associated with the use of dangerous goods and hazardous substances that may arise during the construction and operation of the project. Specifically, this report:

- Describes the existing environment with respect to the project
- Screens the quantities of dangerous goods expected to be used during construction and operation of the project
- Assesses the impacts of construction and operation of the project specific to dangerous goods and other hazardous substances
- Recommends measures to mitigate the impacts identified

1.3 Limitations

This report has been prepared by GHD for BlueScope Steel (AIS) Pty Ltd and may only be used and relied on by BlueScope Steel (AIS) Pty Ltd for the purpose agreed between GHD and BlueScope Steel (AIS) Pty Ltd as set out in section 1.2.

GHD otherwise disclaims responsibility to any person other than BlueScope Steel (AIS) Pty Ltd arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by BlueScope Steel (AIS) Pty Ltd and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

2. Legislative and policy context

The project has been declared CSSI in accordance with Section 5.13 of the EP&A Act.

2.1 Applying SEPP 33: Hazardous and Offensive Development Application Guidelines

The Department of Planning's, NSW, 2011 guideline, "*Applying SEPP 33: Hazardous and Offensive Development Application Guidelines*" provides the process for assessing if developments are potentially hazardous or offensive, including threshold levels that trigger the potentially hazardous or offensive status. SEPP 33 is the main guidance document that has been followed for this assessment.

The project has been declared CSSI and requires approval from the NSW Minister for Planning and Public Spaces. *State Environment Planning Policy No. 33 - Hazardous and Offensive Development* (SEPP 33) is required to be considered as part of the EIS. SEPP 33 provides a process for identifying a potentially hazardous development should storage and transport screening thresholds be exceeded.

2.2 Hazardous Industry Planning Advisory Paper No 4 – Risk Criteria for Land Use Safety Planning

The Department of Planning's, NSW, 2011, *Hazardous Industry Planning Advisory Paper No 4 – Risk Criteria for Land Use Safety Planning* (HIPAP No 4) sets out risk criteria for industries that are considered hazardous. This document is only used if SEPP 33 indicates a development is potentially hazardous.

2.3 Hazardous Industry Planning Advisory Paper No 6 – Guidelines for Hazard Analysis

The Department of Planning's, NSW, 2011, *Hazardous Industry Planning Advisory Paper No 6 – Guidelines for Hazard Analysis* (HIPAP No 6) lists the process required for preliminary hazard analysis (PHA). This document is only used if SEPP 33 indicates a development is potentially hazardous.

2.4 Multi-Level Risk Assessment

The Department of Planning's, NSW, 2011, *Multi-level Risk Assessment* lists the process required for completing a risk assessment at a qualitative, semi-quantitative or fully quantitative level of detail. This document is only used if SEPP 33 indicates a development is potentially hazardous and a PHA is required.

2.5 Secretary's environmental assessment requirements

The SEARs relevant to hazards and risk, together with a reference to where they are addressed in this report, are outlined in Table 2.1.

Table 2.1 Hazard and risk SEARs

Requirements	Where addressed in this report
A preliminary risk screening completed in accordance with State Environmental Planning Policy No. 33 - Hazardous and Offensive Development (SEPP 33) and <i>Applying SEPP 33</i> (2011), with a clear indication of class, quantity and location of all dangerous goods and hazardous materials associated with the development	Section 5
Should preliminary screening indicate that the project is "potentially hazardous", a PHA must be prepared in accordance with <i>Hazardous Industry Planning Advisory Paper No. 6 - Guidelines for Hazard Analysis</i> (2011) and <i>Multi-Level Risk Assessment</i> (2011)	Section 6
Systems and procedures to prevent and manage all types of emergencies	Section 6.1 and Section 7

3. Methodology

This section describes the methodology used to undertake the hazard and risk study.

3.1 Approach to assessment

3.1.1 SEPP 33 screening

SEPP 33 applies to any project which falls under the policy's definition of 'potentially hazardous industry' or 'potentially offensive industry'. If not controlled appropriately, some activities within these industries may create an offsite risk or offence to people, property or the environment thereby making them potentially hazardous or potentially offensive. The purpose of this report is to determine if the project is potentially hazardous using the SEPP 33 risk screening process or potentially offensive considering expected discharge requirements. If the screening indicates that the project is potentially hazardous, then a PHA is required. The overall risk screening process, as outlined in SEPP 33 is summarised in Figure 3.1. If the project is potentially offensive, after considering the quantity and nature of any discharges and the significance of the offence likely to be caused, having regard to surrounding land use and the proposed controls, then additional controls are required.

The risk screening process typically concentrates on the storage of specific dangerous good (DG) classes that have the potential for significant offsite effects. Specifically, the assessment involves the identification of classes and quantities of all DGs to be used, stored or produced on site with an indication of storage locations. The quantities of DGs are then assessed against the SEPP 33 threshold quantities. If any of the SEPP 33 threshold quantities are exceeded, then a PHA is required.

3.1.2 Hazard identification

Following screening and during the final assessment of the project, a determination of whether the project poses significant risk or offence is required. Hazard identification highlights any risks associated with the interaction of the project (as a whole) with the surrounding environment. This is a systematic process to identify any potential offsite impacts. The aim of the hazard identification process is to show the project does not pose any significant risk or offence.

The hazard identification is a desktop qualitative assessment and involves documenting possible events that could lead to a possible off-site incident. The assessment then lists potential causes of the incident, as well as identification of operational and organisational safeguards to prevent the incidents from occurring or to mitigate their impact. The hazard identification is conducted for both construction and operation of the project.

3.1.3 Preliminary Hazard Analysis

For development projects classified as 'potentially hazardous industry', a PHA is completed to determine the risk to people, property and the environment at the proposed location and in the presence of controls. Criteria of acceptability are used to determine if the development project is classified as a 'hazardous industry'. If this is the case, the development project may not be permissible within most industrial zonings in NSW.

The PHA will identify potential hazards, analyse these hazards in terms of their impact to people and the environment and their likelihood of occurrence, quantify the resultant risk to surrounding land uses and assess the risk to demonstrate that the project will not impose an unacceptable level of risk.

Applying SEPP 33 (2011) identifies three levels of PHA. If a PHA is required, a judgement of the level of risk associated with the project is determined using the results of the screening and hazard identification stages. The three levels of PHA are:

- Level 1 – if significant but not serious potential for harm is identified, a qualitative PHA is completed
- Level 2 – if medium potential for harm is identified, a semi-quantitative PHA is completed
- Level 3 – if high potential for harm is identified, a quantitative PHA is completed

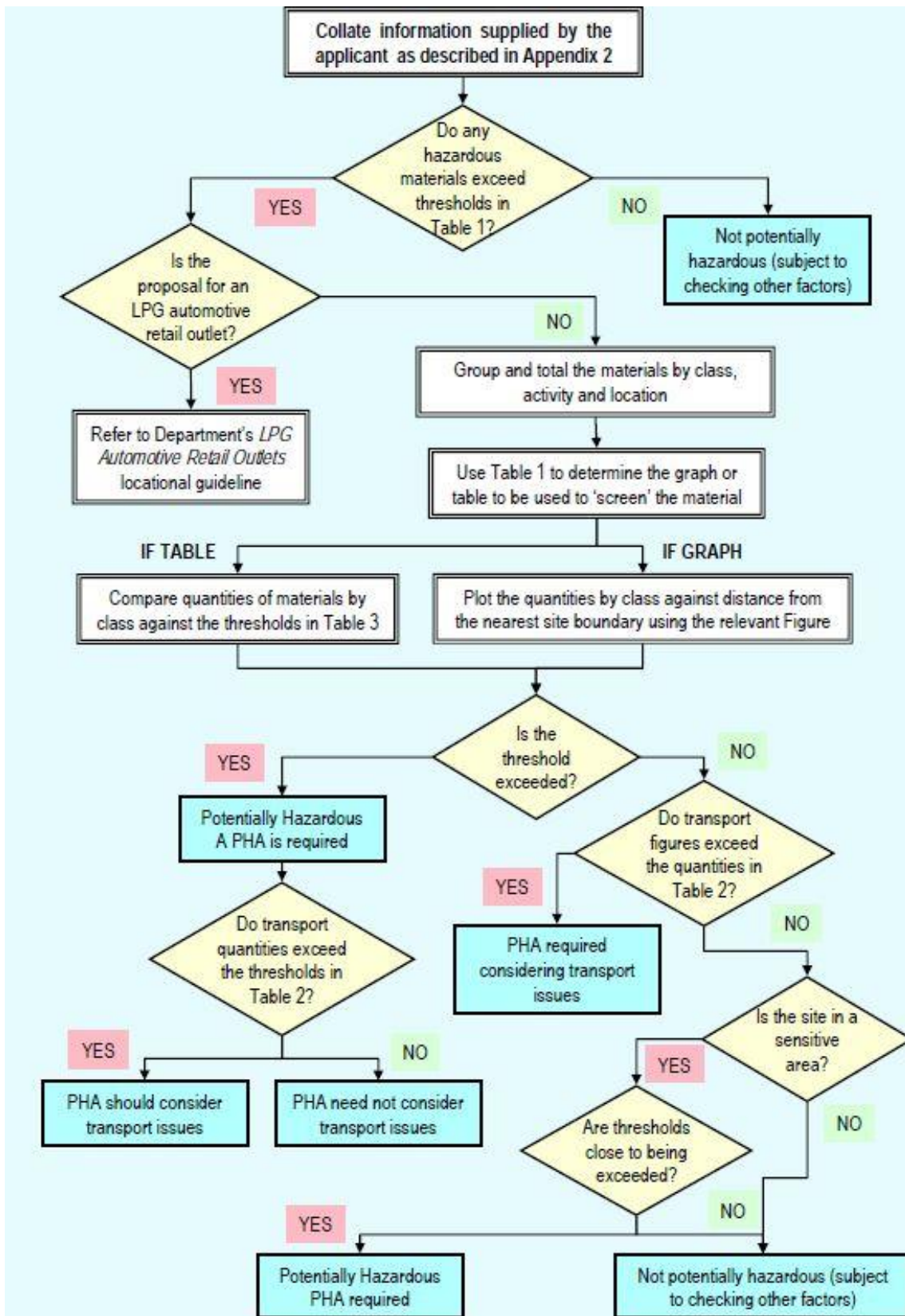


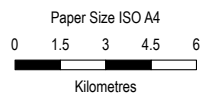
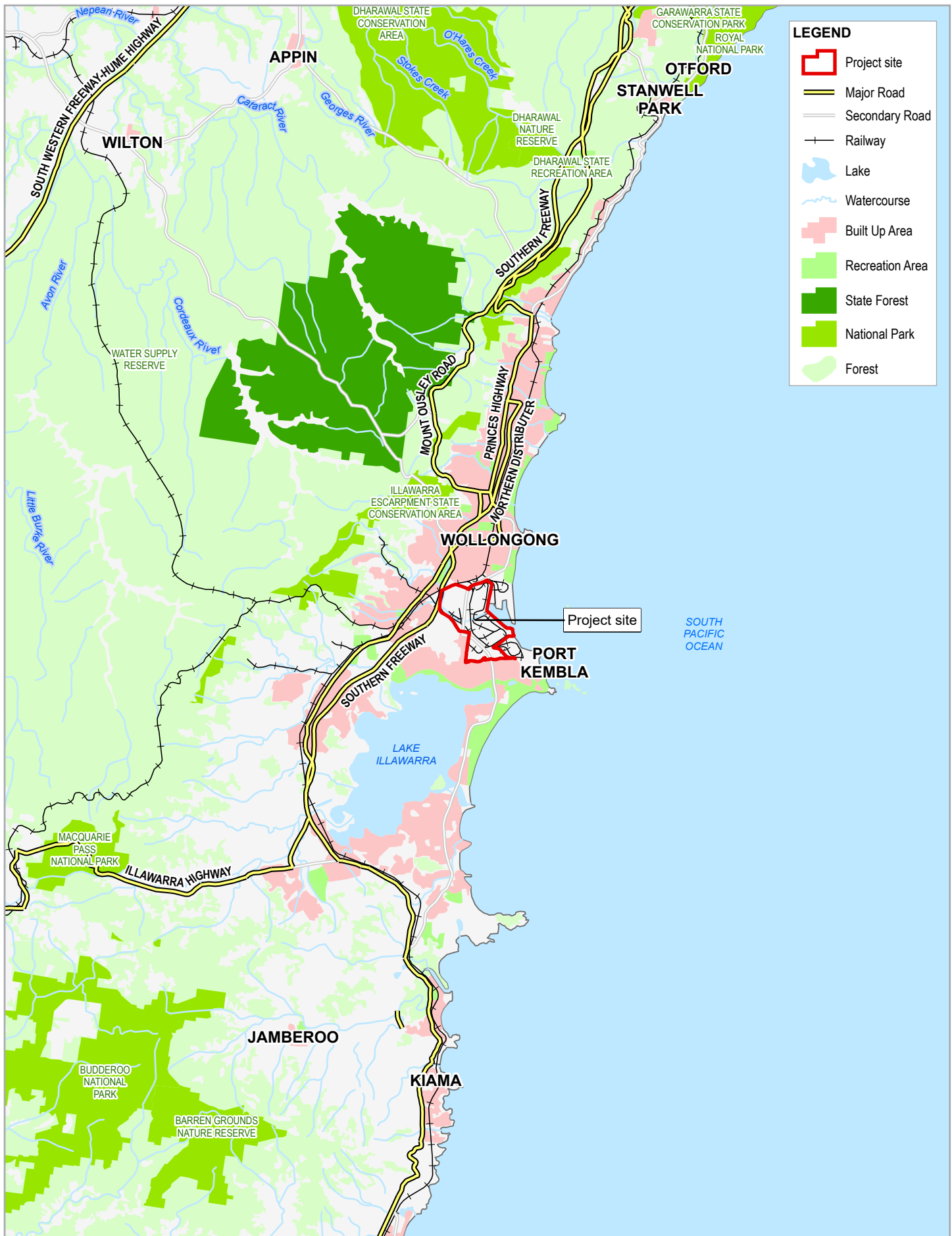
Figure 3.1 SEPP 33 screening process

4. Existing environment

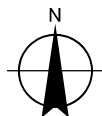
The project is located within an industrial site of approximately 750 hectares (ha) at Port Kembla in the Wollongong LGA and Illawarra region of NSW. Sydney is approximately 80 kilometres (km) to the north of Port Kembla, while the Wollongong Central Business District (CBD) is approximately 2.5 km to the north and Lake Illawarra is approximately 3 km to the south. Port Kembla is the main industrial centre of the Illawarra region.

Key features of Port Kembla are the heavy industrial area and the port including industrial developments such as PKSW, fertiliser production facilities and petroleum hydrocarbon storage and wholesaling. The port of Port Kembla is zoned SP1 – Special Activities. The Inner Harbour, specifically developed as an all-weather shipping port, covers approximately 60 ha with around 2.9 km of commercial shipping berths. BlueScope operates berths in the Inner Harbour that supply materials for the PKSW.

The area surrounding Port Kembla industrial area is primarily occupied by residential development. These urban areas provide small and large-scale retail outlets, community services (e.g. medical facilities, hospital, schools and sporting facilities) and commercial facilities (e.g. banking and post office). The closest urban developments to PKSW are the suburbs of Cringila, Berkeley, Lake Heights, Warrawong and Port Kembla to the south, and Unanderra, Cobblers Hill, Mount St Thomas, Coniston and Figtree to the north and west. The urban areas of Cringila are located adjacent to the No. 1 Works and No. 2 Works areas and are the nearest to the project area, being approximately 1.2 km to the southwest as shown on Figure 4.1 to Figure 4.3.



Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 56

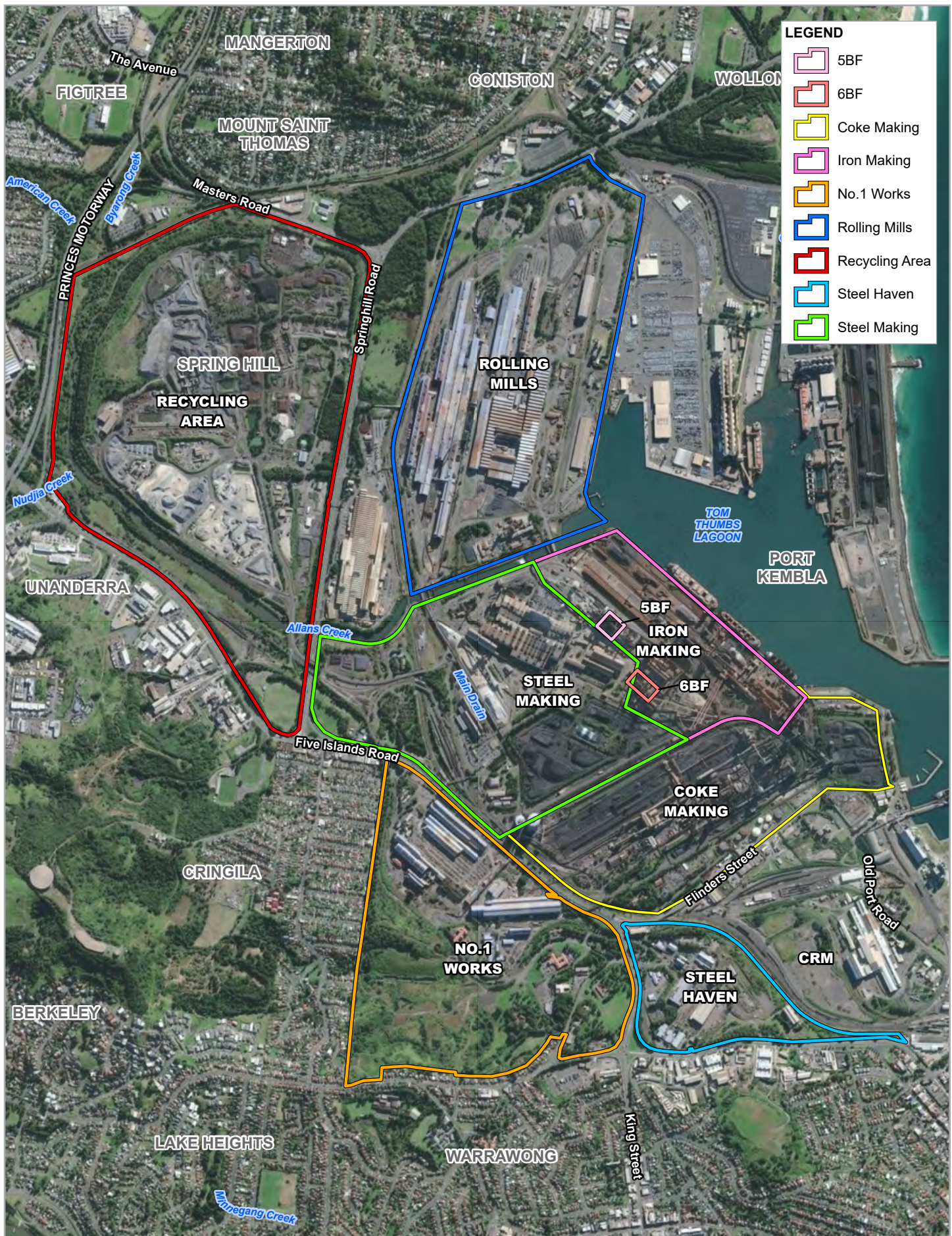


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No.6 Blast Furnace Reline and Operations
Hazard and Risk Report

Project No. **12541101**
 Revision No. **0**
 Date **23/11/2021**

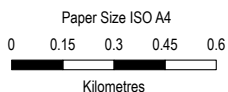
Regional Location

FIGURE 4-1

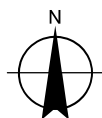


LEGEND

	5BF
	6BF
	Coke Making
	Iron Making
	No.1 Works
	Rolling Mills
	Recycling Area
	Steel Haven
	Steel Making



Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 56










BlueScope Steel Ltd
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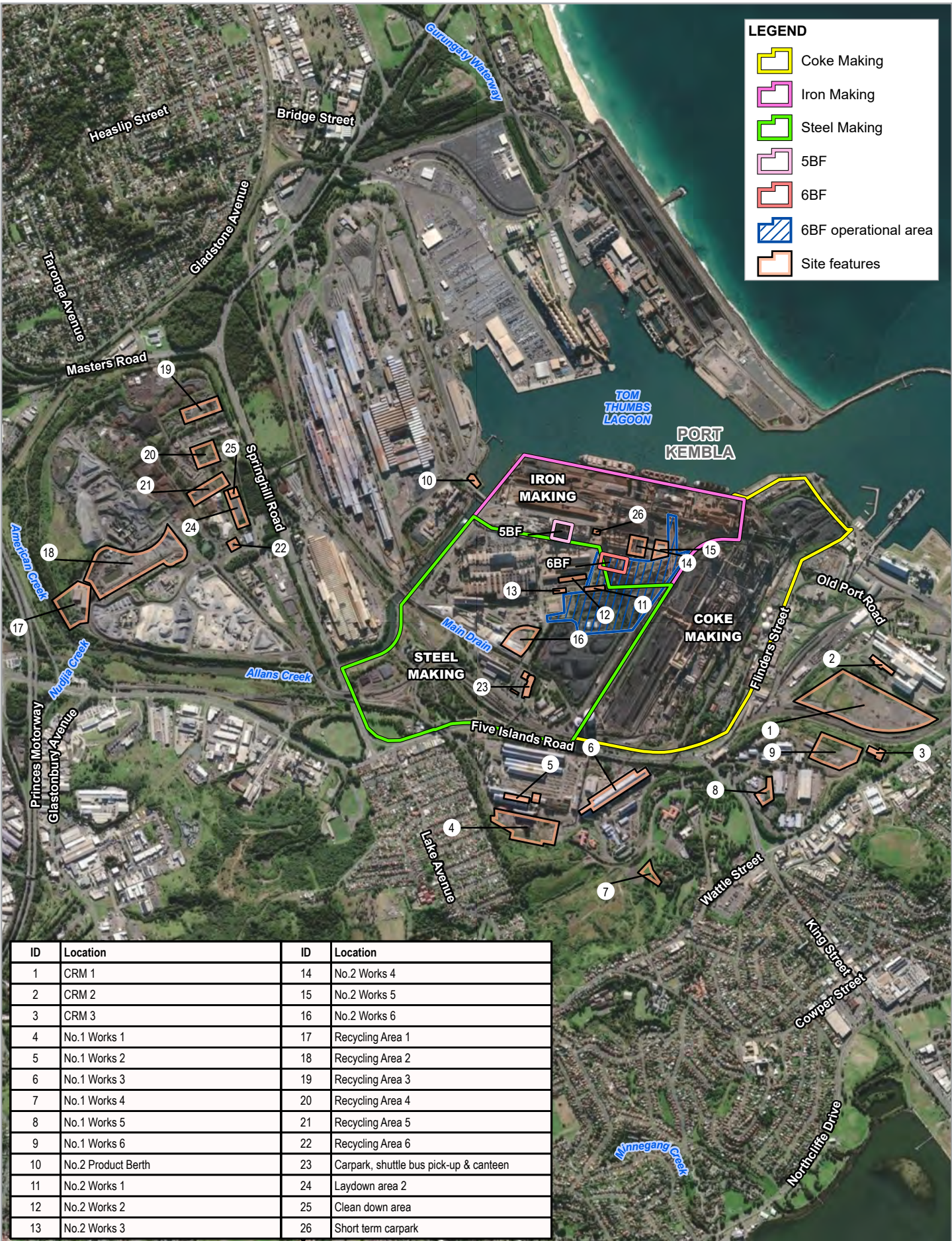
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 Revision No. 0
 Date 23/11/2021

Port Kembla Steelworks
 site layout and locality

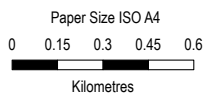
FIGURE 4-2

LEGEND

-  Coke Making
-  Iron Making
-  Steel Making
-  5BF
-  6BF
-  6BF operational area
-  Site features



ID	Location	ID	Location
1	CRM 1	14	No.2 Works 4
2	CRM 2	15	No.2 Works 5
3	CRM 3	16	No.2 Works 6
4	No.1 Works 1	17	Recycling Area 1
5	No.1 Works 2	18	Recycling Area 2
6	No.1 Works 3	19	Recycling Area 3
7	No.1 Works 4	20	Recycling Area 4
8	No.1 Works 5	21	Recycling Area 5
9	No.1 Works 6	22	Recycling Area 6
10	No.2 Product Berth	23	Carpark, shuttle bus pick-up & canteen
11	No.2 Works 1	24	Laydown area 2
12	No.2 Works 2	25	Clean down area
13	No.2 Works 3	26	Short term carpark



Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 56

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Key project features

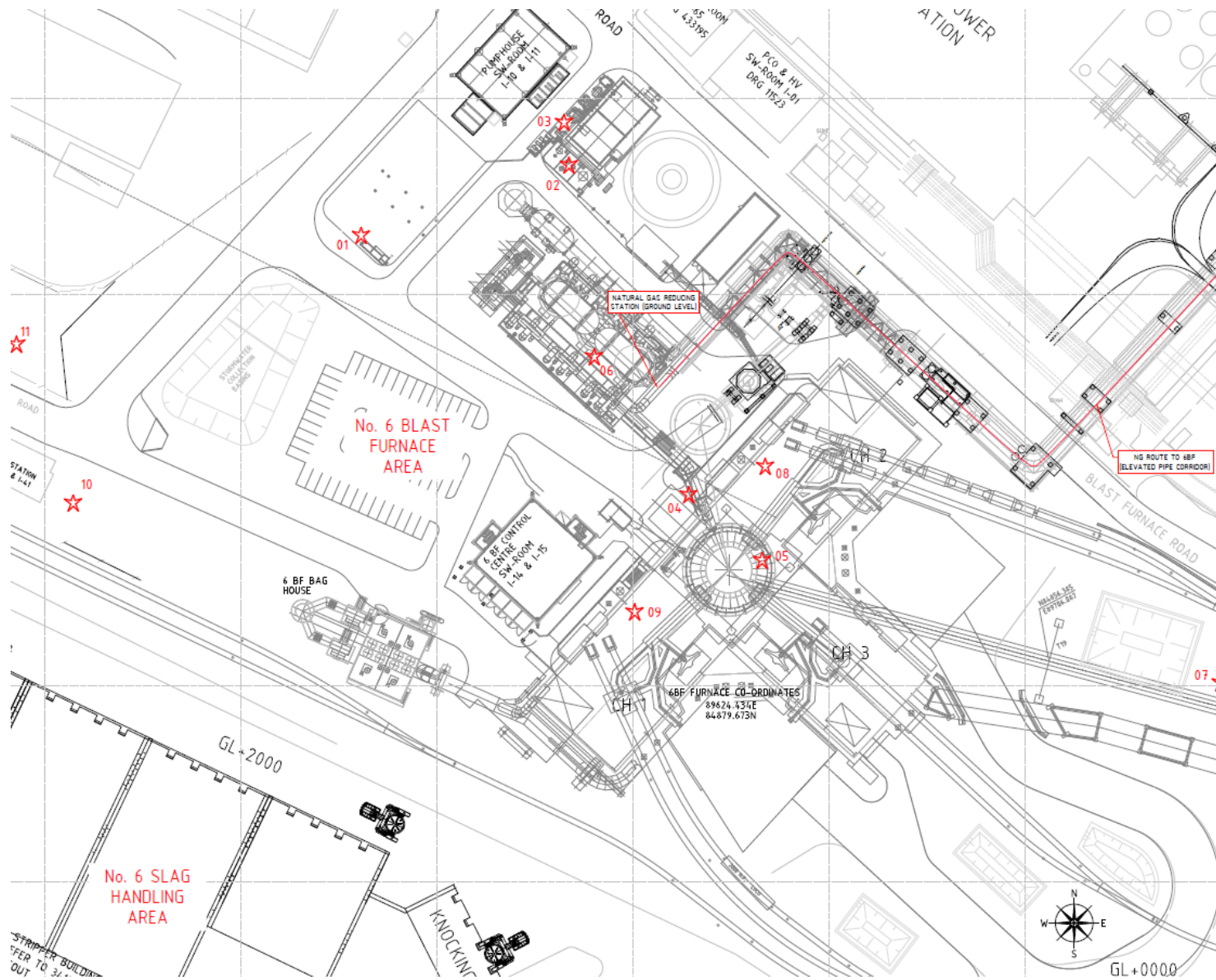
FIGURE 4-3

4.1 Project area

For the purpose of the EIS, the project area includes 6BF and the associated construction area. The project area is shown in Figure 4.4. The project involves the relining of 6BF over a period of approximately 3 years to return it to service and commence ironmaking after 5BF ceases operation.

The reline of the furnace involves:

- Removal of remaining burden material and iron skull
- Stripping of the staves, refractories and hearth from inside the shell
- Repairs to the furnace shell where required
- Installation of the new hearth, sidewall refractories and staves
- Repairs/replacement of the tuyeres, tapholes, furnace cooling systems and instrumentation
- Upgrade work to the 6BF ancillary systems for continuous operation



★ 01 - HAZARDOUS MATERIAL LOCATION

PHASE	LOCATION	HAZARDOUS SUBSTANCE
MANUFACTURING	01	CORROSION INHIBITOR
	02	ETP - SODIUM HYPOCHLORITE, POLYMER, BIODISPERSANT & SODIUM HYDROXIDE.
	03	ETP - ANTISCALANT
	04	CORROSION INHIBITOR
	05	CORROSION INHIBITOR
	06	OXYGEN, ACETYLENE, HELIUM.
	07	HANDGAS (LPG)
CONSTRUCTION	08	OXYGEN, ARGON, ARGONSHIELD
	09	LPG, ACETYLENE
	10	VARIOUS CHEMICALS (REFER TO HAZARDOUS SUBSTANCE SPREADSHEET FOR DETAILS)
	11	VARIOUS CHEMICALS (REFER TO HAZARDOUS SUBSTANCE SPREADSHEET FOR DETAILS)
SLAG HANDLING AREA (LOCATION NOT SHOWN ON MAP)		EXPLOSIVES

Figure 4.4 Project Area

5. Preliminary risk screening and emissions

5.1 Dangerous goods storage

5.1.1 Construction

A summary of the chemicals used and/or stored on-site during construction of the project is shown in Table 5.1. During construction it is assumed that minimal storage of chemicals will occur, and no stockpiling will occur (just-in-time use). The maximum expected quantity and DG classification are provided in Table 5.1.

Table 5.1 Construction chemicals

Product Name	UN number	DG Class	Packing group (PG)	SUB RISK/S	Maximum Quantity (kg)
Bottled Gases					
Oxygen	1072	2.2		5.1	729
LPG	1075	2.1			180
Acetylene	1001	2.1			249
Argon	1006	2.2			922
Argoshield	1956	2.2			944
Nitrogen	1066	2.2			906
Medical air		2.2			559
Miscellaneous					
Paint (spray cans)	various	2.1			50
Paint (liquid)	various	3	II		500
Solvents - thinners, MEK	various	3	II		1,000
Diesel	3082	9	III		5,000
Kerosene	1223	3	III		200
Epoxies	various	3	III		500
Welding fluxes	N/A	N/A			50
Adhesives	various	3	III		100
Cleaning agents	various	8	II		1,000
Carbon and ceramic refractory blocks (monolithic and brick)	N/A	N/A			1,300,000
COG residue	N/A	N/A			1,000
BFG residue	N/A	9	III		1,000
Gearbox oil	various	3	III		500
Grease	various	3	III		500
Aircon refrigerant	various	2.2			200
Explosives		1.1			150

The screening thresholds for on-site storage are shown in Table 5.2. Based on the DG class, the SEPP 33 storage thresholds for the construction of the project are exceeded for explosives if storage is unconstrained. It is possible for the storage of explosives to not exceed the thresholds if the location is set back from the boundary (see section 6.2.3 for more details).

Table 5.2 Construction chemical threshold comparison

DG class	Combined storage threshold (tonnes)	Combined quantity (tonne)	Exceedance of SEPP 33 threshold
1.1	0.1	0.15	Fail (exceeds the threshold)
2.1	0.5	0.25	Pass (does not exceed)
2.1 (LPG)	10	0.18	Pass (does not exceed)
2.2	None	3.33	Pass (excluded) *
3 - II	5	1.50	Pass (does not exceed)
3 - III	5	2.20	Pass (does not exceed)
5.1	5	0.73	Pass (does not exceed)
8 - II	25	1.0	Pass (does not exceed)
9 - III	None	6.0	Pass (excluded) *

* This refers to dangerous goods that SEPP 33 has excluded from requiring a threshold quantity.

5.1.2 Operation

A summary of the chemicals used and/or stored on-site during operation of the project is shown in Table 5.3. Assumptions have been made about the usage of these chemicals on-site. The DG classification and the quantities have also been provided in Table 5.3.

Table 5.3 Operational chemicals

Product Name	UN number	DG Class	PG	SUB RISK/S	Quantity (kg)
Water Treatment Chemicals					
NALCO® 1392	3265	8	III		1500
ACTI-BROM 7342	N/A	N/A			1500
HI-TEX 82220	N/A	N/A			4500
CAT-FLOC 8103 PLUS	N/A	N/A			1500
Sodium Hypochlorite 12.5% Solution	1791	8	II		3450
Caustic soda - Liquid (46% - 50%)	1824	8	II		18000
Furnace Cooling Chemicals					
Nalco 8338	3266	8	III		354
Nalco 8338	3266	8	III		2596
Nalco 8338	3266	8	III		354
Manufacturing Bottled Gases					
Air Compressed		2.2			121
Oxygen Compressed	1072	2.2		5.1	541.6
HANDIGAS (LPG)	1075	2.1			90
Acetylene	1001	2.1			444
HELIUM COMPRESSED	1046	2.2			25.35
Piped Gases					
COG	1023	2.3		2.1	No storage vessels onsite
BFG	1953	2.3		2.1	No storage vessels onsite

Product Name	UN number	DG Class	PG	SUB RISK/S	Quantity (kg)
Natural gas	1971	2.1			No storage vessels onsite
Oxygen	1072	2.2		5.1	No storage vessels onsite
Nitrogen	1066	2.2			No storage vessels onsite
Miscellaneous					
CIGWELD COMMWELD BRONZE FLUX	1458	5.1	III		20
CONCRETSIVE 2530 (B)	2735	8	III		20
Gearbox oil	various	3	III		1,000
Grease	various	3	III		1,000
KEROSENE	1223	3	III		160
WHITE KNIGHT SQUIRTS GLOSS BLACK AEROSOL	1950	2.1			6
WORMALD HFC-227EA (WORMALD HFC-227EA)	3296	2.2			No storage vessels onsite
BELZONA® 2921 (ELASTOMER GP CONDITIONER)	1193	3	II		20
BELZONA® 2211 (MP HI-BUILD ELASTOMER) SOLIDIFIER	3082	9	III		20

The screening thresholds for on-site storage are shown in Table 5.4. Based on the DG class, the SEPP 33 storage thresholds for operation of the project are not exceeded for any chemical.

Table 5.4 Operation chemical threshold comparison

DG class	Combined storage threshold (tonnes)	Combined quantity (tonne)	Exceedance of SEPP 33 threshold
2.1	0.5	0.45	Pass (does not exceed)
2.1 (LPG)	10	0.09	Pass (does not exceed)
2.2	None	0.69	Pass (excluded) *
3 - II	5	0.02	Pass (does not exceed)
3 - III	5	2.16	Pass (does not exceed)
5.1	5	0.56	Pass (does not exceed)
8 - II	25	21.5	Pass (does not exceed)
8 - III	50	4.8	Pass (does not exceed)
9 - III	None	0.02	Pass (excluded) *

* This refers to dangerous goods that SEPP 33 has excluded from requiring a threshold quantity.

5.2 Transport screening

5.2.1 Construction of the project

It is assumed that during construction of the project, there would be low volumes of DGs stored in the construction compounds, using a just-in-time usage regime. Therefore, the transportation volumes of chemicals during construction are considered minimal. The transport screening minimum threshold for any DG vehicle movements is 100 per year. Based on this, the SEPP 33 transport thresholds for construction of the project are not exceeded. In accordance with the requirements of SEPP 33, BlueScope will undertake further consultation with DPIE regarding the proposed transport and handling arrangement associated with the project.

5.2.2 Operation of project

Transport of DGs during operation of the project is expected to follow similar patterns to current blast furnace operations. As such, the transportation screening thresholds for operation are not exceeded. At this stage of the project's development, it is assumed that DGs would primarily access the site via Springhill Road from Port Kembla.

5.3 Summary of risk screening results

The results of the dangerous goods and transport screening indicate that the project does not exceed any of the thresholds for operation but does exceed the thresholds for storage of explosives during construction. Given the use of explosives during construction, the project has been considered 'potentially hazardous' and a PHA has been prepared.

5.4 Amenity overview

Assessments of the air quality, and noise and vibration impact of the project have been completed as part of the EIS, as the development is 'potentially offensive'.

5.4.1 Air quality assessment

The air quality assessment results predict minor criteria exceedances at receptors located across the study area. Exceedances as a result of the project are incremental and for some pollutants, such as particulate matter, have been modelled to occur as a result of elevated background levels. Overall the air quality assessment found that the operation of 6BF would result in a net reduction of emissions to air as a result of environmental control improvements proposed as part of the project. Emissions can be managed through appropriate selection of construction equipment, compliance monitoring in accordance with the site Environmental Protection Licence (EPL) and community engagement. The results of the air quality assessment are detailed in Appendix C of the EIS.

5.4.2 Noise and vibration impact assessment

The noise and vibration impact assessment results indicate that the predicted noise levels during construction of the project would meet noise management levels (NML) for most construction scenarios during standard hours and outside of standard hours. Some high noise intensity but short duration works such as pile driving and blasting may result in exceedances of the NMLs at some receivers. The assessment is dependent on the location and intensity of construction activities and has recommended locations for activities to minimise noise impacts at sensitive receptors. Reasonable and feasible management measures including consulting with potentially impacted residents have been recommended to manage these impacts.

For operations, the predicted noise levels at residences against project noise trigger levels indicate compliance with the requirements subsequent to the incorporation of mitigation measures to reduce noise levels at the source. Generally speaking, operational noise from 6BF will be similar to noise currently generated by 5BF. The results of the noise and vibration impact assessment are detailed in Appendix D of the EIS.

5.5 Summary of emissions results

The results from the air quality, and noise and vibration assessments indicate that if appropriate control measures are in place during construction and operation, the project will minimise the impact of the relevant amenity criteria. Over the lifecycle of the project, and with safeguards, the project is not expected to release a significant quantity of pollutant emissions and is not considered to be an 'offensive industry'.

6. Preliminary hazard analysis

The results of the SEPP 33 screening indicate that due to the quantity of explosives stored on site during construction, a PHA is required. It is considered that there is potential for moderately serious harm, and a Level 2 PHA is appropriate.

A Level 2 PHA uses a semi-quantitative approach based on comprehensive hazard identification to demonstrate that the activity does not pose a significant risk. The PHA follows the process shown in Figure 6.1, which complies with the Department of Planning's *Multi-level Risk Assessment Guideline*.

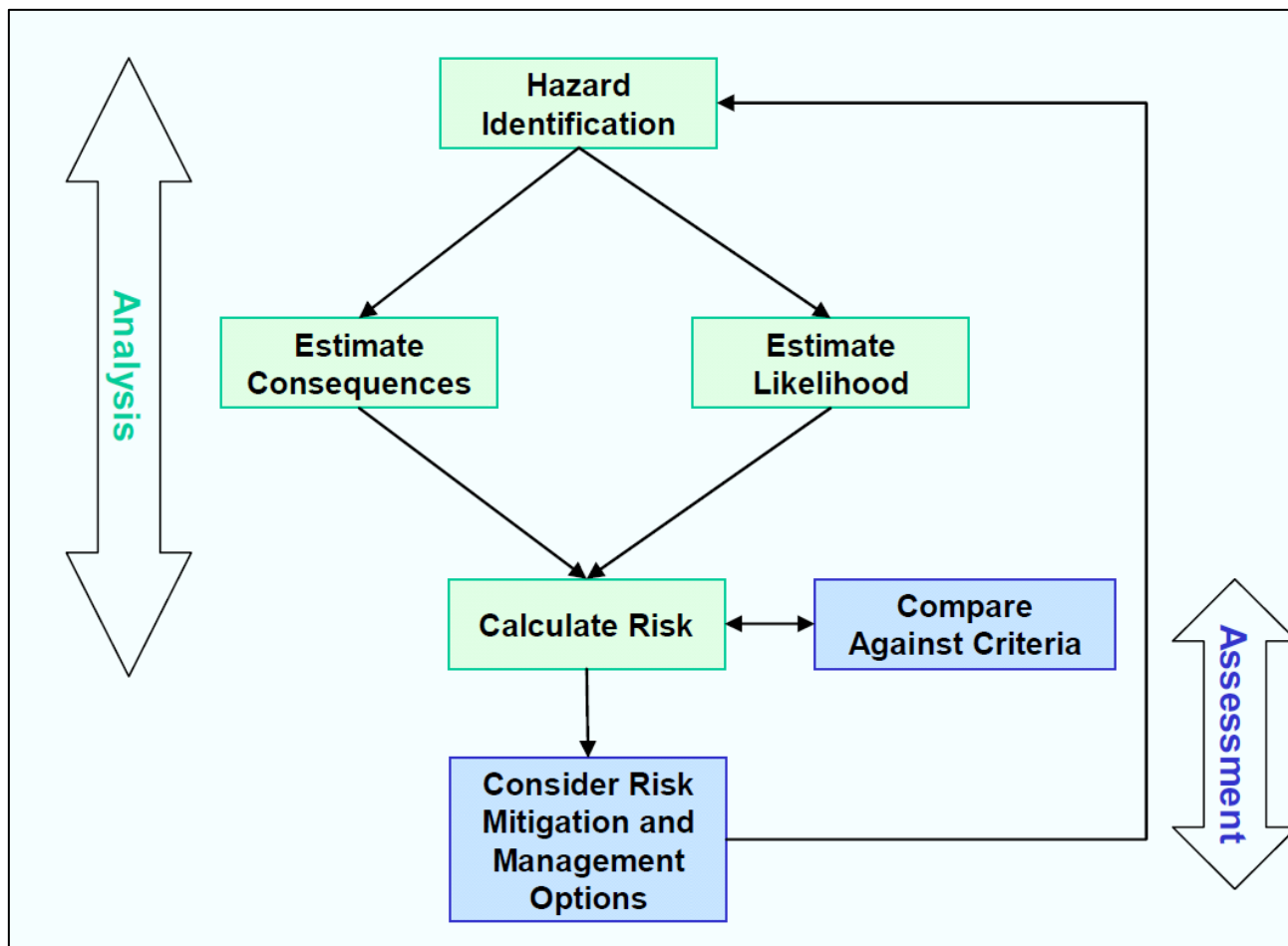


Figure 6.1 PHA process

6.1 Hazard identification

The results of the hazard identification are provided in Table 6.1. The hazard identification was conducted as a desktop study and focussed specifically on both the construction and operation activities of the project. Safeguards are also outlined in Table 6.1 and are required to ensure the risk scenarios that were identified are contained or at least controlled to an acceptable level.

Table 6.1 Hazard identification list

Hazard scenario	Causes	Consequence	Further assessment to assess potential off-site impacts	Identified/ recommended safeguards
Vehicle interactions	Vehicle movements in vicinity of personnel	Personal injury	No	Traffic management plan including standard traffic rules, signage Site speed limits One way traffic movement through the site for delivery vehicles Designated pedestrian areas Driver competency Construction management plan
Natural hazards	Flooding, earthquake, lightning	Personal injury Plant shut down Possible fire	No	Structures and tanks designed to appropriate codes and standards Housekeeping standards Site drainage
External fire (adjacent to site)	Fire or explosion from adjacent land users	Asset damage Plant shut down Personal injury	No	Site fuel management Buildings designed to appropriate codes Fire protection systems Housekeeping standards
Furnace explosion	Incorrect fuel / air mix Internal water leak	Asset damage Personal injury	No	Standard operating procedures Closed loop cooling system with leak detection system Process monitoring systems Gas Safety Regulations, training and accreditations based on AS3814 (Industrial and Commercial Gas Fired Appliances) and AS1375 (Industrial Fuel Fired Appliances)
Molten metal spill	Splash Loss of containment	Asset damage Personal injury	No	Standard operating procedures Maintenance and inspection strategies Furnace operation training and accreditations for personnel Plant and process design
Molten metal explosion	Contact with water	Asset damage Personal injury	Yes	Closed loop cooling system with leak detection system Standard operating procedures Maintenance and inspection strategies Furnace operation training and accreditations for personnel Plant and process design
Flammable gas leak and ignition	Fire or explosion following a fuel gas leak due: <ul style="list-style-type: none"> – Failure/ damage of pipework – Failure/ damage of cylinders – Impact damage – Corrosion 	Asset damage Personal injury	Yes	Barriers erected around gas pipe in key areas Pressure piping and pressure vessel design Standard operating procedures Maintenance and inspection strategies

Hazard scenario	Causes	Consequence	Further assessment to assess potential off-site impacts	Identified/ recommended safeguards
Use/ handling of explosives	Removal of furnace skull	Asset damage Personal injury	Yes	Licenced explosives contractor Handling procedures Safe Working Method Statement Use as minimal amounts as possible Containment (within blast furnace)
Loss of containment of chemicals, including dangerous goods	Damage to storage containers e.g. due to external impact Corrosion Wear & tear	Environmental damage Personal injury	No	Purpose designed chemical store, including bunds Inspection and maintenance strategies Handling procedures Standard operating procedures Spill kits
Contact with chemicals, including dangerous goods	Transfer and handling	Personal injury	No	Transfer and handling procedures Standard operating procedures PPE
Toxic release	Failure/ damage of pipework	Personal injury	Yes	Safe piping design Inspection and maintenance strategies

6.2 Hazardous materials

Based on the results of the hazard identification, the following scenarios may have the potential for off-site impacts:

- Fire/explosion from the natural gas supply
- Fire/explosion from self-generated gas (coke ovens gas)
- Explosion from molten metal and water
- Discharge of toxic dust and/or fumes (blast furnace gas and coke ovens gas)
- Use/handling of explosives

6.2.1 Natural gas

Fire/explosion incident resulting from leaks in the gas supply branch pipeline extending from the gas mains to the on-site gas reducing station could result in high heat radiation levels with potential for off-site impacts. However, the likelihood of this occurring is low as the pipeline is on an elevated pipe corridor, fully welded and situated in a controlled industrial environment. Additionally, whilst the location of the fuel gas will move from 5BF to 6BF, there is no fundamental change in the quantity of fuel gas on site. The potential hazards associated with the quantity of fuel gas on site have been considered previously in applications for consent. As such it is not considered in the consequence analysis.

At the gas reducing station (ground level), the pressure is reduced from the feed pressure of 1,140 kPag to a value of 400 kPag downstream in the reticulation system for gas appliance usage and 15 kPag for the stoves.

The worst-case scenario considered is that of an ignited gas release occurring at the gas reducing station. The reducing station is considered to have the highest potential risk because of the pressure and exposure to surrounding activities. Likely leak sources include piping connections and flanges. With the elevated pipe corridor, the potential for damage by impact from a vehicle on internal roads is limited to the reducing station, so is not considered beyond this location.

6.2.2 Molten metal

The scenario of a molten metal-water explosion resulting from water contacting molten metal in a furnace could conceivably occur if moisture was accidentally introduced (from a leak in a cooling element). Outside of the furnace, a molten metal-water explosion could occur if moisture or pooled water contacts molten metal or slag during transfer processes. There are documented molten metal-water explosions, with associated fatalities, in the metal processing industry e.g. Aluminium Association data compiled in the past 19 years shows 25 severe molten aluminium-water explosions with 19 associated fatalities (Jacoby 2000), although it is noted that steel molten metal explosions may not be as severe as aluminium molten metal explosions (Tabatabaei and Turner 2009).

Both iron and steel molten metal explosions have occurred previously on site, which have resulted in projectiles impacting and/or penetrating building walls but have not impacted locations at or beyond the site boundary. As such, missile effects off-site are not considered further. Impurities if present could also increase the risk of explosion. It is considered that most of the effects of the above scenarios would be limited to the site, however, given the possibility of overpressure impacts off-site, limited quantitative analysis was conducted. Whilst molten metal explosions can occur both inside and outside of the furnace, the analysis has focused only on the interior furnace explosion as the confined nature of the furnace as opposed to the semi-confined, more open nature outside, will result in a higher explosion efficiency with correspondingly larger consequences, however will still not have offsite impacts.

6.2.3 Explosives

Blasting is expected to be undertaken to remove the salamander material retained inside the 6BF hearth should the ability to remove this material by mechanical means such as jack hammer mounted excavator prove insufficient. It is estimated that 500 tonnes of residual iron skull/salamander material must be removed. Based on this, it is assumed that the maximum quantity of explosives stored on site at any point in time during construction is 150 kg. To comply with DG storage thresholds, it is recommended that the explosives are stored at least 90 metres from the site boundary. If explosives storage is near 6BF, it is recommended that storage is an appropriate distance away from any blasting activities and in accordance with AS 2187.1 - *Explosive storage, transport and use - storage*. As the storage location can be 90 metres from any boundary given size of PKSW and the location of 6BF, the offsite risk is negligible, and it is not considered in the consequence analysis.

6.2.4 Blast furnace gas

Blast Furnace Gas is a toxic gas. It comprises of carbon monoxide, carbon dioxide, nitrogen, water vapour and hydrogen. A failure in the pipework or associated fittings could result in a potential release to the atmosphere. There are a number of engineering controls designed to reduce this likelihood to rare. Additionally, whilst the location of the blast furnace gas will move from 5BF to 6BF, there is no fundamental change in the quantity of blast furnace gas on site. The potential hazards associated with the quantity of blast furnace gas on site have been considered previously in applications for consent. Blast Furnace Gas will have a localised toxic effect and the offsite risk is negligible, so is not considered in the consequence analysis.

6.2.5 Coke ovens gas

Coke Ovens Gas is a flammable and toxic gas. It is a composition of hydrogen, methane, carbon monoxide, carbon dioxide, nitrogen, ethylene, ethane, benzene, toluene, hydrogen sulphide and trace amounts of acetylene. A failure in the pipework or associated fittings could result in a potential release to the atmosphere. There are a number of engineering controls designed to reduce this likelihood to rare. Additionally, whilst the location of the coke ovens gas will move from 5BF to 6BF, there is no fundamental change in the quantity of coke ovens gas on site. The potential hazards associated with the quantity of coke ovens gas on site have been considered previously in applications for consent. Coke Ovens Gas will also have a localised toxic effect, but the offsite risk is negligible, so is not considered in the consequence analysis. However, given the possibility of overpressure impacts off-site, limited quantitative analysis was conducted.

6.3 Hazard scenarios

The following scenarios were identified as being worthy of further analysis:

- Flange leak (5 mm) in the above-ground section of the 50 mm gas branch pipeline (11.4 barg) at the gas reducing station
- Split (50 mm) to the 100 mm fuel gas piping connection on the gas reducing station outlet (4 barg)
- Rupture (50 mm) to the above-ground section of the 500 mm gas branch pipeline (11.4 barg) at the gas reducing station by vehicle impact
- Explosion resulting from the contacting of molten metal and 100 litres of water (cooling system leak) in a furnace
- Coke ovens gas connection leak (10 mm) to the 400 mm pipeline (0.14 barg)
- Coke ovens gas pipe split (200 mm) to the 400 mm pipeline (0.14 barg)

Smaller leaks from the natural gas fuel supply and the piped coke ovens gas are also possible but will have consequences less than the hazard scenarios analysed. As such they have not been considered in this PHA.

6.4 Consequence determination

The release, dispersion and flammable effect for natural gas pipeline/fitting leaks, vehicle impact to the natural gas reducing station and molten metal – water explosions are calculated using the appropriate textbook calculations (see Appendix A). A description of the consequence conditions employed is provided in Table 6.2.

For coke ovens gas releases, the release, dispersion and flammable effects are performed using PHAST (Process Hazard Analysis Software Tool) 8.4, a commercial software package. PHAST 8.4 package models have been extensively utilised, and a description of the consequence models employed is provided in Appendix B.

It should be noted that consequence modelling is not the same as risk modelling. Consequence modelling only represents the impact zone that would be affected if a release should occur. It does not consider the following important risk considerations:

- Likelihood of a release, i.e. a leak frequency
- Probability of a wind direction towards a particular location

6.4.1 Assumptions

The conditions outlined in Table 6.2 and Table 6.3 were used in the consequence determination.

Table 6.2 Conditions for textbook calculations

Condition	Natural Gas (methane)		Molten Metal
Temperature	20 °C	20 °C	1,500 °C
Storage pressure	inlet – 11.4 bar gauge	outlet – 4 bar gauge	Not applicable
Quantity	continuous	continuous	100 kg water

Table 6.3 Conditions for PHAST modelling

Condition	Coke Ovens Gas		
Composition (vol/vol) for modelling	Hydrogen	62.0%	0.1742 kg
	Methane	26.5%	0.5532 kg
	Carbon monoxide	5.6%	0.2039 kg
	Carbon dioxide	1.9%	0.1094 kg
	Nitrogen	1.2%	0.0394 kg
	Ethylene	1.0%	0.0437 kg
	Ethane	1.0%	0.0395 kg
	Benzene	0.6%	0.0065 kg
	Hydrogen Sulphide	0.2%	0.0009 kg
Temperature	20 °C		
Pipeline pressure	0.14 bar gauge		
Pipeline internal diameter	400 mm		
Quantity	continuous, 1.9 kg/s (21,000 m ³ /hr)		
Surface roughness	1 m (regular large obstacle coverage)		
Weather conditions	1.5 / F (stable night time conditions with light wind and moderate clouds) 20 °C		

6.4.2 Results

A summary of the determined consequences is provided in Table 6.4 and Table 6.5. The consequences are worst case scenarios as they assume no intervention to limit the release. For the leak scenarios some level of intervention would be expected. As such, the contours can be considered conservative.

Table 6.4 Summary of heat radiation consequences

Release Scenario	Maximum Distance Downwind of Release to Heat Radiation (m)		
	4.7 kW/m ² (injury)	12.6 kW/m ² (fatality)	23 kW/m ² (property damage)
Natural gas pipeline (inlet pipeline of gas reducing station) – flange leak	5.1	4.0	3.5
Natural gas pipeline (outlet pipeline of gas reducing station) – pipe split	31.1	24.6	21.9
Natural gas pipeline (inlet pipeline of gas reducing station) – vehicle strike pipe rupture	48.6	38.5	34.3
Coke ovens gas pipeline – connection leak	Does not reach level	Does not reach level	Does not reach level
Coke ovens gas pipeline – connection split	26.9	21.7	18.2

Details of the calculations are in Appendix A.

Table 6.5 Summary of overpressure consequences

Release Scenario	Maximum Distance Downwind of Release to Overpressure (m)		
	0.07 bar (injury)	0.14 bar (property damage)	0.21 bar (fatality)
Molten metal – water contact	100.0	68.0	48.0
Coke ovens gas pipeline – connection split (delayed explosion)	38.8	30.8	28.1

Details of the calculations are in Appendix A.

None of the consequence distances extend beyond the boundary and there is no off-site impact. All scenarios have the potential to affect the on-site worker population.

6.5 Likelihood estimation

The likelihood of the worst-case scenarios resulting in a fatality or injury was calculated using an event tree. The assignment of the frequency and probability values has been made based on industry failure frequencies, specialist risk management judgement and the quantified consequences.

It is important to note that the determination of 'absolute values' for assigned probabilities is less important than consistently using 'comparative' or 'relative' values. The overall aim is to provide a ranking to compare with risk criteria.

A summary of the results is shown in Table 6.6 and Table 6.7. As no consequences reach off-site, these frequencies are not included.

Table 6.6 On-site jet fire frequencies

Scenario	Natural Gas Flange Leak	Natural Gas Pipe Split	Natural Gas Vehicle Impact	Coke Ovens Gas Connection Leak	Coke Ovens Gas Pipe Split
Frequency of gas release (per annum)	5.00×10^{-06}	6.70×10^{-07}	1.10×10^{-08}	1.60×10^{-06}	6.5×10^{-08}
Frequency of jet fire (per annum)	5.00×10^{-09}	1.27×10^{-09}	3.24×10^{-09}	1.60×10^{-09}	1.24×10^{-10}
Frequency of fatality (per annum)	5.00×10^{-10}	1.02×10^{-09}	2.91×10^{-09}	0.00	9.88×10^{-11}

Details of the calculations are provided in Appendix C.

Table 6.7 On-site explosion frequencies

Scenario	Molten Metal – Water Interaction	Coke Ovens Gas Pipe Split
Frequency of explosion (per annum)	1.00×10^{-06}	6.50×10^{-08}
Frequency of fatality (per annum)	8.00×10^{-07}	4.16×10^{-08}

Details of the calculations are provided in Appendix C.

6.6 Risk assessment

A summary of the compliance of all the events with the relevant risk criteria from HIPAP 4 is provided in Table 6.8. This assessment shows that the project will comply with the risk criteria.

Table 6.8 Risk criteria compliance

Event	Individual Fatality Risk	One Injury / Fatality every X Years	HIPAP Risk Criteria	Compliance
Fire and explosion scenarios with property damage offsite	0.00	–	5.00×10^{-05}	Complies
Fire and explosion scenarios with serious injury to offsite people	0.00	–	5.00×10^{-05}	Complies
Fire and explosion scenarios with fatality of offsite people	0.00	–	1.00×10^{-06}	Complies
Fire and explosion scenarios with fatality of onsite personnel	8.46×10^{-07}	1,200,000	5.00×10^{-05}	Complies

7. Recommendations

It is recommended that management procedures be implemented that incorporate practices that will prevent risk scenarios occurring through:

- Inspection and maintenance regime for the gas reducing station, the coke ovens gas and the blast furnace gas pipework and associated fittings
- Separation, or tightly controlled usage, of water around the furnace areas, including procedures/training regarding the expectations for management of water leaks
- Furnace design to avoid inadvertent water leakage into the furnace areas
- Inspection and maintenance regime for furnace closed water systems
- Bollards or equivalent to protect ground level fuel gas infrastructure such as the natural gas reducing station

Explosives being stored at least 90 metres from the site boundary. It is important to note that any new equipment should have procedures developed for safe operation. This is particularly important for the operation of any new fixed or mobile machinery to prevent injury to people.

Any changes to the assumptions used in this report should result in a review of the PHA and updates as required.

7.1 Explosives management

Explosives will be used on site during construction as part of skull breaking activities in the blast furnace.

Explosives should be stored in a non-ferrous receptacle clearly marked 'Explosives' that is kept closed and locked (except during use by authorised personnel) and stored in the original containers which are securely sealed. The storage area should be a well-ventilated magazine licenced for Class 1.1 explosives, which protects the explosives from the weather, contamination, sources of ignition and access from unauthorised individuals. Storage should be isolated from other dangerous good stores and the area free of debris, waste and combustibles. The explosives containers should be protected against physical damage and regularly checked for spills and leaks.

Magazines are required to comply with the requirements of AS 2187.1 *Explosives – Storage, transport and use – Storage* which addresses issues with design and location of the magazine, security, inventory and management of the explosives, and safety concerns.

Where more than 2.5 kg of Class 1.1 explosives are stored on a site, every perimeter entrance to the designated construction site must be labelled with a 'Hazchem' placard in accordance with the Explosives Regulations. Adequate security needs to be provided for the explosives storage area, and only those who are authorised for unsupervised access to the area may have means to unlock the explosive storage magazine.

Limited quantities of explosives are expected to be stored on site at any one time, however, at the storage area and during use, there shall be no smoking, naked light, heat or ignition source present. The explosives stock should be rotated to prevent ageing (use on first in-first out basis).

7.2 Emergency management

In order to manage emergency situations that may arise as part of the project, an Emergency Response Plan will be developed. The response plan will include as a minimum:

- Details of each of the hazard scenarios as identified in Section 6.3 of this report
- Details of the risks associated with each of these scenarios
- Emergency response plans detailing measures to be undertaken should an emergency scenario eventuate

BlueScope has significant experience in managing risks associated with blast furnace operation and currently operates 5BF in accordance with an existing Emergency Response Plan. An Emergency Response Plan was in place at 6BF during its previous campaign, and therefore has well established protocols in place to manage the identified risks.

8. Conclusions

This report includes a preliminary risk screening of the project in accordance with the requirements of SEPP 33. The results of the dangerous goods screening indicate that the project does exceed the thresholds within the SEPP 33 requirements for dangerous good storage, specifically class 1 (explosive) chemicals, however the results of the transport screening do not exceed the dangerous good movement thresholds. As a result, the project is deemed a 'potentially hazardous industry'.

The intent during construction is that there would be low volumes of dangerous goods stored in construction compounds, using a just-in-time usage regime.

A qualitative hazard identification study was completed as a systematic way to identify any potential offsite impacts, during construction and operation. The hazard identification study identified the following hazards with the potential for offsite impact, all of which can be suitably controlled:

- Furnace molten metal explosion
- Natural gas leak and ignition
- Coke ovens gas leak and ignition
- Use/ handling of explosives
- Toxic release

Of these impacts, three were considered serious enough that further analysis was warranted; specifically furnace molten metal explosions, coke ovens gas leaks and ignition and natural gas leaks and ignition. The assessment showed that there was no off-site impact and that the risk complies to HIPAP 4 risk criteria.

All risks identified can be managed to tolerable levels provided the safeguards identified (see Table 6.1) are enacted.

The hazard identification study demonstrates that the project could be designed, constructed and operated in a manner that will meet relevant regulations, standards and policies.

Assessments of the air quality, and noise and vibration impact of the project have been completed as part of the EIS, as the development is 'potentially offensive'. The results from the air quality and noise and vibration assessments indicate that if appropriate control measures are in place during construction and operation, the project will minimise the impact of the relevant amenity criteria. Over the lifecycle of the project, and with safeguards, the project is not expected to release a significant quantity of pollutant emissions and is not considered to be an 'offensive industry'.

9. References

- Department of Planning, NSW, (2011), *Applying SEPP 33: Hazardous and Offensive Development Application Guidelines*.
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- Department of Planning, NSW, (2011), *Multi-level Risk Assessment Guideline*.
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- Safe Work Australia, (2012) *Code of Practice: Managing risks of hazardous chemicals in the workplace*.
- Jacoby, J.E., Explosions During Aluminium Scrap Melting in the Recycling Industry - Causes and Prevention, in Fourth International Symposium on the recycling of metals and engineered materials, Stewart, D.L., Stephens, R. and Daley, J.C., Editors, 2000, TMS-AIME, Warrendale, PA.
- Tabatabaei E. and Turner, R., August 2009, Molten Metal Splash and Furnace Refractory Safety (website accessed September 2021 Molten Metal Splash and Furnace Refractory Safety | Foundry Management & Technology (foundrymag.com)).
- Dangerous Goods Safety Guidance Note – Storage of explosives, Government of Western Australia – Department of Mines, Industry Regulation and Safety, January 2018.

Appendix A

Consequence Calculation Summary

A-1 Introduction

The consequences of selected hazard scenarios identified in section 6.3 of the report are calculated in the following sections. Namely:

- Jet fire resulting from a natural gas release (flange leak and pipe split)
- Molten metal – water explosion (moisture from water bottle into a furnace)

A-2 Jet fire

The models used to calculate the magnitude and radiation levels of the resulting jet fire scenarios are presented in Lees (1996).

The scenarios considered are:

- Flange leak (5 mm) in the above-ground section of the 50 mm gas branch pipeline (11.4 barg) at the gas reducing station
- Split (50 mm) to the 100 mm fuel gas piping connection on the gas reducing station outlet (4 barg)

Failure of the pipe or connection will result in a sustained release of gas under pressure, potentially resulting in a jet fire. For the purposes of the calculations, it is assumed that the fire is based on the formation of an unobstructed, turbulent free jet.

A-3 Jet fire gas flow

Gas flow from both the high pressure sections of the facility (approximately 11 barg on the inlet to the metering station and 4 barg on the outlet respectively) is critical, i.e. sonic or choked.

The discharge rate (G) is calculated using the following formula from Coulson *et al* (1999).

$$G = C_d A_r P_1 \left[\left(\frac{M \gamma}{R T_1} \right) \left(\frac{2}{\gamma + 1} \right)^{\frac{\gamma + 1}{\gamma - 1}} \right]^{1/2}$$

Where:

C_d = discharge coefficient (assumed 0.61)

A_r = effective open area (m^2)

P_1 = initial release pressure (Pa)

M = molecular weight (assumed methane, 0.016 kg/mol)

R = universal gas constant (8.314 J/mol.K)

T_1 = initial release temperature

γ = Specific heat ratio, assumed 1.4

A-4 Jet fire magnitude

It is generally assumed that the flame will have approximately the same length as an unignited jet. The shape of the gas jet release and the resultant jet fire can be approximately predicted using models from TNO (1979). The jet is modelled as a long cylinder at ambient conditions.

The jet diameter (d_f) is given by:

$$d_f = \frac{D_o}{2 K_1 \sqrt{b_2}}$$
$$K_1 = \left(\frac{0.32 \rho_a}{\sqrt{\rho_o}} \right) \left(\frac{b_1}{b_1 + b_2} \right) j$$
$$b_1 = 50.5 + 48.2 \rho_a - 9.95 \rho_a^2$$
$$b_2 = 23 + 41 \rho_a$$

Where

D_o = diameter of the rupture in gas flow calculations (m)

ρ_o = density of gas at outflow conditions (kg/m³)

ρ_a = density of gas at ambient conditions (kg/m³)

j = composition at the end of the flare, assumed 0.05 vol fraction (LEL)

The flow is assumed to reach ambient conditions instantaneously so the jet diameter can be considered as being coincident with the discharge point.

The jet length (L_f) is given by:

$$L_f = \frac{D_o}{K_1}$$

A-5 Jet fire radiation

The model used for calculation of the radiation from the jet fire is from Lees (1999) and is an extension of the model from API RP521 'Flare Radiation'.

The radiated heat from the midpoint on the flare centerline (Q_p) is given by:

$$Q_p = n G H_c$$

Where

n = efficiency factor, assumed 0.35

G = total gas release rate (kg/s)

H_c = heat of combustion (kJ/kg)

The heat radiation (I) from the midpoint on the flare centreline to a receptor at distance (x) is given by:

$$I = \frac{\tau_g Q_p}{4 \pi x^2}$$
$$\tau_g = 1 - 0.0565 \ln x$$

A-6 Jet fire results

The results of the consequence analysis are summarised below.

Table A.1 Jet fire results

Scenarios	Flange Leak	Pipe Split	Vehicle Impact
Release Duration (min)	Continuous	Continuous	Continuous
Release hole size (m)	0.005	0.05	0.05
Release area A_r (m ²)	0.0000196	0.00196	0.00196
Pressure P_1 (Pa)	1,241,325	501,325	1,241,325
Temperature T_1 (K)	293.15	293.15	293.15
Methane molecular weight M (kg/mol)	0.016	0.016	0.016
Universal gas constant R	8.314	8.314	8.314
Gas Flow Rate G (kg/s)	0.026	1.053	2.608
ρ_o (kg/m ³)	8.290	3.308	8.190
ρ_a (kg/m ³)	0.666	0.666	0.666
K_1	0.00225	0.00357	0.00227
Jet Fire Diameter d_f (m)	0.156	0.988	0.988
Jet Fire Length L_f (m)	2.2	14.0	22.1
Radiation Q_p (kW)	509	20,537	50,851
Distance (m) to heat radiation I of 23 kW/m ²	3.5	21.9	34.3
Distance (m) to heat radiation I of 12.6 kW/m ²	4.0	24.6	38.5
Distance (m) to heat radiation I of 4.7 kW/m ²	5.1	31.1	48.6

A-7 Explosion

The scenario considered is:

- Explosion resulting from the contacting of molten metal and water in a furnace.

The scenario considered is that of 100 kg of water (0.1 m³) contacting molten metal in a furnace. The process is considered in two steps; firstly, the water is heated at constant volume to 1772 K, resulting in a large pressure build up; secondly, the resultant vapor undergoes a reversible isothermal expansion to atmospheric pressure.

The initial pressure (P_s) of the vapor after the first step is calculated using the ideal gas equation.

$$P_s = \frac{n R T}{V}$$

Where

P_s = pressure (Pa)

n = number of moles of gas

R = universal gas constant (8.314 J/mol.K)

T = temperature of the gas (K)

V = initial volume of gas (m³)

The ideal work resulting from the second step is calculated using the following formula from Sandler (1999).

$$W = n R T \ln \frac{P_s}{P_E}$$

Where

W = Work (KJ)

P_s = Initial pressure (Pa)

P_E = Final pressure (Pa)

n = Number of moles of gas

R = Universal gas constant (8.314 J/mol.K)

T = Temperature of the gas (K)

Schubach (1996) suggest an explosive efficiency (energy transferred to shock wave) for a pressure burst explosion of 30% to 40% of the maximum theoretical reversible work output. For the purposes of determining the consequence of a molten metal / water reaction, the worst-case efficiency (40%) is used.

In order to determine the blast overpressure at a distance from the explosion, the graphical correlation between scaled distance (Z) and peak overpressure (P_r) is used as stated in Shin (2015).

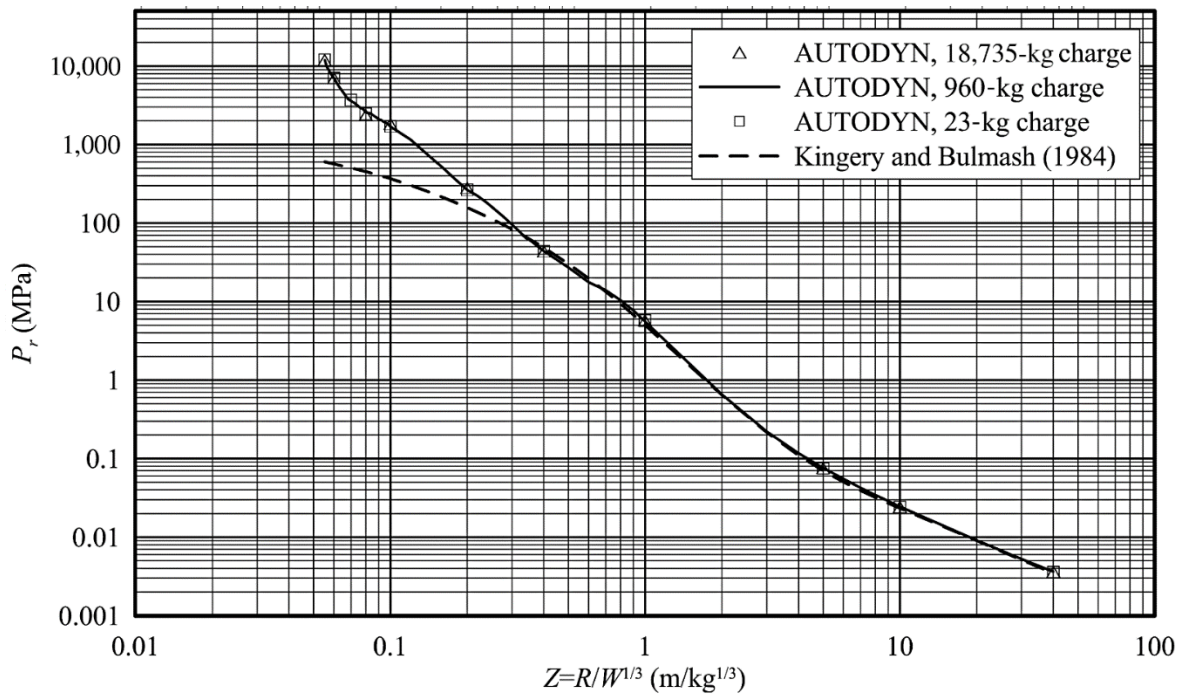


Figure A.1 Reflected peak overpressure versus scaled distance (Shin, 2015)

Once the scaled distance is known, the relationship between the scaled distance (Z) and the actual distance (R) is used.

$$Z = \frac{R}{W^{1/3}}$$

A-8 Explosion results

The results of the explosive consequence analysis are presented in the tables below.

Table A.2 Work results

Parameter	Value
Mass H ₂ O (kg)	100.0
H ₂ O Moles n (mole)	55.6
Temperature T (K)	1772
Universal gas constant R	8.314
Initial Pressure P _B (kPa)	819,122
Final Pressure P _E (kPa)	101.3
Total Theoretical Work W _t (kJ)	737,017
Explosion efficiency	40%
Actual Work W (kJ)	294.8

Table A.3 Explosion results

Peak Overpressure (kPa)	Scaled Distance (m/kg ^{1/3})	Actual Distance (m)
3.5	40	159.9
7 (injury)	25	100.0
14 (property damage)	17	68.0
21 (fatality)	12	48.0
35	8	32.0
70	5	20.0

A-9 References

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Appendix B

PHAST Consequence Modelling Summary

B-1 Discharge modelling

If there is a hole in a pipeline, vessel, flange or other piece of process equipment, the fluid inside will be released through the opening, provided the process pressure or static head is higher than ambient pressure. The properties of the fluid upon exiting the hole play a large role in determining consequences, e.g., vapour or liquid, velocity of release etc. Figure B1 illustrates an example scenario.

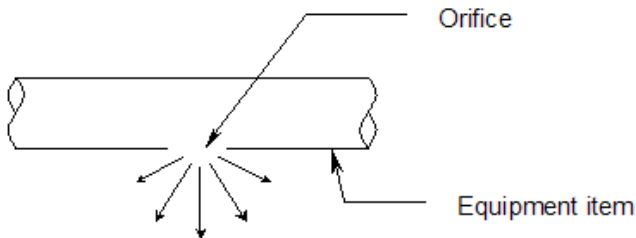


Figure B.1 Typical Discharge

The discharge can be considered to have two stages; the first is expansion from initial storage conditions to orifice conditions, the second from orifice conditions to ambient conditions.

The conditions at the orifice are calculated by assuming isentropic expansion, i.e., entropy before release = entropy at orifice. This allows enthalpy and specific volume at the orifice to be calculated.

The equations for mass flow rate (\dot{m}) and discharge velocity (u_0) are then given by:

$$\dot{m} = C_d A_0 \rho_0 \sqrt{-2(H_0 - H_i)}$$
$$u_0 = C_d \sqrt{-2(H_0 - H_i)}$$

Where:

C_d	=	Discharge Coefficients
A_0	=	Area of the Orifice
ρ_0	=	Density of the Material in the Orifice
H_0	=	Enthalpy at the Orifice
H_i	=	Enthalpy at Initial Storage Conditions

The discharge parameters passed forward to the dispersion model are as follows:

- Release height (m) and orientation.
- Thermodynamic data: release temperature (single phase) (°C) or liquid mass fraction (two-phase), initial drop size (m).
- Other data:
 - For instantaneous release: mass of released material (kg), expansion energy (J).
 - For continuous release: release angle (degrees), rate of release (kg/s), release velocity (m/s), release duration (s).

B-2 Dispersion

When a vapour leak occurs, some material will be released into the atmosphere. Upon being released it will start to disperse and dilute into the surrounding atmosphere. The limiting (lowest) concentration of interest is related to flammable and toxic limits for flammable and toxic substances respectively. The model used to determine extent of release is described below, along with some of the key input parameters.

The consequence modelling package SAFETI utilises the Unified Dispersion Model. This models the dispersion following a ground level or elevated two-phase unpressurised or pressurised release. It allows for continuous, instantaneous, constant finite duration and general time varying releases. It includes a unified model for jet, heavy and passive two phase dispersion including possible droplet rain out, pool spreading and re-evaporation.

B-3 Jet dispersion

For a continuous, pressurised release, a vapour is released as a jet, i.e., high momentum release. The jet eventually loses momentum and disperses as a passive cloud. Figure B2 below shows a typical release and the various phases involved.

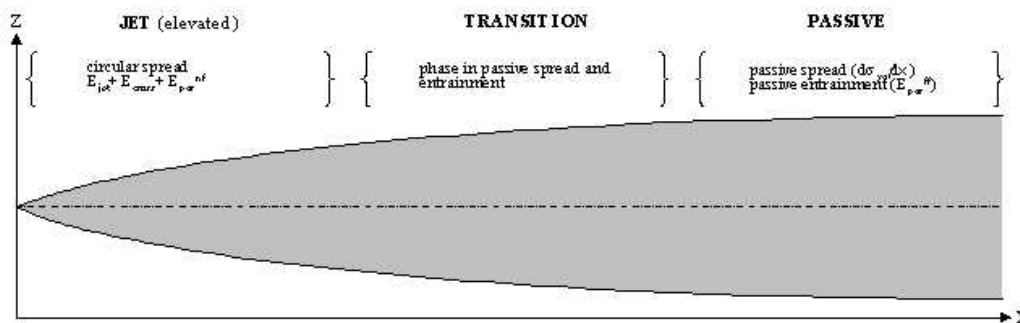


Figure B.2 Jet Dispersion

The cloud is diluted by air entrainment until it eventually reaches the lower limit of concern. During the jet phase, the mixing is turbulent and much air is entrained. In the passive phase, less air is potentially entrained, and it occurs via a different mechanism to the turbulent jet phase. The calculation of the plume therefore depends on many factors, the key parameters being:

- Vapour released, specifically molecular weight
- Discharge conditions including phase(s) of release, velocity etc.
- Atmospheric conditions (a cloud will generally travel further in more stable conditions with lower wind speeds)

B-4 Dispersion from pool evaporation

If a rupture occurs from a drum or vessel containing a liquefied gas, the liquefied gas pools on the ground whilst rapid vaporisation occurs forming a vapour cloud, which ultimately disperses, as a low momentum cloud. Due to the low momentum, the cloud is not turbulent, which is a significant factor in air entrainment and dilution of the cloud. Figure B3 below shows a typical release and some of the inputs into the calculation.

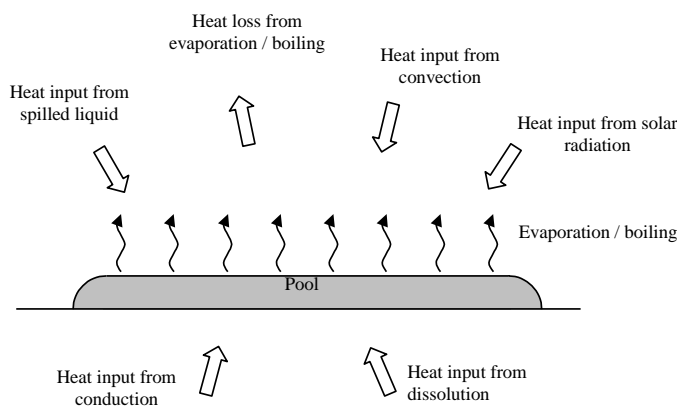


Figure B.3 Pool Evaporation Heat Balance

The rate of the evaporation depends on numerous factors, the most important ones being:

- Surface it is released onto (e.g. its thermal properties and temperature)
- Atmospheric conditions (a cloud will generally travel further in more stable conditions with lower wind speeds)
- Boiling point of the liquid
- Pool size

The concentration of interest is normally related to the toxic limits or specified Emergency Response Planning Guideline (ERPG) limits set for the contained hazardous material.

B-5 Toxic load and probability of death

The toxic load L_{toxic} , for a given component i , is calculated from the concentration of the material at a given position. In the case of a continuous cloud, the concentration does not vary with time and the toxic load is given by:

$$L_{Toxic\ i} = t_{exp} \times (f_i C)^{T_{N(i)}}$$

The probability of death P_{death} , for a given component i , at a given position is calculated from a “probit number”, P_i , which is calculated from the “toxic load” and calculated given by the following equations:

$$P(i) = T_A(i) + T_B(i) \ln L_{Toxic}(i)$$
$$P_{Death}(i) = \frac{1}{2} \left\{ 1 + erf \left[\frac{P(i) - 5}{\sqrt{2}} \right] \right\}$$

Where:

t_{exp}	=	Exposure Time
f_i	=	Fraction of the Toxic Component in the Cloud
C	=	Concentration of the Component at a Given Position
$T_{N(i)}$	=	Probit Number N of the Component i
$T_A(i)$	=	Probit Number N of the Component i
$T_B(i)$	=	Probit Number N of the Component i

B-6 Flammable effects

If the release is of a flammable material, it is possible for the release to be ignited. The resulting type of fire (e.g. jet, pool, explosion etc.) depends on the physical properties of the release and whether the ignition is immediate or delayed.

B-6-1 Jet fire

Jet fires are a result of high momentum releases. If a flammable release is ignited instantaneously, a jet fire will result. The flame will have a degree of ‘lift off’ as the flammable mixture has to dilute to be within the flammable limits. This section briefly discusses the model used for jet fires as well as key parameters in the calculation.

The jet fire calculation utilises the Chamberlain model. In this model, jet fires are modelled as a conical flame, with the ignited portion lift off, inclination and shape being determined by the material being released, the pressure at which it is being released and the hole size that it is being released through. These release parameters are the main inputs to the jet fire radiation calculations. Figure B4 below shows a graphical representation of the jet fire model.

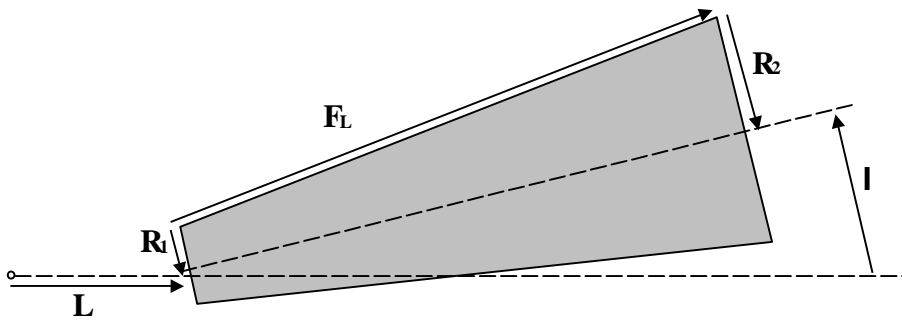


Figure B.4 Truncated Cone Jet Fire Model

Where:

L = Lift off

I = Flame Inclination

R₁ = Flame Base Radius

R₂ = Flame End Radius

F_L = Flame Length

The jet fire calculations model radiation from the entire surface of the ignited portion of the jet. This includes radiation from the cone forming the body of the flame, as well as from the ends of the cone. The amount of radiation that a nearby receiver is exposed to is determined by its distance from the flame surface, as well as by the orientation of the flame relative to the receiver. The key parameters in the calculation of the radiation exposure of a receiver are therefore the flame lift off, the flame inclination, and the dimensions of the ignited portion of the jet (i.e. flame length and end radii).

B-6-2 Fireball model

Fireballs are short-lived flames which generally result from the ignition and combustion of turbulent vapour/two phase (i.e. aerosol) fuels in air. Releases that fuel fireballs are usually near instantaneous and commonly involve the catastrophic failure of pressured vessels/pipelines. Fireballs can dissipate large amounts of thermal radiation which away from their visible boundaries may transmit heat energy that could be hazardous to life and property.

SAFETI uses static models to evaluate fireballs. Static models assume a fireball exists at its maximum size over its lifespan and ignore transient flame characteristics. It provides a conservative flame shape and incident radiation estimates.

The fireball model (Figure B5) determines the flammable mass, fireball duration, radius and lift-off height (height from the centre of the fireball to the ground under the fireball) as well as the surface emissive power to generate the heat radiation effect.

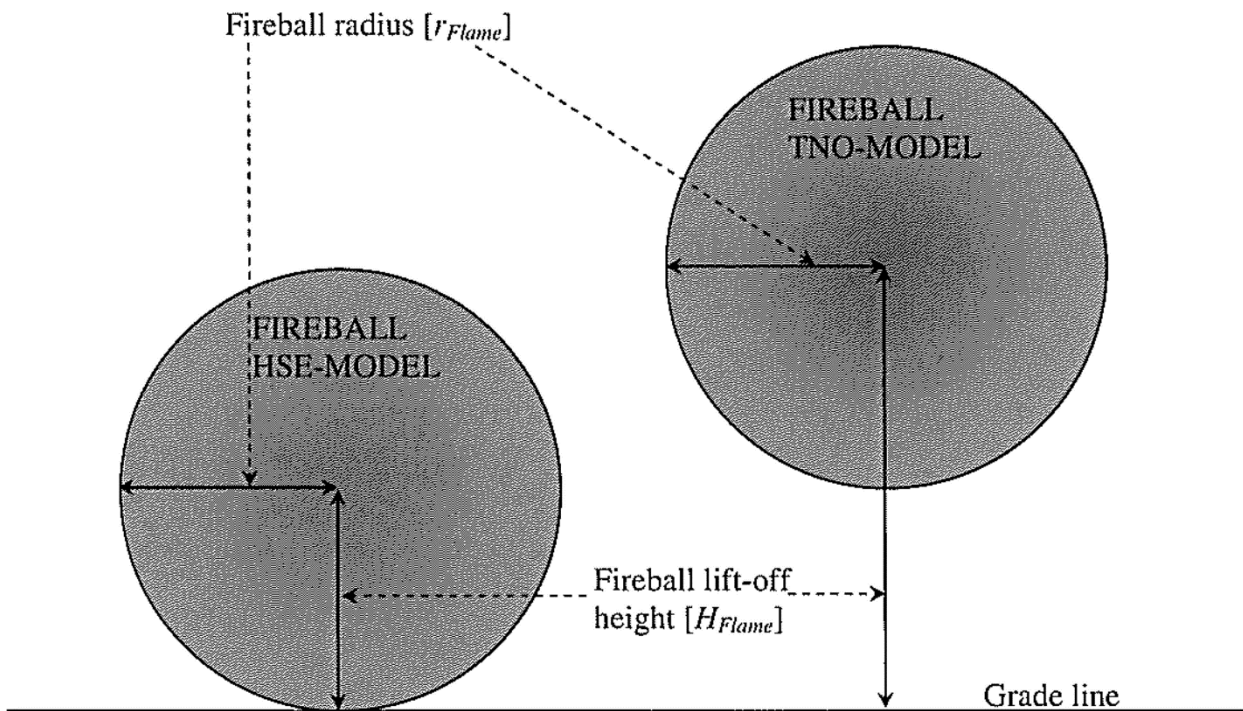


Figure B.5 Fireball Model

B-6-3 Multi energy explosion model

The Multi Energy Model gives overpressure of an explosion as a function of distance from the explosion. The explosion is modelled as a sphere and overpressure is calculated based on scaled distance from the centre. This section explains the key parameters involved in the multi energy model.

The energy released by the explosion, E, is calculated as the product of the mass of fuel in the cloud and the heat of combustion. This assumes a stoichiometric mixture of fuel and air.

The distance scaling factor, S, is related to the energy released by the explosion and the atmospheric pressure by:

$$S = \left[\frac{E}{P_a} \right]^{1/3}$$

The scaled distance r is then given by:

$$r = \frac{d}{S}$$

where d is the actual distance of the receiver from the cloud centre.

To calculate overpressure a set of 10 curves is used. The actual curve used depends on the degree of confinement, with a confinement of 1 being least confined and 10 most confined. Process plants generally have a confinement factor of 7, though it needs to be assessed for each individual process. The graph showing the 10 curves is included in Figure B6.

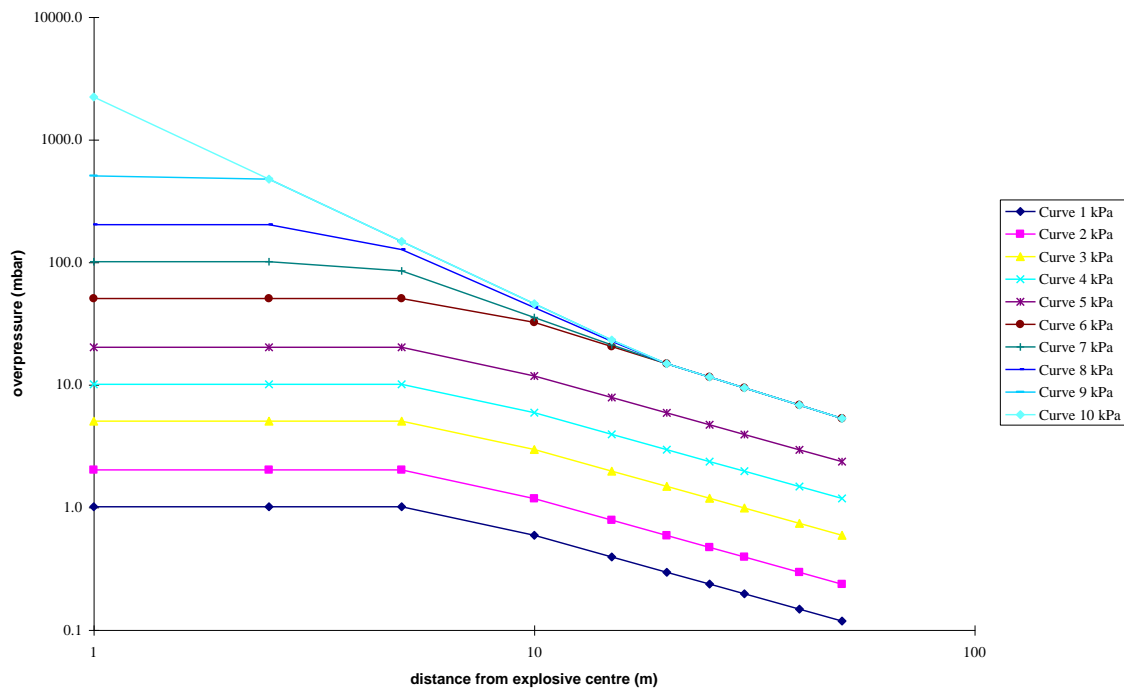


Figure B.6 Multi Energy Curves

B-7 References

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Appendix C

Frequency Calculation Summary

C-1 Introduction

The frequencies of all hazard scenarios are calculated in the following section. The expected frequency is needed to enable a calculation of the risk. The scenarios are:

- Natural gas flange leak
- Natural gas pipe split
- Natural gas pipe vehicle impact
- Coke ovens gas connection leak
- Coke ovens gas pipe split
- Coke ovens gas pipe split delayed explosion
- Molten metal – water explosion

C-2 Release frequencies

An estimate of appropriate release frequencies is from HSE UK failure rates (2017).

Table C.1 Release frequency

Parameter	Basis	Value
50 mm natural gas flange failure – 5 mm (per flange per year)	1 flange	5.00×10^{-06}
100 mm natural gas pipe split – 50 mm (per meter per year)	10 meters pipe	6.70×10^{-07}
400 mm coke ovens gas pipe pin hole – 10 mm (per meter per year)	10 meters pipe	1.00×10^{-06}
400 mm coke ovens gas pipe split – 200 mm (per meter per year)	10 meters pipe	6.50×10^{-08}
Fixed cooling water pipework failure (per meter per year)	1 meter pipe	1.00×10^{-06}
Serious vehicle accident on site	Estimated repair cost at least \$10k	2.20×10^{-07}

C-3 Ignition probability

Once a gas leak has occurred, in order for a jet fire to eventuate, the escaping gas must be ignited by an ignition source. Ignition probability is dependent on the extent of the gas leak as well as the position of the ignition source in the surrounding area.

An estimate of appropriate small plant ignition probabilities is from OPG (2010). The ignition probability for a vehicle strike is from HSE CRR (1997).

Table C.2 Ignition probabilities

Parameter	Value
Gas release within a small plant at 0.1 kg/s	0.001
Gas release within a small plant at 0.5 kg/s	0.0019
Gas release within a small plant at 1,000 kg/s	1.0
Gas release from a vehicle strike	0.29

C-4 Jet fire frequency results

The results of the frequency analysis and risk assessment are summarised below.

Table C.3 On-site jet fire results

	Natural Gas Flange Leak	Natural Gas Pipe Split	Natural Gas Pipe Vehicle Impact	Coke Ovens Gas Connection Leak	Coke Ovens Gas Pipe Split
Frequency of serious accident (per annum) – Table C.1	Not applicable	Not applicable	2.20×10^{-07}	Not applicable	Not applicable
probability accident ruptures natural gas inlet pipeline (conservative assumption)	Not applicable	Not applicable	0.05 (On-site speed is low)	Not applicable	Not applicable
Frequency of gas release (per annum) – Table C.1	5.00×10^{-06}	6.70×10^{-07}	1.10×10^{-08}	1.00×10^{-06}	6.50×10^{-08}
Probability of ignition – Table C.2	0.001	0.0019	0.29	0.001	0.0019
Frequency of jet fire (per annum)	5.00×10^{-09}	1.27×10^{-09}	3.24×10^{-09}	1.00×10^{-09}	1.24×10^{-10}
Probability of person impacted (based on consequence)	1	1	1	1	1
Probability impact results in fatality (conservative assumption)	0.1 (On-site operators in immediate area impacted – but not in main thoroughfare)	0.8 (On-site operators in area impacted – near control room)	0.9 (Driver may be incapacitated by accident)	0.0 (Heat contours expected to result in injury only)	0.8 (On-site operators in area impacted)
Frequency of fatality (per annum)	5.00×10^{-10}	1.02×10^{-09}	2.91×10^{-09}	0.00	9.88×10^{-11}

C-5 Explosion frequency results

An estimate of the frequency of fixed pipe leak uses HSE UK failure rates (2017).

Table C.4 Molten metal explosion frequency

Parameter	Value
Frequency of failure of the water-cooling pipework (per annum) – Table C.1	1.00×10^{-06}
Probability water leak is exposed to molten metal (conservative assumption)	1
Explosion frequency (per annum)	1.00×10^{-06}
Probability of person impacted (based on consequence)	1
Probability impact results in fatality (conservative assumption)	0.8 (On-site operators in area impacted – within furnace room)
Frequency of fatality (per annum)	8.00×10^{-07}

Table C.5 *Coke ovens gas pipe split delayed explosion frequency*

Parameter	Value
Frequency of split of the coke ovens gas pipe (per annum) – Table C.1	6.50×10^{-08}
Probability of delayed ignition (conservative assumption)	0.8 (Working industrial facility with potential ignition sources beyond hazardous area)
Explosion frequency (per annum)	5.20×10^{-08}
Probability of person impacted (based on consequence)	1
Probability impact results in fatality (conservative assumption)	0.8 (On-site operators in area impacted)
Frequency of fatality (per annum)	4.16×10^{-08}

C-6 References

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