Appendix S

Hazard and risk assessment

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Santos Ltd

Narrabri Gas Project - Environmental Impact Statement
Hazard and Risk Assessment

November 2016

Executive summary

Purpose and Objectives

The proponent is proposing to develop natural gas in the Gunnedah Basin in New South Wales (NSW), southwest of Narrabri.

The purpose of this Hazard and Risk Assessment was to identify the potential safety issues associated with construction and operation of the project, and to address the Secretary of the Department of Planning's environmental assessment requirements for the project. The objectives of this report are to undertake a Preliminary Hazard Analysis (PHA) to address:

*"**Public Safety** – including an assessment of the likely risks to public safety. Paying particular attention to potential bushfire risks and the transport, handling and use of any dangerous goods"*

The risk assessment methodology used for the PHA was based on the New South Wales State Environmental Planning Policy No. 33 (SEPP 33) – *Hazardous and Offensive Development*, presents a systematic risk based approach to planning and assessing proposals for potentially hazardous and offensive development for the purpose of industry or storage.

Preliminary Risk Screening

The classes of dangerous goods identified in the preliminary risk screening that have quantity thresholds listed in SEPP 33 included; Class 2.1 Flammable Gases, Class 2.2 Non Flammable Non Toxic Gases, Class 3 Flammable Liquids, Class 4.1 Flammable Solids, Class 6.1 Toxic Substances, Class 8 Corrosive Substances and Class 8 Corrosive Liquids, Acidic, Organic N.O.S.

The project is considered to be 'potentially hazardous industry' on the basis of large volumes of Class 2.1 Flammable Gases being present i.e. methane. Therefore, a PHA was conducted to further assess the risk these flammable gases pose to surrounding land users as per the requirements of SEPP 33.

Based on the quantities of Class 3 Flammable Liquids at the Bibblewindi in-field gas compression facility, hydraulic oil and lubricating oil storage tanks would be at least 10 metres from the facility boundary. At the Leewood central gas compression facility, hydraulic oil, lubricating oil and corrosion inhibitor storage tanks would be at least 15 metres from the facility boundary. If these distances are maintained, these locations would not be considered a potentially hazardous industry and therefore a PHA was not required on the basis of Class 3 Flammable Liquids.

The biocide used for water treatment at the Leewood central gas compression facility was assumed to represent a Class 6.1 Toxic Substance. If this is to be the case, it would be present in quantities in excess of the threshold set out in SEPP 33 and represents a 'potentially hazardous industry'. On this basis, a PHA was conducted.

Quantities of Class 8 Corrosive Substances including amines in the Leewood central gas compression facility, and water treatment chemicals for use in in the Leewood water treatment plant were assessed to be above SEPP 33 thresholds. Therefore, the facilities are considered a potentially hazardous industry and a PHA was conducted.

Hazard identification and qualitative risk assessment

A hazard identification and qualitative risk assessment was completed to identify potential hazards with offsite impacts, and assess the risk those hazards pose to surrounding land users. The hazards identified were classified into the categories of:

- An uncontrolled loss of containment of gas leading to a fire or explosion.
- An uncontrolled loss of containment of liquid chemicals or dangerous goods.
- A sudden loss of containment of significant quantities of water resulting from a catastrophic failure of a pond wall.
- A bushfire starting as a result of project related activity.

All uncontrolled loss of containment of flammable gas (methane) scenarios were assessed as having a low or very low residual risk with regards to offsite consequences. These scenarios include a loss of containment from the wellheads, gas gathering lines, Bibblewindi in-field compression facility, Bibblewindi to Leewood gas line and Leewood central gas processing facility and power generation facility.

All uncontrolled loss of containment scenarios for liquid chemicals or dangerous goods have been assessed qualitatively as having low or very low residual risk with regards to offsite consequences.

The risk of a pond bursting or overtopping resulting in an offsite safety consequence was assessed qualitatively as very low on the basis that the ponds are designed to Australian Standards and in accordance with guidelines set by the Australian National Committee on Large Dams (ANCOLD) and NSW Dam Safety Committee procedures and guidelines that would be followed.

Preliminary Hazard Analysis – semi quantitative risk assessment

A PHA has been undertaken using the HIPAP 4 risk criteria. The NSW HIPAP 4 risk criteria suggest that:

- Incident heat flux radiation at residential and sensitive use areas should not exceed 4.7 kW/m^2 at a frequency of more than 50 chances in a million per year (5 x 10^{-5} p.a.).
- Incident explosion overpressure at residential and sensitive use areas should not exceed 7.0 kPa at frequencies of more than 50 chances in a million per year (5 x 10^{-5} p.a.).
- Toxic concentrations in residential and sensitive use areas should not exceed a level which would be seriously injurious to sensitive members of the community following a relatively short period of exposure at a maximum frequency of 10 in a million per year (1 x 10^{-5} p.a.).
- Toxic concentrations in residential and sensitive use areas should not cause irritation to eyes or throat, coughing or other acute physiological responses in sensitive members of the community over a maximum frequency of 50 in a million per year (5 x 10^{-5} p.a.).

The PHA of the loss of containment of Class 2.1 Flammable Gases (methane) assessed the risk of fires and explosions in further detail using a semi quantitative approach. It was determined the risk of 4.7 kW/m^2 heat radiation exposure meets the HIPAP 4 risk criteria as it would not exceed 50 chances in a million per year (5 x 10^{-5} p.a.) at sensitive receivers. It was also determined that the risk of 7 kPa explosion overpressure meets the HIPAP 4 risk criteria as it would not exceed 50 chances in a million per year (5 x 10^{-5} p.a.) at sensitive receivers.

The PHA of the loss of containment of Class 6.1 Toxic Substances (biocide) assessed the risk of exposure to toxic chemicals from the biocide in further detail using a semi quantitative approach. It was determined the risk of injury and irritation at sensitive receivers meets the HIPAP 4 risk criteria.

The PHA of the loss of containment of Class 8 Corrosive Substances assessed the risk of exposure to toxic gases resulting from the heating or chemical reaction of the chemicals and determined that the risk of injury and irritation at sensitive receivers meets the HIPAP 4 risk criteria.

Bushfire risk assessment

The bushfire risk assessment considered the risks during the construction and operational stages of the project of a bushfire igniting from a project related activity and impacting on life and property. The analysis considered the existing mitigation measures as well as addition mitigation measures to mitigate the risk to as low as is reasonably practicable.

The proponent is able to apply fire prevention and mitigation measures to reduce the potential for fires to start as a result of project related activities. The proponent would prepare a Bushfire Management Plan, informed by the proponent's participation in the Resource Industry Fire Management Group and consultation with relevant stakeholders including the Rural Fire Service, Forestry Corporation of NSW and landholders. Additional bushfire prevention and mitigation measures are proposed by the proponent to further reduce the risks (as low as reasonably practicable for the proponent to apply).

The existing fire prevention and mitigation measures reduce the likelihood of the project potentially starting a fire to 'remote'. Despite comprehensive current and additional proposed fire prevention and mitigation measures the proponent, as with other activities located in similar bushfire prone environments, is unable to influence the consequence of a bushfire event. Based on the Santos corporate risk matrix used in this risk assessment, the residual consequence falls into the category of 'single fatality and / or severe irreversible disability to multiple people', and despite being of 'remote' likelihood, results as a 'medium' overall residual risk for the bushfire risk category assessed for the construction and operation of the project.

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Definitions

Term	Definition
As Low As Reasonably Practicable (ALARP)	A level of risk that is below the intolerable level and either the cost of further risk reduction is disproportionate to the benefit gained or where the solution is technically impractical to implement.
Bushfire	An uncontrolled fire burning in forest, scrub or grassland vegetation.
Consequence	The severity associated with an event in this instance the heat radiation from jet fire, flash fire and fireball events or explosion overpressure, i.e. the potential effects of a hazardous scenario.
Consequence Event	The end event associated with a failure and release, considering all detection, isolation and ignition factors, e.g. jet fire, flash fire etc.
Event Frequency	The frequency assigned to a specific consequence event
Fireball	The instantaneous flashing of the material due to the catastrophic failure of the container vessel creates an expanding cloud of material. A fireball is created if this cloud is ignited, often from the flame source that caused the initial vessel failure. As buoyancy forces of the hot gases begin to dominate, the burning cloud rises and becomes more spherical in shape.
Flash Fire	The delayed ignition of a vapour cloud. A flash fire occurs when a vapour cloud burns but no significant overpressure is created at the flame front. Unlike a vapour cloud explosion, the negligible overpressure created does not accelerate the flame front and thus energy released from the combustion does not take the form of an explosive blast. It is assumed there is a 100% likelihood of fatality within the ignited vapour cloud.
Frequency	The number of occurrences of an event expressed per unit time. It is usually expressed as the likelihood of an event occurring per annum.
Hazard	A physical situation with the potential for human injury, damage to property, damage to the environment or some combination of these.
Hazardous Scenario	The accidental release of a hazardous material from equipment or piping, from identified isolatable section of equipment.
Individual Risk	The frequency at which an individual may be expected to sustain a given level of harm from the realisation of specified hazards.
Individual Risk of Fatality	Individual risk, with “harm” measured in terms of fatality. It is calculated at a particular point for a stationary, unprotected person for 24 hours per day, 365 days per year. Commonly expressed in chances of fatality per year.

Term	Definition
Jet Fire	A jet fire occurs when a flammable liquid or gas, under some degree of pressure, is ignited after release, resulting in the formation of a long stable flame. A jet fire risk is present whenever there are pressurised flammable gases or liquids. Turbulence evoked by pressurised fluid escape entrains ambient oxygen and can create a mixture that lays within the materials flammability limits.
Probability	The expression for the likelihood of an occurrence of an event or an event sequence or the likelihood of the success or failure of an event on test or demand. By definition, probability must be expressed as a number between 0 and 1.
Quantitative Risk Assessment	A risk assessment undertaken by combining quantitative evaluations of event frequency and consequence.
Risk	The combination of frequency and consequences, the chance of an event happening that can cause specific consequences.
Vapour Cloud Explosion	Vapour cloud explosions result from the combustion of flammable vapour clouds within a congested or confined area creating an overpressure in the process. Under certain conditions the flame front may be accelerated by the overpressure created to a high velocity producing considerable blast effects.

Abbreviations

Abbreviation	Explanation
ANCOLD	Australian National Committee on Large Dams
AC	Alternating Current
APIA	Australian Pipeline Industry Association
APZ	Asset Protection Zone
AS	Australian Standard
BOM	Bureau of Meteorology
CSG	Coal Seam Gas
DC	Direct Current
DG	Dangerous Good
DNV GL	Det Norske Veritas Germanischer Lloyd
DoP	Department of Planning
FBR	Full Bore Rupture
HAZID	Hazard Identification
HAZOP	Hazard and Operability
HCR	Hydrocarbon releases
HDPE	High Density Poly Ethylene
HIPAP	Hazardous Industry Planning Advisory Paper
kPa	Kilo Pascals
kPag	Kilo Pascal Gauge
kW/m^2	Kilo watts per square metre
LFL	Lower Flammable Limit
LOC	Loss of Containment
ME	Multi Energy
mm	Millimetre
m/s	Metres per second
MPa	Mega Pascal
NSWRFS	NSW Rural Fire Service
NZS	New Zealand Standard
OGP	International Association of Oil and Gas Producers
OSD	(UK HSE) Offshore Division
PHA	Preliminary Hazard Analysis
Phast	Process Hazard Analysis Software Tool
QRA	Quantitative Risk Assessment
RIDDOR	Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (1995)

Abbreviation	Explanation
Safeti	Software for the Assessment of Flammable, Explosive and Toxic Impact
SCC	Stress Corrosion Cracking
SEPP	New South Wales State Environmental Planning Policy
SFAZ	Strategic Fire Advantage Zone
SMS	Safety Management Study
UFL	Upper Flammable Limit
UK HSE	United Kingdom Health and Safety Executive
VCE	Vapour Cloud Explosion
WTP	Water Treatment Plant

1. Introduction

1.1 Overview

The Proponent is proposing to develop natural gas in the Gunnedah Basin in New South Wales (NSW), southwest of Narrabri (refer Figure 1-1).

The Narrabri Gas Project (the project) seeks to develop and operate a gas production field, requiring the installation of gas wells, gas and water gathering systems, and supporting infrastructure. The natural gas produced would be treated at a central gas processing facility on a local rural property (Leewood), approximately 25 kilometres south-west of Narrabri. The gas would then be piped via a high-pressure gas transmission pipeline to market. This pipeline would be part of a separate approvals process and is therefore not part of this development proposal.

The primary objective of the project is to commercialise natural gas to be made available to the NSW gas market and to support the energy security needs of NSW. Production of natural gas under the project would deliver economic, environmental and social benefits to the Narrabri region and the broader NSW community. The key benefits of the project can be summarised as follows:

- Development of a new source of gas supply into NSW would lead to an improvement in energy security and independence to the State. This would give NSW gas markets greater choice when entering into gas purchase arrangements. Potential would also exist for improved competition on price. Improved competition on price would have flow on benefits for NSW's economic efficiency, productivity and prosperity.
- The provision of a reduced greenhouse gas emission fuel source for power generation in NSW as compared to traditional coal-fired power generation.
- Increased local production and regional economic development through employment and provision of services and infrastructure to the project.
- The establishment of a regional community benefit fund equivalent to five per cent of the royalty payment made to the NSW Government within the future production licence area. If matched by the NSW Government, the fund could reach $120 million over the next two decades.

1.2 Description of the project

The project would involve the construction and operation of a range of exploration and production activities and infrastructure including the continued use of some existing infrastructure. The key components of the project are presented in Table 1-1 and are shown on Figure 1-1.

Table 1-1 Key project components

Component	Infrastructure or activity
Major facilities	
Leewood	• a central gas processing facility for the compression, dehydration and treatment of gas • a central water management facility including storage and treatment of produced water and brine • optional power generation for the project • a safety flare • treated water management infrastructure to facilitate the transfer of treated water for irrigation, dust suppression, construction and drilling activities • other supporting infrastructure including storage and utility buildings, staff amenities, equipment shelters, car parking, and diesel and chemical storage • continued use of existing facilities such as the brine and produced water ponds • operation of the facility
Bibblewindi	• in-field compression facility • a safety flare • supporting infrastructure including storage and utility areas, treated water holding tank, and a communications tower • upgrades and expansion to the staff amenities and car parking • produced water, brine and construction water storage, including recommissioning of two existing ponds • continued use of existing facilities such as the 5ML water balance tank • operation of the expanded facility
Bibblewindi to Leewood infrastructure corridor	• widening of the existing corridor to allow for construction and operation of an additional buried medium pressure gas pipeline, a water pipeline, underground (up to 132 kV) power, and buried communications transmission lines
Leewood to Wilga Park underground power line	• installation and operation of an underground power line (up to 132 kV) within the existing gas pipeline corridor
Gas field	

Gas exploration, appraisal and production infrastructure	• seismic geophysical survey
	• installation of up to 850 new wells on a maximum of 425 well pads
	  – new well types would include exploration, appraisal and production wells
	  – includes well pad surface infrastructure
	• installation of water and gas gathering lines and supporting infrastructure
	• construction of new access tracks where required
	• water balance tanks
	• communications towers
	• conversion or upgrade of existing exploration and appraisal wells to production in addition to the 850 new wells

Component	Infrastructure or activity

Ancillary	• upgrades to intersections on the Newell Highway
	• expansion of worker accommodation at Westport
	• a treated water pipeline and diffuser from Leewood to Bohena Creek
	• treated water irrigation infrastructure including:
	  – pipeline(s) from Leewood to the irrigation area(s)
	  – treated water storage dam(s) offsite from Leewood
	• operation of the irrigation scheme

The project is expected to generate approximately 1,300 jobs during the construction phase and sustain around 200 jobs during the operational phase; the latter excluding an ongoing drilling workforce comprising approximately 100 jobs.

Subject to obtaining the required regulatory approvals, and a financial investment decision, construction of the project is expected to commence in early 2018, with first gas scheduled for 2019/2020. Progressive construction of the gas processing and water management facilities would take around three years and would be undertaken between approximately early/mid-2018 and early/mid-2021. The gas wells would be progressively drilled during the first 20 or so years of the project. For the purpose of impact assessment, a 25-year construction and operational period has been adopted.

1.3 Project location

The project would be located in north-western NSW, approximately 20 kilometres south-west of Narrabri, within the Narrabri local government area (LGA) (see Figure 1-1).

The project area covers about 950 square kilometres (95,000 hectares), and the project footprint would directly impact about one percent of that area.

The project area contains a portion of the region known as 'the Pilliga', which is an agglomeration of forested area covering more than 500,000 hectares in north-western NSW around Coonabarabran, Baradine and Narrabri. Nearly half of the Pilliga is allocated to conservation, managed under the NSW *National Parks and Wildlife Act 1974*. The Pilliga has spiritual meaning and cultural significance for the Aboriginal people of the region.

Other parts of the Pilliga were dedicated as State forest, and set aside for the purpose of 'forestry, recreation and mineral extraction, with a strategic aim to "provide for exploration, mining, petroleum production and extractive industry" under the *Brigalow and Nandewar Community Conservation Area Act 2005*. The parts of the project area on state land are located within this section of the Pilliga.

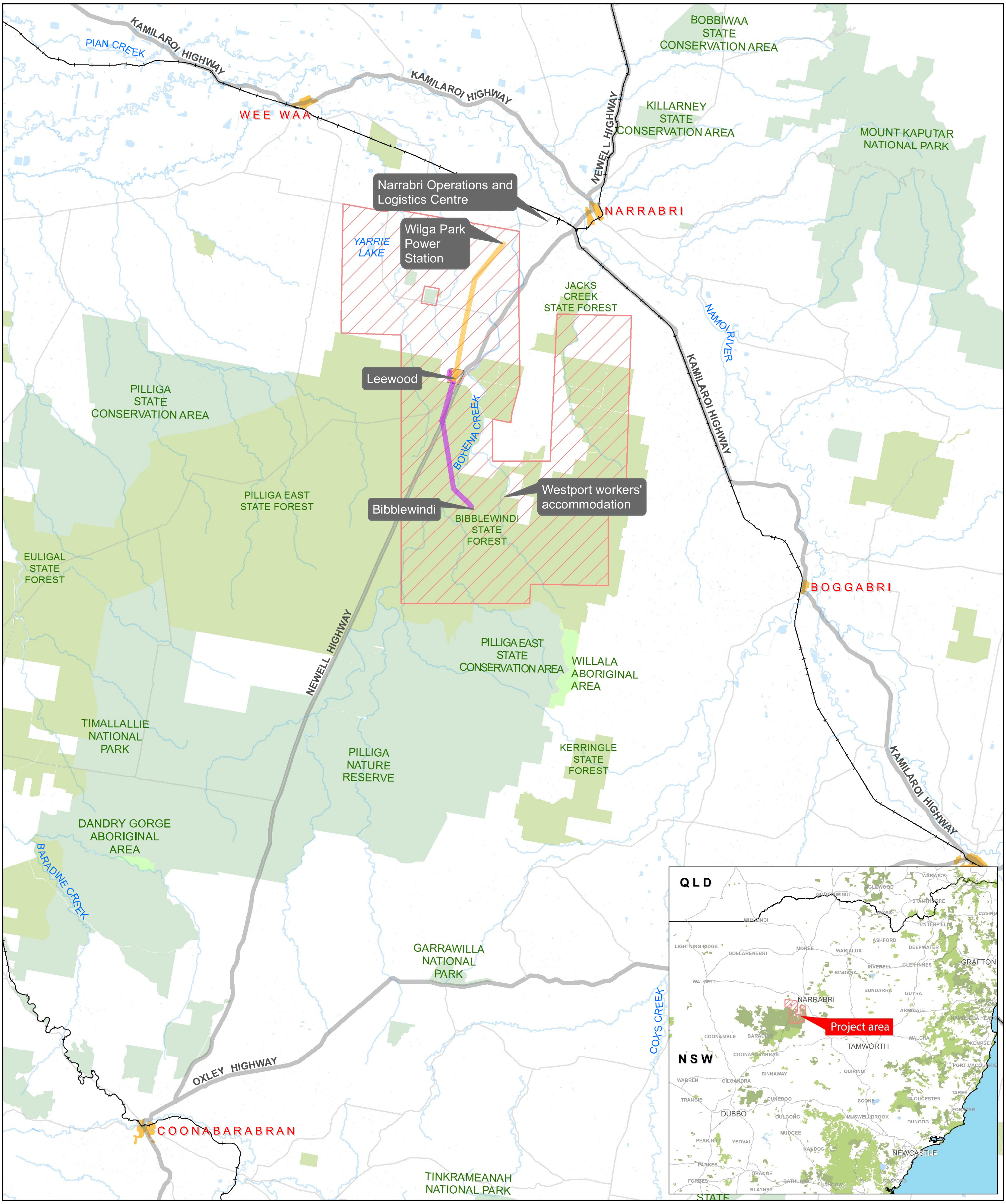
The semi-arid climate of the region and general unsuitability of the soils for agriculture have combined to protect the Pilliga from widespread clearing. Commercial timber harvesting activities in the Pilliga were preceded by unsuccessful attempts in the mid-1800s to establish a wool production industry. Resource exploration has been occurring in the area since the 1960s; initially for oil, but more recently for coal and gas.

The ecology of the Pilliga has been fragmented and otherwise impacted by commercial timber harvesting and related activities over the last century through:

- the establishment of more than 5,000 kilometres of roads, tracks and trails
- the introduction of pest species
- the occurrence of drought and wildfire.

The project area avoids the Pilliga National Park, Pilliga State Conservation Area, Pilliga Nature Reserve and Brigalow Park Nature Reserve. Brigalow State Conservation Area is within the project area but would be protected by a 50 metre surface exclusion zone.

Agriculture is a major land use within the Narrabri LGA; about half of the LGA is used for agriculture, split between cropping and grazing. Although the majority of the project area would be within State forests, much of the remaining area is situated on agricultural land that supports dry-land cropping and livestock. No agricultural land in the project area is mapped by the NSW Government to be biophysical strategic agricultural land (BSAL) and detailed soil analysis has established the absence of BSAL. This has been confirmed by the issue of a BSAL Certificate for the project area by the NSW Government.



LEGEND

- Project area
- Leewood
- Urban Areas
- State forest
- Parks and reserves
- Aboriginal areas
- Lakes and dams
- Watercourses
- Highways
- Major Roads
- Train line
- Leewood to Wilga Park infrastructure corridor
- Bibblewindi to Leewood infrastructure corridor

0 5 10 20
Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Narrabri Gas Project
EIS Technical Appendix Hazard and Risk Assessment

Job Number 21-22463
Revision A
Date 12 Mar 2015

Regional context and location of key infrastructure

Figure 1-1

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Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

Data source: NSW Department of Lands: DTDB and DCDB - 2012-13. Santos: Operational and Base Data - 2013. Created by: afoddy

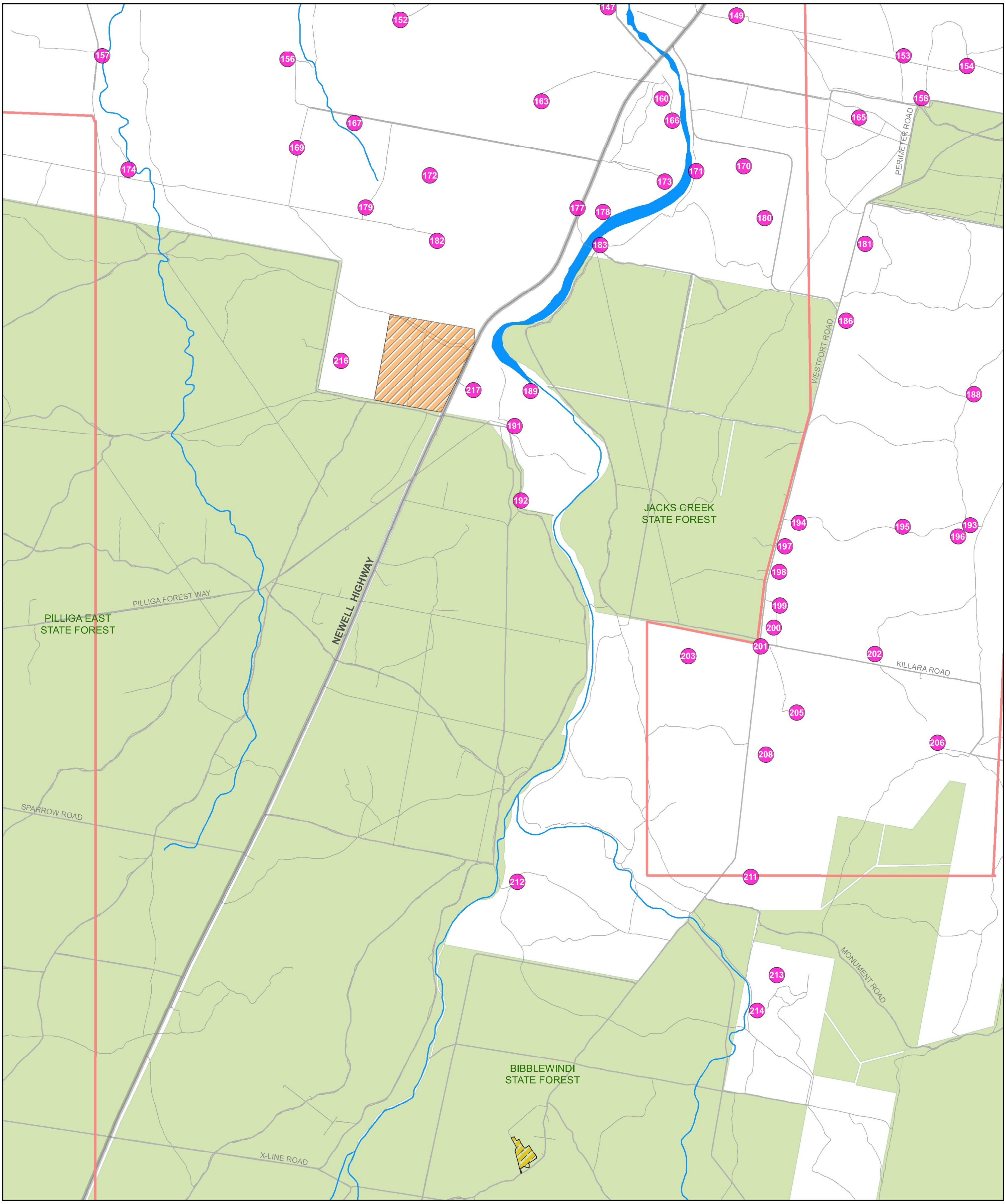
1.4 Surrounding land use and sensitive receivers

The land use within the project area is predominantly State forest. There are 114 sensitive receivers within the project area which are all dwellings except for University of Sydney Cosmic Ray Field Station.

A summary of the closest sensitive receivers, within approximately 5 kilometres, to Bibblewindi and Leewood is provided in Table 1-2. The location of these sensitive receivers is shown in Figure 1-2.

Table 1-2 Sensitive receivers in proximity to Leewood and Bibblewindi gas compression facilities

Sensitive receptor	Distance Leewood (m)	Distance Bibblewindi (m)	Lot	Plan	Easting	Northing
217	350	> 5000	2	DP771141	752947	6622483
216	750	> 5000	62	DP804736	750465	6623033
189	1333	> 5000	1	DP623250	754023	6622462
191	1351	> 5000	2	DP623250	753725.4	6621811
182	1513	> 5000	4	DP757097	752266.9	6625285
179	2064	> 5000	183	DP814965	750922.1	6625912
192	2229	> 5000	3	DP623250	753839.5	6620410
172	2698	> 5000	185	DP814965	752133	6626511
183	2838	> 5000	5	DP843278	755332.2	6625208
177	2982	> 5000	5	DP790376	754902.9	6625901
178	3259	> 5000	1	DP232897	755380.8	6625826
169	3589	> 5000	17	DP757084	749633.3	6627032
167	3656	> 5000	182	DP814965	750712.5	6627495
163	4458	> 5000	161	DP802977	754230.7	6627905
173	4518	> 5000	22	DP746781	756542.9	6626399
214	> 5000	4969	4	DP757126	758278.2	6610833
212	8930	4784	35	DP757087	753772.8	6613249



LEGEND

- Project area
- Leewood property
- Bibblewindi
- State forest
- Lakes and dams
- Watercourses
- Roads
- Sensitive receivers

0 0.75 1.5 3
Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Narrabri Gas Project - Gas Field
EIS Technical Appendix Hazard and Risk Assessment

Job Number 21-22463
Revision A
Date 12 Mar 2015

Sensitive receivers in the vicinity of the project area

Figure 1-2

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Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

NSW Department of Lands: DTDB and DCDB - 2012-13. Santos: Operational and Base Data - 2013.

1.5 Project facilities

The following project facilities are included within the scope of the hazard and risk assessment.

1.5.1 Wellheads and gas gathering lines

A photo of a typical well pad is provided in Figure 1-3. In the operational phase of the project, the well pad site will be approximately one quarter of a hectare in size.

Figure 1-3 Typical well pad layout

Gas gathering lines are underground pipelines used to transfer gas from each of the wellhead facilities to the in-field and / or central gas compression facilities at Bibblewindi and Leewood respectively.

1.5.2 Bibblewindi in-field compression facility

A schematic of the overall proposed site layout for the Bibblewindi facility is provided in Figure 1-4, with the proposed in-field gas compression facility shown in outline.

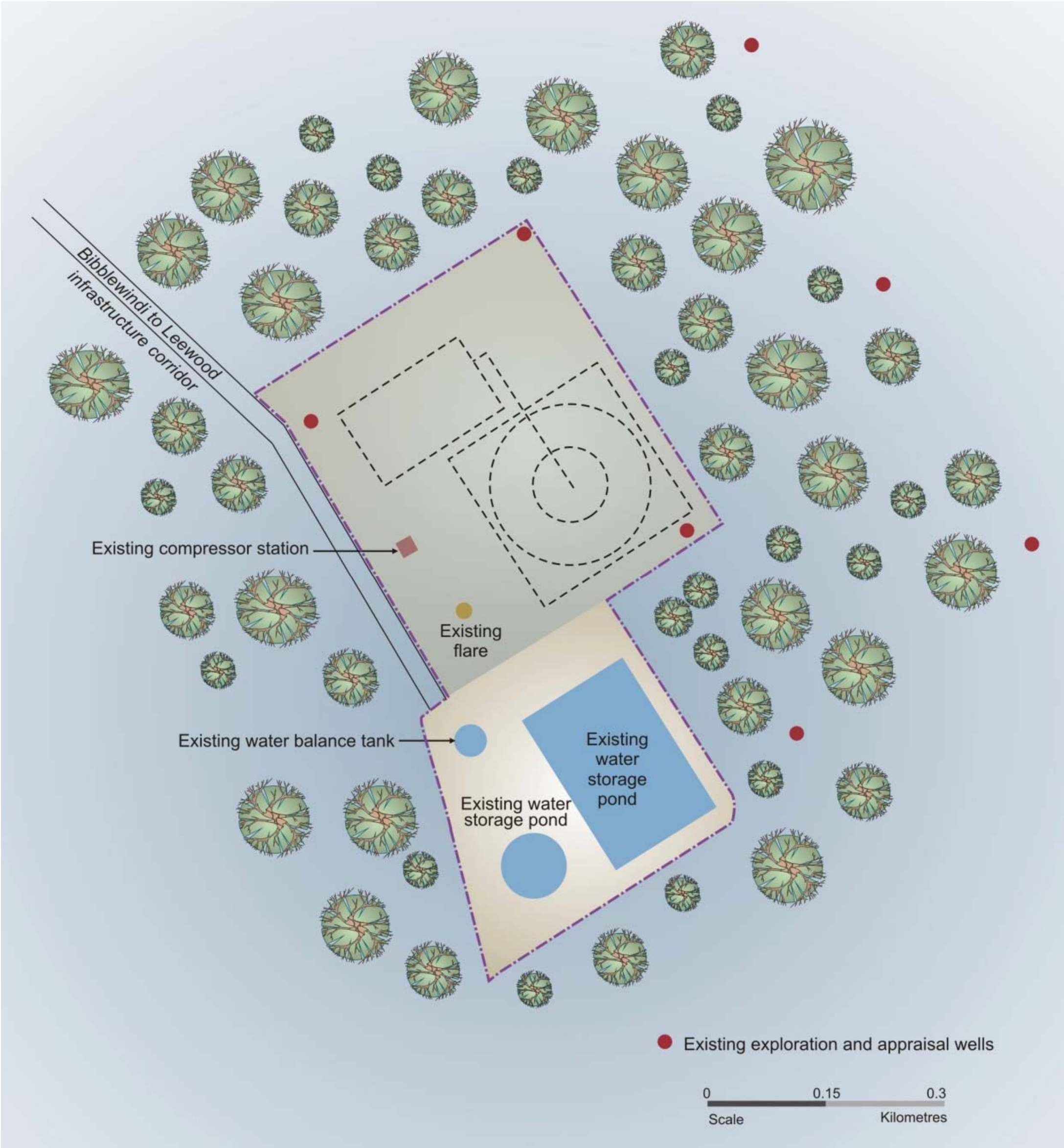

Figure 1-4 Indicative layout of Bibblewindi

A schematic drawing of the in-field gas compression facility at Bibblewindi is provided in Figure 1-5. Chemicals present at the in-field gas compression facility are included in the risk screening.

The Bibblewindi to Leewood medium pressure gas pipeline is then used to transfer gas from Bibblewindi to the Leewood central gas compression facility.

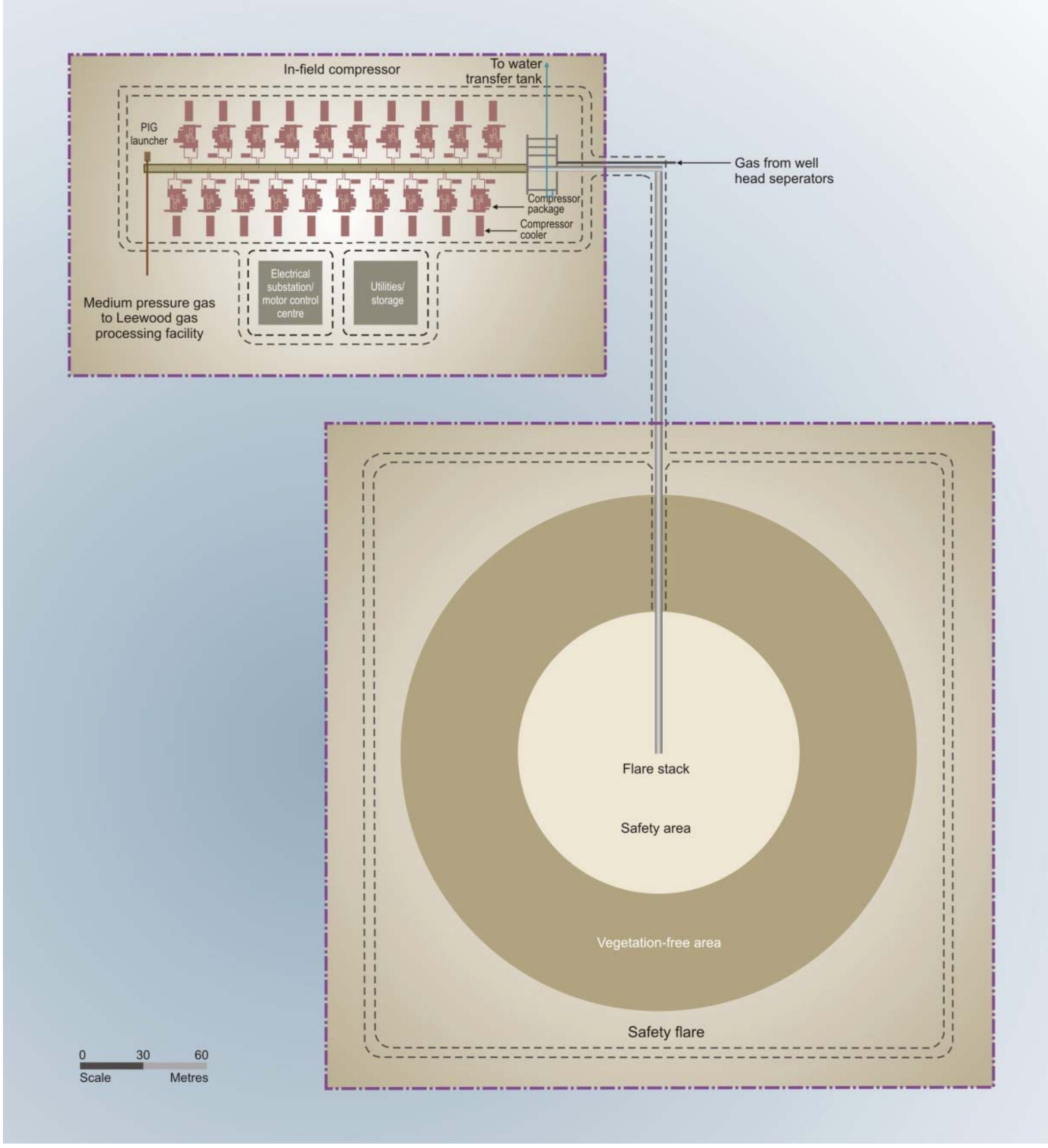

Figure 1-5 Indicative layout of the in-field gas compression facility at Bibblewindi

1.5.3 Leewood

A schematic of the proposed site layout for the Leewood Property is provided in Figure 1-6. It includes the proposed central gas compression facility, water treatment plant, and optional power generation facility. Chemicals present at the central gas compression facility, water treatment plant and optional power generation facility are included in the risk screening.

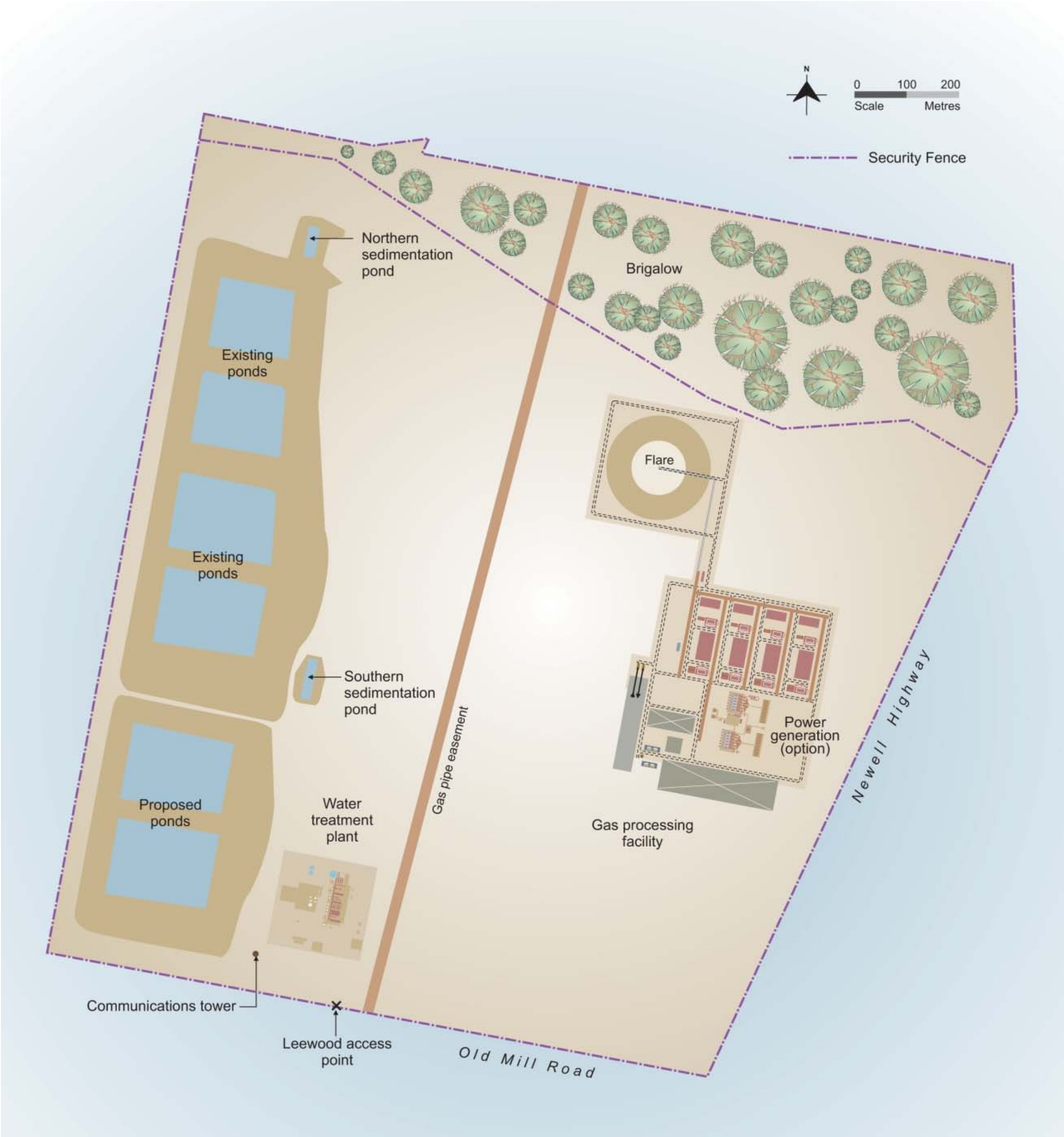

Figure 1-6 Indicative layout of Leewood

A schematic of the Leewood central gas compression facility is provided in Figure 1-7; noting that the location of the facility is set back from the site boundary.

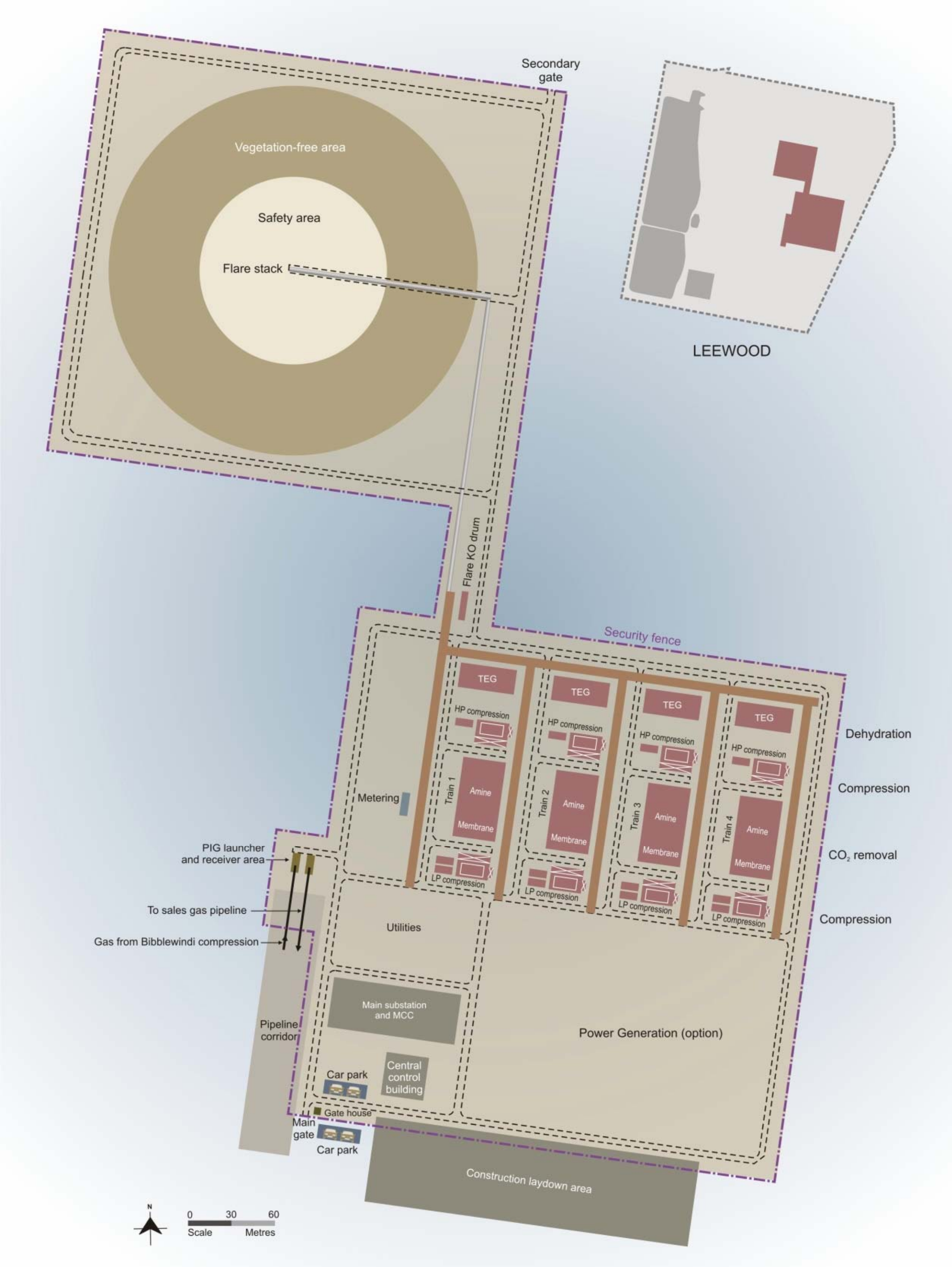

Figure 1-7 Layout of the Leewood central gas compression facility

1.6 Planning framework and structure of this report

1.6.1 Planning framework

The project is permissible with development consent under the *State Environmental Planning Policy (Mining, Petroleum and Extractive Industries) 2007*, and is identified as 'State significant development' under section 89C (2) of the *Environmental Planning and Assessment Act 1979* (EP&A Act) and the *State Environmental Planning Policy (State and Regional Development) 2011*.

The project is subject to the assessment and approval provisions of Division 4.1 of Part 4 of the EP&A Act. The Minister for Planning is the consent authority, who is able to delegate the consent authority function to the Planning Assessment Commission, the Secretary of the Department of Planning and Environment or to any other public authority.

The project is also a controlled action under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. The project was declared to be a controlled action on 5 December 2014, to be assessed under the bilateral agreement between the Commonwealth and NSW Governments, and triggering the following controlling provisions:

- listed threatened species and ecological communities
- a water resource, in relation to coal seam gas development and large coal mining development
- Commonwealth land.

This Hazard and Risk Assessment identifies the potential safety issues associated with construction and operation of the project and in addition addresses the Secretary's environmental assessment requirements for the project. The requirements addressed in this report include:

*"**Public Safety** – including an assessment of the likely risks to public safety. Paying particular attention to potential bushfire risks and the transport, handling and use of any dangerous goods"*

The assessment will be used to support the EIS for the project.

1.6.2 Report structure

- **Chapter 1 – Introduction.** This chapter introduces the project and the proponent and describes the project area.
- **Chapter 2 – Methodology.** This chapter defines the study area assessed in this report and describes the steps undertaken in the assessment.
- **Chapter 3 – Legislative context.** This chapter outlines the relevant Commonwealth and State legislation relating to the assessment. Guidelines and assessment criteria (where applicable) relevant to the gas field construction, operation and decommissioning are also identified.
- **Chapter 4 – Hazard and Risk Assessment.** This chapter identifies the public safety risks, their impacts and mitigation measures.
- **Chapter 5 – Conclusion.** This chapter presents a conclusion to the report and presents the next steps in the advancement of the project.

2. Methodology

2.1 SEPP 33 requirements

The New South Wales State Environmental Planning Policy No.33 (SEPP 33) – *Hazardous and Offensive Development*, presents a systematic approach to planning and assessing proposals for potentially hazardous and offensive development for the purpose of industry or storage.

SEPP 33 applies to proposals which fall under the policy's definition of 'potentially hazardous industry' or 'potentially offensive industry'. If not controlled appropriately, some activities within such 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 or potentially offensive using the SEPP 33 risk screening process.

SEPP 33 requires that a preliminary risk screening be done. More detailed risk assessments will be undertaken by the proponent during the detailed design of plant and equipment prior to construction. That is, that further, and more detailed hazard analysis would be undertaken to assess risk scenarios based on the final operating conditions, and plant design and layout. Therefore, the modelling reported herein may be considered highly conservative as it has been undertaken without consideration of standard design and operational systems such as automatic shutdown, blowdown and isolation systems that limit gas release. These are systems that will be utilised in the project to limit gas release that would be incorporated into the consequence and risk modelling undertaken during detailed design.

2.2 Preliminary risk screening

An initial preliminary risk screening of the project informs the need for a Preliminary Hazard Analysis (PHA), pursuant to SEPP 33. The preliminary risk screening methodology concentrates on the storage of specific classes of dangerous goods that have the potential for significant offsite effects. Specifically, the assessment involves the identification of classes and quantities of all dangerous goods to be used, stored or produced on site; with an indication of storage locations.

Consequently, if a PHA is not required, the process is completed at this step under SEPP 33 requirements. For development proposals classified as 'potentially hazardous industry', a PHA is completed to determine the risk to people, property and the environment surrounding the project and in the presence of controls. Criteria of acceptability are used to determine if the development proposal is classified as 'hazardous industry'. If this is the case, the development proposal may not be permissible within most industrial zonings in NSW.

The overall risk screening process outlined in SEPP 33 is illustrated in Figure 2-1 as a point of reference.

This report outlines the preliminary risk screening and PHA for the project.

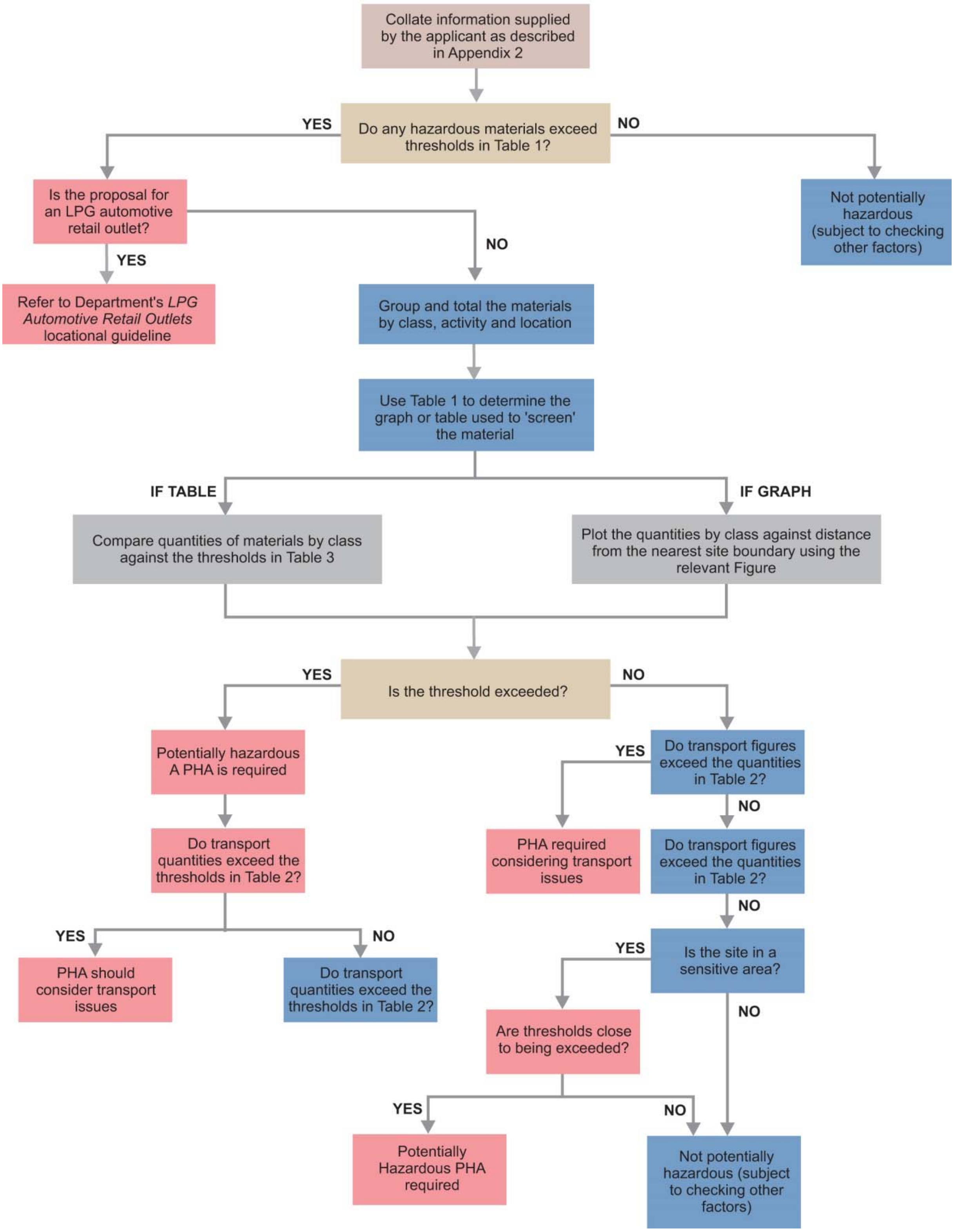

Figure 2-1 SEPP 33 risk screening process

2.3 Preliminary Hazard Analysis (PHA)

2.3.1 Hazard identification

The PHA assesses hazards that have a potential for offsite consequences or involving dangerous goods identified during the risk screening process. The hazard identification involved a scoping process to identify hazards within the project that have the potential for offsite impacts. This approach draws upon the Proponent's knowledge and experience in similar operations within Australia to identify the potential range of hazard scenarios that could be present. These hazards are captured in a risk register where the risk of the hazard is assessed using a risk matrix, as described in Section 2.3.2.

Hazards determined to have offsite consequences or involving dangerous goods were identified and consolidated to form the list of risks as discussed in the PHA in Section 4.3.1. The PHA does not cover occupational hazards to onsite personnel such as electrocution, drowning and vehicle accidents. These risks would be managed through a formal Safety Management System for the project. It also does not address health risks associated with the potential for aquifer contamination due to chemical release. This is covered in the Chemical Risk Assessment (refer to Appendix T3 of the EIS - EHS Support 2016).

2.3.2 Risk assessment

The hazards identified with potential offsite impacts or involving dangerous goods were assessed qualitatively using the Santos risk matrix (refer to Figure 2-2). Consequence levels and descriptors are listed in Table 2-1, with likelihood levels and descriptors listed in Table 2-2.

		LIKELIHOOD				
		E	D	C	B	A
CONSEQUENCE	V	Very High	Very High	High	High	Medium
	IV	Very High	High	High	Medium	Medium
	III	High	Medium	Medium	Medium	Low
	II	Medium	Medium	Low	Low	Very Low
	I	Medium	Low	Low	Very Low	Very Low

Figure 2-2 Santos risk matrix used for the risk and safety assessment

Source: Santos

Table 2-1 Consequence levels and descriptors

Level	Descriptor
I - Negligible	**First aid treatment** Illness / injury not requiring medical treatment (no lost time injuries)
II - Minor	**Minor or Medically Treated Injury** Injury / Injuries requiring medical treatment with lost time
III - Moderate	**Permanent Disability** – Permanent disabling injury / injuries
IV - Major	**Single Fatality** Single fatality
V - Critical	**Multiple Fatality** Multiple fatalities

Table 2-2 Likelihood levels and descriptors

Level	Descriptor
E	**Almost Certain** Is expected to occur in most circumstances or could occur within days to weeks
D	**Likely** Could occur in most circumstances or could occur within weeks to months
C	**Possible** Has occurred before in the industry or could occur within next few years
B	**Unlikely** Has occurred elsewhere or could occur within decades
A	**Remote** Requires exceptional circumstances, is unlikely even in the long term, 100 year event

2.3.3 Level of assessment

Multi-level Risk Assessment (New South Wales Department of Planning 2011) provides a guideline for determining the appropriate level of risk assessment (refer to Figure 2-3).

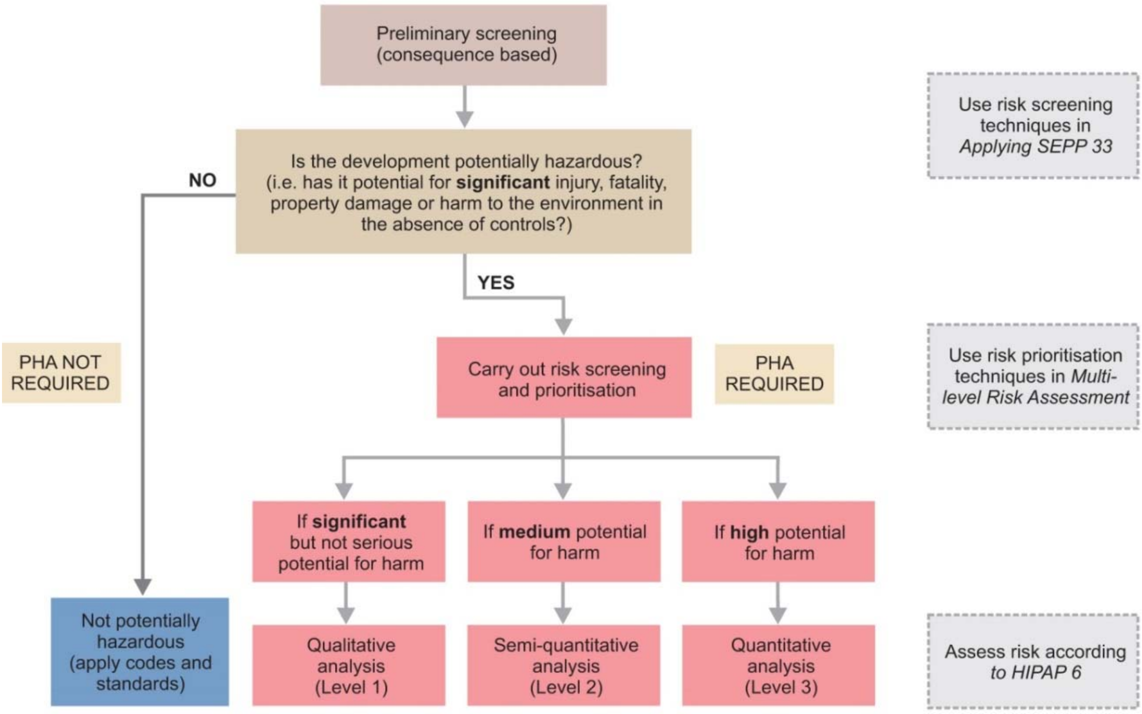

Figure 2-3 Multi-level risk assessment approach

The risk assessment method to be applied when a PHA is required is described in *Hazardous Industry Planning Advisory Paper (HIPAP) No. 6* (NSW Department of Planning 2011a).

A Level 2 assessment can be justified if the societal risk estimates fall within the middle *As Low As Reasonably Practicable* (ALARP) zone and the frequency of risk contributors having offsite consequences is relatively low. This is detailed further in section 2.3.4.

A Level 2 assessment is semi-quantitative, in that it should, in addition to all the elements of the Level 1 analysis, include sufficient quantification of risk contributors to demonstrate that risk criteria will be met.

In particular:

- Appropriate modelling tools should be used to calculate the consequences of all events determined by the preliminary assessment to have the potential for harmful offsite effects.
- There should be an estimate of likelihood for each event confirmed by the consequence modelling to have significant offsite effects, using appropriate failure data and techniques, such as fault and event trees.
- There should be an indicative estimate of the offsite risk, taking into account the cumulative impact of multiple events.
- The study must demonstrate that all relevant numerical risk criteria will be met.

From the preliminary risk screening, hazard identification and qualitative risk assessment, the risks with offsite consequences that have been included in the PHA can be classified into three categories:

1. An uncontrolled loss of containment of gas leading to a fire or explosion

These have been assessed further using a semi-quantitative approach by modelling the consequences of a fire or explosion if the hazard were to occur. Consequence modelling was undertaken using Phast Risk 6.7. This software is produced and maintained by DNV GL (formerly Det Norske Veritas) and is commonly used throughout the Australian oil and gas industry. Results from the consequence modelling were combined with failure data to determine the likelihood of the consequences.

2. An uncontrolled loss of containment of liquid chemicals or dangerous goods

Where dangerous goods other than gas occur in quantities above those stated in SEPP 33, these were assessed qualitatively.

Where liquid hydrocarbons which are classified as dangerous goods occur in quantities above those stated in SEPP 33, these were assessed qualitatively. A qualitative assessment was undertaken and it was determined that no hydrocarbons which are classified as dangerous goods occur in quantities above those stated in SEPP 33. Therefore, no PHA was undertaken.

3. Sudden loss of containment of significant quantities of water resulting from catastrophic failure of pond wall

These were assessed qualitatively and determined to not need further detailed assessment as the risk of offsite safety impacts is very low. This is because all ponds will be designed in accordance with guidelines set by the Australian National Committee on Large Dams (ANCOLD), and NSW Dam Safety Committee procedures and guidelines would be followed.

2.3.4 The ALARP principle

The *Hazardous Industry Planning Advisory Paper No 4 – Risk Criteria for Land Use Safety Planning* (HIPAP 4) (New South Wales Department of Planning, 2011b) endorses the “As Low As Reasonably Practicable”, or ALARP principle. Societal risk is presented in three bands, being ‘unacceptable or intolerable’, ‘tolerable if reduced ALARP’ and ‘negligible’. These are presented in Figure 2-4.

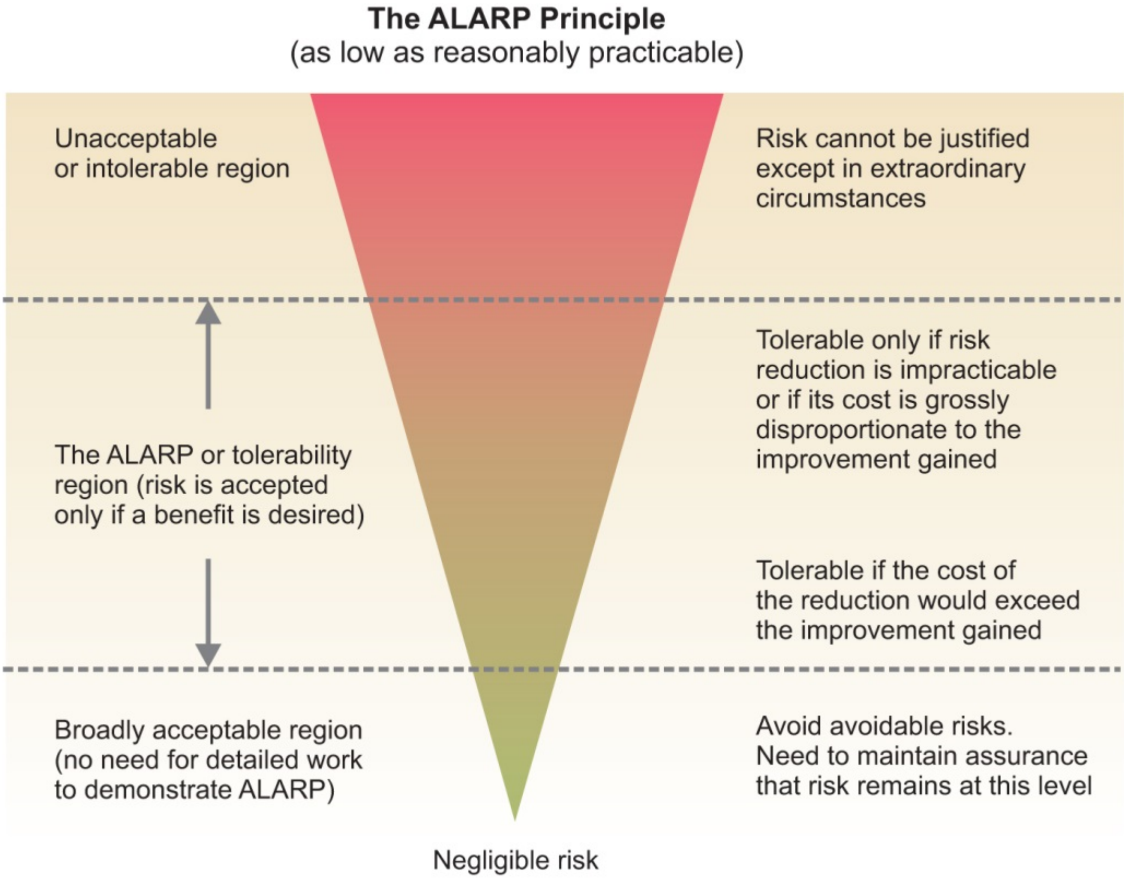

Figure 2-4 The ALARP principle

2.3.5 HIPAP 4 criteria

HIPAP 4 provides the relevant consequence and risk criteria to be applied in a PHA. Appendix 1 of HIPAP 4 provides tables of consequences. Where the consequences of a loss of containment are a fire or explosion, HIPAP 4 describes the effect of heat radiation and explosion overpressure as reproduced in Table 2-3 and Table 2-4.

Table 2-3 Consequences of heat radiation

Heat Radiation (kW/m^2)	Effect
1.2	Received from the sun at noon in summer
2.1	Minimum to cause pain after one minute
4.7	Will cause pain in 15 to 20 seconds and injury after 30 seconds’ exposure (at least second degree burns will occur)
12.6	• significant chance of fatality for extended exposure. High chance of injury • causes the temperature of wood to rise to a point where it can be ignited by a naked flame after long exposure • thin steel with insulation on the side away from the fire may reach a thermal stress level high enough to cause structural failure
23	• likely fatality for extended exposure and chance of fatality for instantaneous exposure • spontaneous ignition of wood after long exposure • unprotected steel will reach thermal stress temperatures which can cause failure • pressure vessel needs to be relieved or failure would occur
35	• cellulosic material will pilot ignite within one minute of exposure • significant chance of fatality for people exposed instantaneously

Table 2-4 Effects of explosion overpressure

Explosion Overpressure	Effect
3.5 kPa (0.5 psi)	• 90 percent glass breakage • no fatality and very low probability of injury
7 kPa (1 psi)	• damage to internal partitions and joinery but can be repaired • probability of injury is 10 percent. No fatality
14 kPa (2 psi)	• house uninhabitable and badly cracked
21 kPa (3 psi)	• reinforced structures distort • storage tanks fail • 20 percent chance of fatality to a person within a building
35 kPa (5 psi)	• house uninhabitable • plant items overturned • threshold of eardrum damage • 50 percent chance of fatality for a person in a building and 15 percent chance of a fatality for a person in the open
70 kPa (10 psi)	• threshold of lung damage • 100 percent chance of fatality for a person in a building or in the open • complete demolition of houses

The level of injury received from a fire depends on the duration of people's exposure to the fire and the level of heat radiation received. Since a flash fire has a very short duration and does not radiate away from the flash fire envelope, it is conservatively assumed that the impact will be fatal for people within the envelope. Therefore, the impact criteria for flash fire is assumed as 100 percent fatality probability within the flash fire (or Lower Flammable Limit - LFL) envelope.

HIPAP 4 also provides criteria for individual and societal risks. The criteria are used as a conservative tool for assessing these risks. The following risk criteria for fires and explosions and toxic gas releases are suggested in HIPAP 4:

1. Incident heat flux radiation at residential and sensitive use areas should not exceed 4.7 kW/m^2 at a frequency of more than 50 chances in a million per year.
2. Incident explosion overpressure at residential and sensitive use areas should not exceed 7 kPa at frequencies of more than 50 chances in a million per year.
3. Toxic concentrations in residential and sensitive use areas should not exceed a level which would be seriously injurious to sensitive members of the community following a relatively short period of exposure at a maximum frequency of 10 in a million per year.
4. Toxic concentrations in residential and sensitive use areas should not cause irritation to eyes or throat, coughing or other acute physiological responses in sensitive members of the community over a maximum frequency of 50 in a million per year.

2.3.6 Gas composition

Gas composition will vary between wells and throughout a well's life. For the purpose of consequence modelling, it has been assumed that all gas is 100 percent methane. This represents the most conservative assessment approach.

2.3.7 Consequence modelling of fire and explosion scenarios

Consequence modelling of these scenarios was undertaken using DNV software, Phast Risk 6.7.

All consequence scenarios have been identified as representing situations that could arise from a typical range of operating conditions and process equipment that are utilised at these types of facilities. Inputs used for modelling are based on assumed plant design and layout, and the typical operating conditions for similar facilities operated by the proponent. During detailed design, further hazard analysis would be undertaken to assess the scenarios based on the final operating conditions and plant design and layout.

The consequence modelling may be considered highly conservative as it has been undertaken without consideration of standard design and operational systems such as automatic shutdown, blowdown and isolation systems that limit gas release. These are systems that will be utilised in the project to limit gas release that would be incorporated into the consequence and risk modelling undertaken during detailed design.

Wellheads

Scenarios modelled for consequence analysis at wellheads are summarised in Table 2-5 (at a temperature of 25 C).

Table 2-5 Wellhead consequence modelling scenarios

Wellheads	Pressure	Phast Risk 6.7 model	Scenario
Leaks from pipes or vessels	620 kPag	Vessel / Pipe source (leak)	• 10 mm hole • 50 mm hole • 100 mm hole
Vessel (separators, filters etc.) catastrophic failure	620 kPag	Vessel / Pipe source (catastrophic rupture)	• 0.5 m^3 vessel rupture

The above scenarios are based on an estimated maximum operating pressure. The hazard analysis and consequence modelling would be refined during detailed design utilising the well pressure and associated over pressure protection system designs once these are finalised.

Gathering Lines

Scenarios modelled for consequence analysis at gas gathering lines are shown in Table 2-6 (at a temperature of 25 C).

Table 2-6 Gas gathering line consequence modelling scenarios

Gathering Lines	Pressure	Phast Risk 6.7 model	Intervals	Gas Flowrate	Scenario
Leaks from gathering line	420 kPag	Vessel / Pipe source (leak)	N/A	N/A	• 10 mm hole • 50 mm hole • 100 mm hole
Rupture of gathering line	420 kPag	Vessel / Pipe source (long pipeline)	Every 500 m for 5,000 m	1.5 MMSCFD	• Full bore rupture

The length of gas gathering lines will vary across the field. For the purposes of this risk assessment; a 5,000 metre line at 700 mm diameter is assumed to be typical of the project. Shorter or longer lines will have different consequences.

Bibblewindi in-field gas compression facility

Scenarios modelled for consequence analysis at the Bibblewindi in-field gas compression facility are show in Table 2-7, (modelled at 25°C and 60 C).

Table 2-7 Bibblewindi in-field gas compression facility consequence modelling scenarios

Bibblewindi Gas Compression Facility	Pressure	Temperature	Phast Risk 6.7 model	Scenario
Leaks from pipes or vessels on the suction side of the compressors	172 kPag	25°C	Vessel/Pipe source (leak)	• 10 mm hole • 50 mm hole • 100 mm hole
Vessel (separators, filters etc.) catastrophic failure on the suction side of the compressors	172 kPag	25°C	Vessel/Pipe source (catastrophic rupture)	• 0.5 m^3 vessel rupture • 1 m^3 vessel rupture • 2 m^3 vessel rupture
Leaks from pipes or vessels on the discharge side of the compressors	2,000 kPag	60°C	Vessel/Pipe source (leak)	• 10 mm hole • 50 mm hole • 100 mm hole
Vessel (separators, filters etc.) catastrophic failure on the discharge side of the compressors	2,000 kPag	60°C	Vessel/Pipe source (catastrophic rupture)	• 0.5 m^3 vessel rupture • 1 m^3 vessel rupture • 2 m^3 vessel rupture

Large diameter pipeline full bore ruptures are modelled as an equivalent pipe diameter representing a double ended break in the pipeline.

Bibblewindi to Leewood medium pressure gas pipeline

Scenarios modelled for consequence analysis of the Bibblewindi to Leewood medium pressure gas pipeline are show in in Table 2-8 (at a temperature of 25 C).

Table 2-8 Bibblewindi to Leewood medium pressure gas pipeline modelling scenarios

Bibblewindi to Leewood Gas Pipeline	Pressure	Phast Risk 6.7 model	Intervals	Gas Flowrate	Scenario
Leaks from intermediate pressure transmission line	2,000 kPag	Vessel / Pipe source (leak)	N/A	N/A	• 10 mm hole • 50 mm hole • 100 mm hole
Rupture of intermediate pressure transmission line	2,000 kPag	Vessel / Pipe source (long pipeline)	Every 500 m for 16,000 m	177,000 kg/h	• Full bore rupture

An 864 mm diameter pipeline is assumed for the Bibblewindi to Leewood medium pressure gas pipeline for the purpose of assessment.

Leewood Central Compression Facility, Water Treatment Plant and Power Generation Facility

Scenarios modelled for consequence analysis of the Leewood central gas compression facility and power generation facility are shown in Table 2-9, (modelled at 25°C and 60 C).

Table 2-9 Leewood central gas compression facility and power generation facility consequence modelling scenarios

Leewood Central Compression Facility	Pressure	Temperature	Phast Risk 6.7 model	Scenario
Leaks from pipes or vessels	2,000 kPag	25 °C	Vessel / Pipe source (leak)	• 10 mm hole • 50 mm hole • 100 mm hole
Vessel (separators, filters etc.) catastrophic failure	2,000 kPag	25°C	Vessel / Pipe source (catastrophic rupture)	• 0.5 m^3 vessel rupture • 1 m^3 vessel rupture • 2 m^3 vessel rupture
Leaks from pipes or vessels	6,500 kPag	60°C	Vessel / Pipe source (leak)	• 10 mm hole • 50 mm hole • 100 mm hole • 250 mm pipe rupture
Vessel (separators, filters etc.) catastrophic failure	6,500 kPag	60°C	Vessel / Pipe source (catastrophic rupture)	• 0.5 m^3 vessel rupture • 1 m^3 vessel rupture • 2 m^3 vessel rupture
Leaks from pipes or vessels	15,000 kPag	60°C	Vessel / Pipe source (leak)	• 10 mm hole • 50 mm hole • 100 mm hole • 200 mm pipe rupture
Vessel (separators, filters etc.) catastrophic failure	15,000 kPag	60°C	Vessel / Pipe source (catastrophic rupture)	• 0.5 m^3 vessel rupture • 1 m^3 vessel rupture • 2 m^3 vessel rupture

2.4 Bushfire risk

A desktop bushfire risk assessment was undertaken for the project. The bushfire risk assessment was undertaken based on a review of information provided by the proponent and complimented by information obtained from publically available information sources. It considered the potential bushfire risk factors associated with a fire being started through the construction and operation of the proposal.

Bushfire hazard is identified according to the NSW Rural Fire Service (NSWRFS) (NSWRFS 2006) as:

> 'The potential severity of a fire. Usually measured in terms of intensity (kW/m), the factors that influence a bushfire hazard include climate and weather patterns, vegetation (fuel quantity, distribution and moisture) and slope'.

Likelihood and consequence, when applied to a bushfire risk assessment for the project, are described below.

Likelihood refers to the potential that a bushfire might occur from a project related activity. It assumes that a sequence of steps occurs including ignition, spread / growth and intensification and impact upon at-risk values. The likelihood of a bushfire impact event is the product of the likelihood of each of the steps occurring.

Physical environmental factors that can influence bushfire risk include:

- Vegetation / fuel factors such as:
  - where fuels are
  - how extensive they are
  - how flammable they are
  - what fire behaviour they can give rise to
  - how contiguous fuels are (which influences how large a fire can get)
  - what fire ignition potential exists
  - the degree to which local climate / weather factors influence fire seasonal patterns and behaviour.
  - vegetation cover in the surrounding landscape
  - proximity of woody / forested vegetation to an asset or ignition source
- spotting and ember attack potential of vegetation
- land management practices on adjoining land
- topography and access within and surrounding the site
- potential ignition sources within the site
- detection of new ignitions
- initial and sustained attack capacity.

Some or all of the factors can vary significantly across the project area.

Consequence refers to the potential adverse outcomes associated with the scale and impact of a bushfire on life and property.

The level of consequence arising from a bushfire impact event will be driven by:

- the scale of the bushfire hazard (size, intensity and the scale of the impact zone)
- the degree of exposure of at-risk values
- how vulnerable to damage / loss the at-risk values are
- capability
- occupational health and safety (staff and public).

The most significant potential consequences would be loss of life or injuries to persons and long term environmental impacts. Indirect or secondary impacts may occur such as adverse social or economic impacts. Such impacts include the loss of community infrastructure, impacts on agricultural and commercial livelihoods, and associated effects on the local economy if operations were required to temporarily close.

Under adverse conditions a fire could spread at high intensity before it could be controlled, and potentially impact local roads (and vehicles using local roads), people in the open undertaking work or recreation pursuits in local forests / bushland, or spread on to private property potentially impacting assets / people living or working in those locations.

The risk matrix used in the hazard assessment is shown in Figure 2-2. Consequence levels and descriptors are listed in Table 2-1, with likelihood levels and descriptors listed in Table 2-2.

The likelihood and consequence was considered for the risks of a bushfire igniting from a project related activity and impacting on life and property.

The analysis considered the existing mitigation measures as well as addition measures to mitigate the risk to as low as is reasonably practicable (based on the ALARP principle as described in Section 2.3.4).

2.5 Technical assumptions for consequence modelling

2.5.1 Inventory and duration of gas releases

A series of emergency shutdown valves, non-return valves and / or manual isolation valves may limit the quantity of gas that can be released in a loss of containment scenario. The rate of gas released during a loss of containment event would then reduce as the system loses pressure.

For life safety calculations, isolation and depressurisation happen too slowly to significantly alter outcomes. Immediate impacts occur prior to isolation and depressurisation. For delayed impacts, a gas cloud is assumed to have reached a steady state (which is a worst case scenario) prior to the effects of isolation and blowdown becoming apparent.

As escape from process areas is not particularly limited in a small, mainly ground level plant. Therefore, the escalation of events to adjacent inventories is not assumed to impact on life safety risks.

2.5.2 Release scenario outcomes

The outcomes modelled are provided in Table 2-10.

Table 2-10 Scenario Outcomes

Scenario	Outcomes
Leak or rupture of pipeline	• Jet fire (Immediate ignition of gas) • Flash fire (Delayed ignition of gas in unconfined area) • Explosion (Delayed ignition of gas in confined area)
Catastrophic failure of vessel	• Fireball (Immediate ignition of gas)

2.5.3 Release direction and distribution

A release of gas can be directed vertically upwards, horizontally or downwards. It can also impinge upon nearby items.

An above ground release from gas compression facilities and pipework is assumed to be directed horizontally resulting in the furthest impact distances. This gives the worst case scenario. It has been assumed that all above ground releases occur from pipework that is one metre above ground level.

An underground release is assumed to be directed horizontally and will impinge upon trench walls. Impingement is modelled at 25 per cent of the original jet velocity. This is the default setting in Phast Risk 6.7.

A loss of containment (LOC) from the gathering lines or the medium pressure gas line from Bibblewindi to Leewood will have different consequences depending on the location of the LOC. This is due to the loss of pressure as the gas moves through the pipelines, as well as the size of the gas inventories upstream and downstream of the LOC. Modelling at various locations along the length of the pipelines was completed to account for the variation in consequence effects depending on the release location.

2.5.4 Materials of construction

The gas gathering lines from wells to the Bibblewindi and Leewood gas compression facilities are assumed to be constructed from high density polyethylene (HDPE) and have a pipe roughness of 1.5×10^{-5} mm (Green 2007).

The medium pressure gas transfer pipeline from Bibblewindi to Leewood, and all above ground piping, are assumed to be constructed from carbon steel and have a pipe roughness of 4.6×10^{-5} metres, which is the Phast Risk 6.7 default parameter for commercial steel.

2.5.5 Vapour cloud explosions

It is possible that gas from an unignited leak can gather at a congested plant area, forming a cloud. If the gas cloud were to find an ignition source a Vapour Cloud Explosion (VCE) would occur.

An area of congestion has been assumed at the Bibblewindi in-field compression station and the Leewood central gas compression facility. All other areas (wellheads, gathering lines etc.) are assumed to be sufficiently open and do not have areas of congestion that may lead to VCE.

The area of congestion at the Bibblewindi in-field gas compression facility is outlined in red in Figure 2-5.

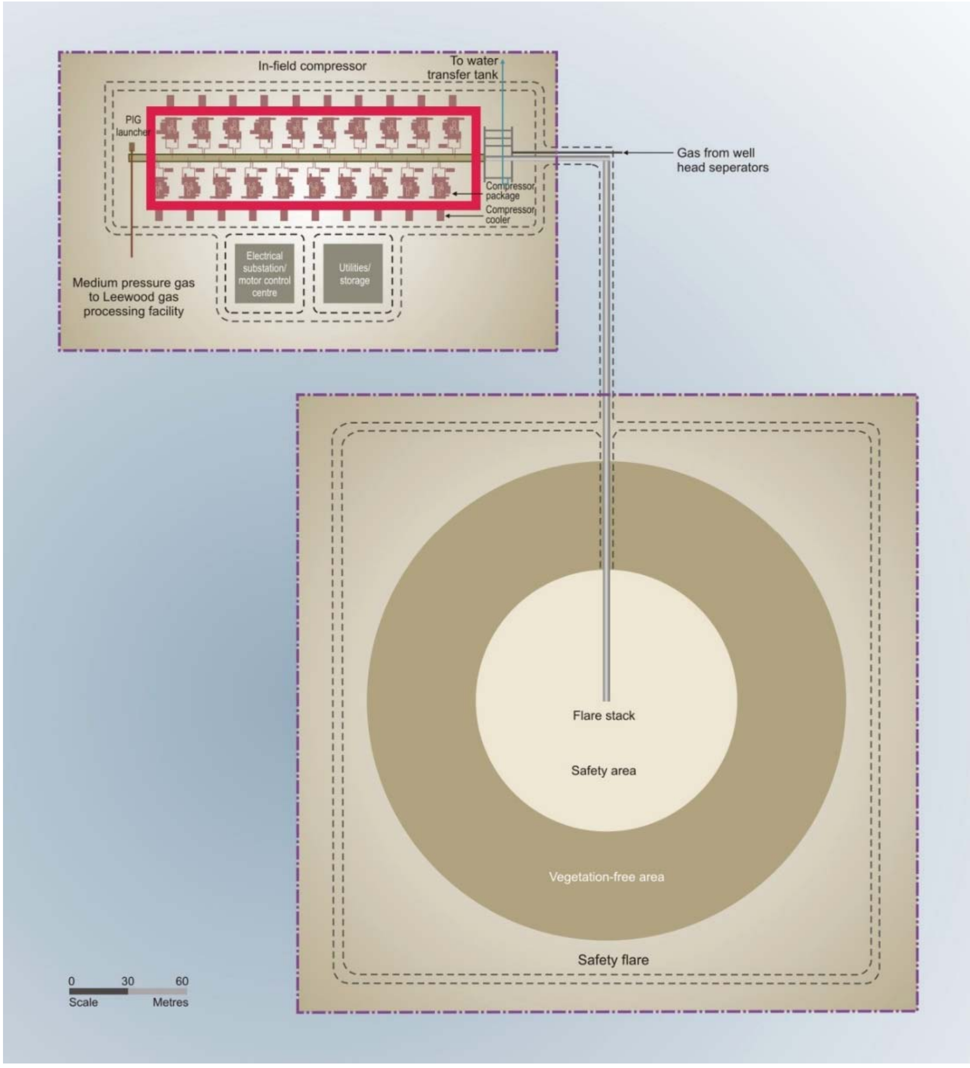

Figure 2-5 Area of congestion at the Bibblewindi in-field gas compression facility

With respect to Figure 2-5, it has been assumed that within the confined area, 35 percent of the volume is occupied by pipework and equipment. This is based on an estimate of the pipe diameter and equipment dimension with respect to the overall volume of space in the area of the compressors.

An area of congestion at the Leewood central gas compression facility is denoted in red on Figure 2-6. With respect to Figure 2-6, it has been assumed that within the confined area, 37 percent of the volume is occupied by pipework and equipment. This is based on an estimate of the pipe diameter and equipment dimensions with respect to the overall volume of space in the area highlighted.

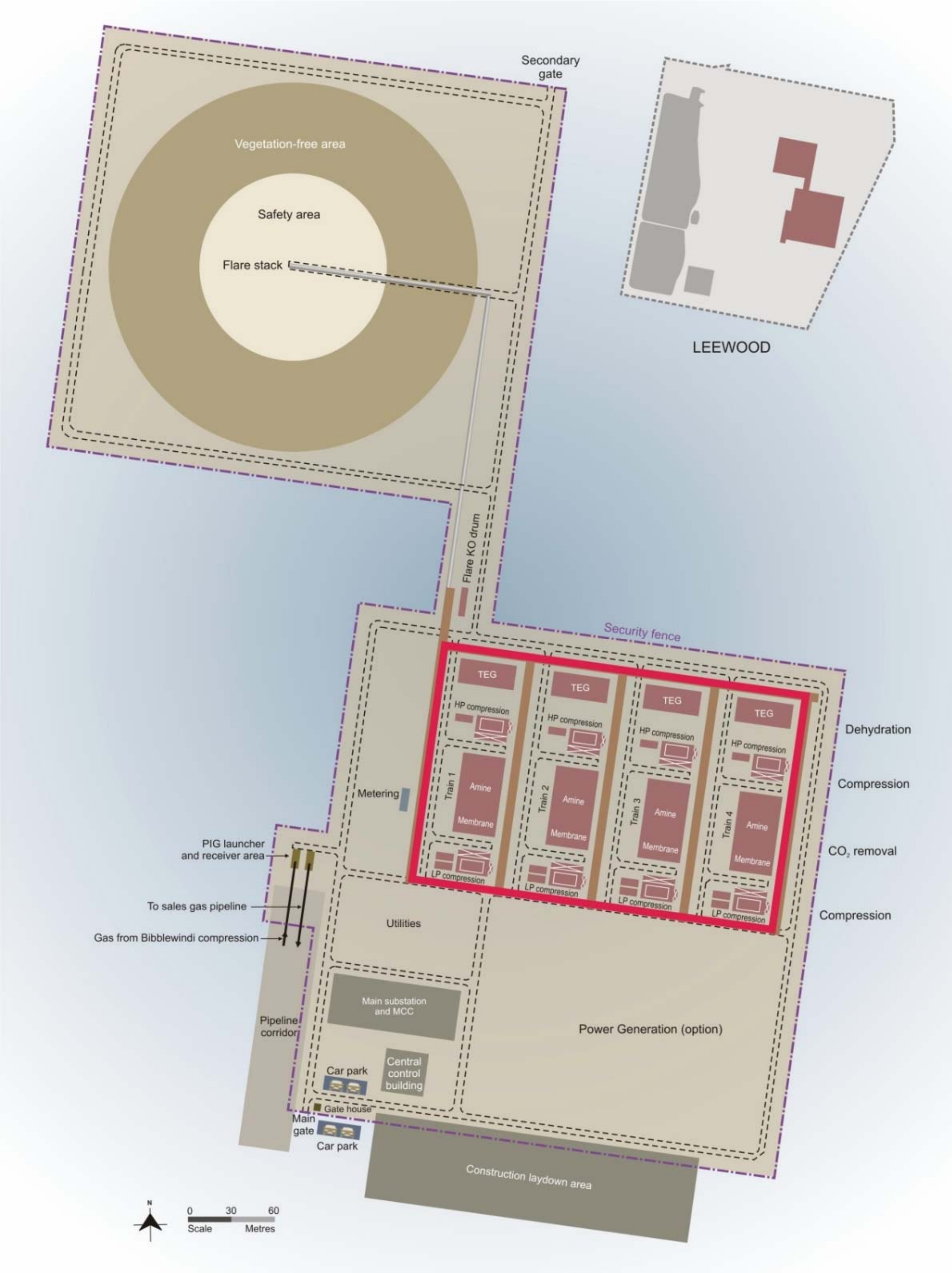

Figure 2-6 Area of congestion at the Leewood Central Gas Compression Facility

VCEs were modelled using the Multi Energy (ME) explosion model because it is widely accepted method used throughout the process industry and generally produces conservative results. The ME model is an empirical method based on experimental, observational and analytical data on fuel-air explosions.

2.5.6 Meteorological

Model input assumptions are provided in Table 2-11.

Table 2-11 Meteorological conditions

Property	Value	Justification
Temperature	25ºC	Standard ambient atmospheric temperature
Atmospheric Pressure	101,325 Pa	Standard ambient atmospheric pressure
Humidity	57%	Average of 2008-2012
Surface Roughness	0.5 m	Phast Risk 6.7 default parameter for “Parklands, bushes, numerous obstacles”

Consequence modelling was undertaken using three representative weather scenarios. The outcomes to be modelled are shown in Table 2-12.

Table 2-12 Atmospheric Conditions

Weather name	Wind Speed	Pasquill atmospheric stability	Pasquill atmospheric stability description	Relative occurrence at Bibblewindi & Leewood
A1	1 m/s	A	Very unstable – sunny, light winds	3-5%
D3.5	3.5 m/s	D	Neutral – little sun and high wind or overcast/windy night	5-10%
F1	1 m/s	F	Stable – night with moderate clouds and light/moderate wind	39-46%

2.5.7 Effect heights

The effects of a fire or explosion vary depending on the height above ground level. A value of 1.5 metres has been used to report all flammable effect results as this is representative of a person in a range of postures.

2.5.1 Other Phast Risk 6.7 parameters

Unless stated above, all other parameters have used the default setting in Phast Risk 6.7.

3. Legislative context

3.1 New South Wales Work Health and Safety legislation

The *Work Health and Safety (Mines and Petroleum Sites) Act 2013* (the WHS (Mines and Petroleum Sites) Act) and the *Work Health and Safety (Mines and Petroleum Sites) Regulation 2014* (the WHS (Mines and Petroleum Sites) Regulation) applies to petroleum sites as at 1 February 2016.

These laws, together with the *Work Health and Safety Act 2011* (WHS Act) and the *Work Health and Safety Regulation 2011* (WHS Regulation), regulate health and safety at workplaces where petroleum operations are carried out in NSW.

The new WHS (Mines and Petroleum Sites) laws replaced the operation of the *Schedule of Onshore Petroleum Exploration and Production Safety Requirements* (the PO Schedule) under the *Petroleum (Onshore) Act 1991*. The PO Schedule had been the primary means to address the specific work, health and safety elements associated with petroleum operations. The WHS (Mines and Petroleum Sites) laws provide for:

- a consistent and robust single WHS regulatory framework that applies to onshore petroleum sites
- specific risks associated with petroleum activities to be appropriately addressed through a modern WHS framework, consistent with the minerals sector
- proactive regulatory oversight of industry's management of the risks associated with a petroleum operation.

The new WHS (Mines and Petroleum Site) laws align with and build on the WHS Act and the WHS Regulation. Risks associated with both mining and petroleum operations can be managed in the same way, with specific provisions included to address the particular risks associated with either mining or petroleum operations, if necessary.

The NSW *Work Health and Safety Regulation 2011* expands on the requirements of the WHS Act. Chapter 9 of the regulation (Major Hazard Facilities) outlines the threshold quantities of designated hazardous chemicals that would deem a facility a Major Hazard Facility. As the quantities of the designated hazardous chemicals do not exceed the thresholds, the facility is not considered to be a Major Hazard Facility, and therefore, does not require a safety report.

There are no specific requirements to be fulfilled during the PHA, as outlined in the WHS Act. The project will comply with the WHS Act, the WHS (Mines and Petroleum Sites) Act and the WHS (Mines and Petroleum Sites) Regulation.

3.2 New South Wales Petroleum (Onshore) Act

The NSW *Petroleum (Onshore) Act 1991* regulates onshore exploration and production of petroleum (i.e. oil and gas). It guides petroleum operations in relation to environment, safety, Cultural / European heritage, royalties, compensation and other issues. Section 128 of the Act requires all petroleum exploration operations are undertaken in accordance with the provisions of the WHS Act.

The NSW *Petroleum (Onshore) Regulation 2016* made under the *Petroleum (Onshore) Act 1991* amended the *Petroleum (Onshore) Regulation 2007* to better align the administrative and regulatory landscape in NSW with that of the mining sector.

The project will comply with the *Petroleum (Onshore) Act 1991* and *Petroleum (Onshore) Regulation 2016.*

3.3 New South Wales Department of Planning & Environment

The project is subject to the assessment and approval provisions of Division 4.1 of Part 4 of the EP&A Act. The Secretary of the Department has required that this EIS address Public Safety as outlined in Section 1.6.2. This report addresses that requirement.

Health impacts associated with the proposal are addressed separately in the Health Impact Assessment (refer to EIS Appendix T2 - EnRisks 2016).

3.4 NSW Rural Fires Act 1997

The following sections of this act are relevant to consideration of risk and mitigation strategies.

Under Section 63 of this Act land owners and occupiers have a duty to take steps to prevent fires occurring and spreading from property under their management:

Duties of public authorities and owners and occupiers of land to prevent bush fires

63 Duties of public authorities and owners and occupiers of land to prevent bush fires

(1) It is the duty of a public authority to take the notified steps (if any) and any other practicable steps to prevent the occurrence of bush fires on, and to minimise the danger of the spread of a bush fire on or from:

(a) any land vested in or under its control or management, or

(b) any highway, road, street, land or thoroughfare, the maintenance of which is charged on the authority.

(2) It is the duty of the owner or occupier of land to take the notified steps (if any) and any other practicable steps to prevent the occurrence of bush fires on, and to minimise the danger of the spread of bush fires on or from, that land.

(3) A public authority or owner or occupier is liable for the costs incurred by it in performing the duty imposed by this section.

(4) The Bush Fire Co-ordinating Committee may advise a person on whom a duty is imposed by this section of any steps (whether or not included in a bush fire risk management plan) that are necessary for the proper performance of the duty.

Under Section 64 of this Act land owners and managers must take steps to extinguish ignitions and notify fire authorities.

64 Occupiers to extinguish fires or notify firefighting authorities

(1) If a fire (not being a fire or part of a fire lit under the authority of this Act or any other Act) is burning on any land at any time during a bush fire danger period applicable to the land the occupier of the land must:

(a) immediately on becoming aware of the fire and whether the occupier has lit or caused the fire to be lit or not, take all possible steps to extinguish the fire, and

(b) if the occupier is unable without assistance to extinguish the fire and any practicable means of communication are available, inform or cause to be informed an appropriate officer of the existence and locality of the fire if it is practicable to do so without leaving the fire unattended.

4. Hazard and risk assessment

4.1 Facilities assessed

The hazard and risk assessment was conducted for the following three project facilities:

1. Well pads and gas gathering lines
2. In-field gas compression at Bibblewindi including the medium pressure gas transfer pipeline between Leewood and Bibblewindi
3. The Leewood central gas compression facility, water treatment facility and optional power generation facility.

The results of the preliminary risk screening, PHA and bushfire risk assessment are presented below.

4.2 Preliminary risk screening

The purpose of the preliminary risk screening is to determine the likely risks to public safety. Due to the regional location of the facilities there are no adjacent industrial facilities that would require the preliminary risk screening to include risks to property.

The determination of whether a facility represents a 'potentially hazardous industry' as defined by SEPP 33 is based on the quantities and storage location of dangerous goods at the site.

The following sections outline the dangerous goods to be stored or produced at the facilities and a determination as to whether they represent a 'potentially hazardous industry', which then requires a Preliminary Hazard Analysis to be undertaken.

4.2.1 Well pads and gas gathering lines

The proposed inventory of dangerous goods to be stored or produced at the well pads and gas gathering lines during operation are provided in Table 4-1.

Table 4-1 Dangerous goods inventory and screening – Well pads and gas gathering lines during operation

Chemical	UN Number	Class	Packing Group	Anticipated Maximum Quantity on site	Threshold
Methane	1971	2.1 Flammable Gas	N/A	See Note A	Varies depending on quantity – minimum is 0.5 T

Note A: Methane will be present within the pipework and vessels at the well pad and gas gathering lines during their operational life. It is therefore not feasible to determine the exact quantity on site at this stage in the project lifecycle. As the purpose of Risk Screening is to determine if a PHA is required, and a PHA is being conducted anyway, it is not deemed necessary to estimate the exact quantity.

For the preliminary risk screening, a conservative approach has been adopted to consider the well pads and gas gathering lines carrying methane as 'potentially hazardous industry' regardless of their distance from sensitive receivers or the location of the dangerous goods from the site boundary. Therefore a PHA has been conducted and can be found in Section 4.3.

During the construction and drilling of wells, chemicals are used at the well site. Many of the chemicals used have broader uses in other applications such as in fertilisers, in paper and glass manufacturing, in medicine or in common food products. The compounds would be transported to the well pad in accordance with regulatory requirements.

Table 4-2 provides a list of the typical components of drilling fluids, with potential products identified for use in both primary and secondary (as required) drilling fluids. Similar products may be substituted for those listed based on the suppliers, market availability and product improvement at the time of drilling. All drilling additives would be tested by a NATA-certified laboratory and demonstrated to meet the Australian Drinking Water Guidelines for benzene, toluene, ethyl benzene or xylene (BTEX) compounds.

Table 4-2 Typical components of drilling fluids

Product use	Chemical name	Alternative product use
Primary drilling fluids		
Base fluid	Water	NA
Inhibitor Reduces reactivity and swelling of shales and clays from water based drilling fluids	Copolymer of acrylamide and sodium acrylate Potassium chloride Polyalkylene Silicic acid, potassium salt	Absorbent (e.g. baby nappies) Medical and pharmaceutical uses Additives used in cleaning solutions Salt substitute Silica gel moisture absorption
Fluid loss stabiliser Prevents formation water from entering the well by blocking pores in the permeable / fractured rock	Glyoxal Starch Sodium carboxymethyl cellulose	Coating in textile and paper industries. Thickening agent and stabilizer used in food industry
Biocide / Antimicrobial Prevents bacteria forming within water and / or corrosion occurring	Pentanedial / Glutaraldehyde Methanol Dazomet	Steriliser for medical equipment Cosmetic and pharmaceutical industries Soil fumigant in agricultural industry.
pH stabiliser Used to optimise the pH value of the drilling fluid	Sodium hydroxide Sodium carbonate	Slaked lime Water softener
Viscosifier Assist in cooling and lubricating the drill bit and lifting cuttings from the well	Xanthum gum	Thickening agent and stabiliser used in food and cosmetics industries
Defoamer Removes trapped air and / or gas from drilling fluids	Ethylene oxide/propylene oxide copolymer Polypropylene glycol	Steriliser for medical equipment Antifreeze used by food and pharmaceutical industry
Weight additive Maintains well stability	Sodium chloride	Salt Sterile solution used in medicine
Secondary drilling fluids		
Inhibitor Reduces reactivity and swelling of shales and clays from water based drilling fluids	Copolymer of acrylamide and potassium acrylate	Water gel crystals used in horticulture
Fluid loss stabiliser Prevents formation water from entering the well by blocking pores in the permeable / fractured rock	Almond hulls Walnut hulls Cellophane Wood fibre Calcined petroleum coke	Fibre source used in agricultural industry Cosmetic industry Food packaging industry Paper industry Aluminium and steel production

Product use	Chemical name	Alternative product use
pH stabiliser Used to optimise the pH value of the drilling fluid	Calcium carbonate	Antacid pharmaceutical
Weight additive Maintains well stability	Bentonite Crystalline silica, cristobalite Crystalline silica, quartz Crystalline silica, tridymite	Absorbent (kitty litter) Glass manufacturing

Table 4-2 are not considered dangerous goods by the Australian Dangerous Goods Code. Therefore, they are removed through the preliminary risk screening process. Those that are classified as Dangerous Goods and their inventories are listed in Table 4-3.

It is anticipated that the drilling chemicals would be stored at the Narrabri Operations Centre and supplied to drilling locations as required.

Table 4-3 Dangerous goods inventory – Drilling Fluids

Chemical	UN Number	Class	Packing Group	Anticipated Maximum Quantity on site	
				Drill Site	Narrabri Operations Centre
Glutaraldehyde	3265	8 Corrosive Liquid, Acidic, Organic N.O.S.	III	1,200 L	6,000 L
Methanol	1230	Class 3 Flammable Liquid Subsidiary risk: 6.1 Toxic Substances	II	70 L	350 L
Sodium Hydroxide	1824	8 Corrosive Substances	II	800 kg	4,000 kg

The biocide / antimicrobial (glutaraldehyde) may be classified as a Class 8 PG III Corrosive Acidic Organic Liquid, and the methanol is a Class 3, PG II Flammable Liquid. The SEPP 33 threshold for these two materials is 50 tonnes for Class 8 and 10 tonnes for Class 3, respectively.

Sodium hydroxide used in pH stabilisation is a Class 8 PG II Corrosive Liquid with a SEPP 33 threshold of 25 tonnes. It is stored at the drill site and the Narrabri Operations Centre.

The quantity of these three materials do not approach the thresholds provided in SEPP 33, therefore they are not necessary to include in the PHA.

Some drilling operations require additional information to be collected from the wellbore using formation evaluation tools. These tools are typically lowered into the wellbore using wireline and can be used to help verify the quality of the reservoir by collecting subsurface data on lithology, pressure, porosity and acoustic response. These data logs are important to assist with the setting of casing strings to achieve the isolation requirements of the well casing and cement. Depending on the logging activity to be undertaken, logging sources may use a live source such as caesium or beryllium, whilst others use passive sensors that detect or use magnetics as a source to gather information.

Caesium (also referred to as caesium-137 or CS-137) is a Class 7 Dangerous good and is used in density measuring devices that are used to monitor and measure various activities during the drilling and well completion processes. CS-137 is one of the most common radioisotopes used in industry and is used in a range of applications including medical applications such as radiotherapy. CS-137 is used in minute amounts in sealed stainless steel capsules, referred to as encapsulated devices, which are removed from the well after the well logging procedure is complete. In NSW, the use of CS-137 is governed by the *Radiation Safety Act 1990* and the *Radiation Control Regulation 2013* with oversight and enforcement from the NSW Environment Protection Authority (EPA).

Both the well logging company and the individual technicians using the device are required to be licensed, and when not in use, the material is securely stored in lead and concrete lined canisters.

There are no quantity thresholds to meet under the requirements of SEPP 33 for Class 7 dangerous goods and therefore CS-137 is not necessary to include in the PHA.

4.2.2 Bibblewindi facility

The proposed inventory of dangerous goods to be stored or produced at Bibblewindi are provided in Table 4-3.

Table 4-4 Dangerous goods inventory – Bibblewindi Facility

Chemical	UN Number	Class	Packing Group	Anticipated Maximum Quantity on site
Methane	1971	2.1 Flammable Gas	N/A	See Note A
Hydraulic oil	See Note B	3 Flammable Liquids	III	400 L
Lubricating oils	See Note B	3 Flammable Liquids	III	500 L
Cleaning and solvents	See Note C	3 Flammable Liquids	III	Negligible
Corrosion inhibitor	See Note B	3 Flammable Liquids	III	6,000 L (5.7 tonne)
Oxygen	1072	2.2 Non-flammable, non-toxic gases	N/A	16 x 7.2 m^3 G Cylinders (0.16 tonne)
Acetylene	1001	2.1 Flammable Gases	N/A	16 x 7.2 m^3 G Cylinders (0.13 tonne)
Compressed Nitrogen	1066	2.2 Non-flammable, non-toxic gases	N/A	32 x 7.2 m^3 G Cylinders (0.29 tonne)

Note A: *Methane will be present within the pipework and vessels throughout the site, but is not stored in a single location. It is therefore not feasible to determine the exact quantity on site at this stage in the project lifecycle. As the purpose of Risk Screening is to determine if a PHA is required, and a PHA is being conducted anyway, it is not deemed necessary to estimate the exact quantity.*

Note B: *The exact hydraulic and lubricating oils will be determined during detailed design, however the Dangerous Goods Class and Packing Group are expected to be as above.*

Note C: *Various cleaning agents and solvents are expected to be used for maintenance purposes. The quantity is expected to be negligible compared to the thresholds for Risk Screening.*

For the preliminary risk screening, the total quantity of dangerous goods to be stored at the Bibblewindi in-field gas compression facility and the thresholds from SEPP 33 are shown in Table 4-5.

Table 4-5 Dangerous goods screening – Bibblewindi facility

Class	Packing Group	Quantity stored	Threshold
2.1 Flammable Gases	N/A	See Note A	Varies depending on quantity – 0.5 T required to be 30 m from boundary assuming the facility has sensitive receivers nearby
2.2 Non-flammable, non-toxic gases	N/A	1 tonne	No limit
3 Flammable Liquids	III	32 tonnes	Storage must 10 m from nearest boundary based on storage quantity and assuming the facility has sensitive receivers nearby

Note A: *Methane will be present within the pipework and vessels throughout the site, but is not stored in a single location. It is therefore not feasible to determine the exact quantity on site at this stage in the project lifecycle. As the purpose of Risk Screening is to determine if a PHA is required, and a PHA is being conducted anyway, it is not deemed necessary to estimate the exact quantity.*

The process equipment containing methane at the Bibblewindi in-field gas compression facility is greater than 30 metres from the site boundary. However, a conservative assumption has been made to consider the Bibblewindi in-field gas compression facility as ‘potentially hazardous industry’ regardless of the proximity of the equipment to the site boundary. Therefore, a PHA has been conducted to further assess the risk the Class 2.1 Flammable Gas poses to surrounding land users. This PHA can be found in Section 4.3.

A quantity of 32 tonnes of Class 3 Packing Group III Flammable Liquids would be considered ‘potentially hazardous industry’ if it was present 10 metres from the facility boundary in areas where there are sensitive receivers. Hydraulic oil and lubricating oil storage tanks will be at least 10 metres from the facility boundary whilst the nearest sensitive receptor to the Bibblewindi facility is approximately 5 km away, therefore on the basis of Class 3 Flammable Liquids, the Bibblewindi in-field gas compression facility is not potentially hazardous.

4.2.3 Leewood facility

The proposed inventory of dangerous goods to be stored at the Leewood facility is provided in Table 4-6. These inventories are inclusive of the dangerous goods proposed for use at the central gas compression facility, power generation facility and water treatment plant.

Table 4-6 Dangerous goods inventory – Leewood facility

Chemical	Purpose	UN Number	Class	Packing Group	Anticipated Maximum Quantity on site	Usage
Methane	Product	1971	2.1 Flammable Gas	N/A	See Note A	Continuous
Hydraulic oil	Hydraulic systems	See Note B	3 Flammable Liquids	III	10 tonne	Continuous
Lubricating oils	Lubrication systems	See Note B	3 Flammable Liquids	III	10 tonne	Continuous
Cleaning and solvents	Maintenance use	See Note C	3 Flammable Liquids	III	Negligible	Continuous
Corrosion inhibitor	Water conditioner	See Note B	3 Flammable Liquids	III	6,000 L (5.7 tonne)	Continuous
Oxygen	Maintenance use	1072	2.2 Non-flammable, non-toxic gases	N/A	16 x 7.2 m^3 G Cylinders (0.16 tonne)	Continuous
Acetylene	Maintenance use	1001	2.1 Flammable Gases	N/A	16 x 7.2 m^3 G Cylinders (0.13 tonne)	Continuous
Compressed Nitrogen	Maintenance use	1066	2.2 Non-flammable, non-toxic gases	N/A	32 x 7.2 m^3 G Cylinders (0.29 tonne)	Continuous
Sodium Hypochlorite 10 %wt / wt	Water treatment chemical	1791	8 Corrosive Substances	III	28 m^3 (37 tonne)	Intermittent
Aqueous Ammonia 25 % wt / wt	Water treatment chemical	2672	8 Corrosive Substances	III	1.5 m^3 (1.4 tonne)	Intermittent
Sodium Bisulphite 33 % wt / wt	Removal of chlorine	2693	8 Corrosive Substances	III	3.5 m^3 (4.8 tonne)	Intermittent
Hydrochloric Acid 33 % wt / wt	Chemical Clean in Place (CIP)	1789	8 Corrosive Substances	II	65 m^3 (75 tonne)	Intermittent
Sulphuric Acid 98 % wt / wt	Chemical Clean in Place (CIP)	1830	8 Corrosive Substances	II	< 1 m^3 (1.85 tonne)	Intermittent
Caustic Soda 30 % wt / wt	Membrane filtration CEB/CIP	1824	8 Corrosive Substances	II	19 m^3 (25 tonne)	Intermittent
Biocide (Nalco 7330) Isothiazolinone (See Note D)	Inhibition of bacterial growth	2922	8 Corrosive Substances Subsidiary risk: 6.1 Toxic Substances	III	9 m^3 (11 tonne)	Intermittent

Chemical	Purpose	UN Number	Class	Packing Group	Anticipated Maximum Quantity on site	Usage
Biocide (Osmocide) 2,2-dibromo-3-nitrilopropionamide (See Note D)	Inhibition of bacterial growth	2922	8 Corrosive Substances Subsidiary risk: 6.1 Toxic Substances	III	9 m^3 (12 tonne)	Intermittent
Kuriverter IK-110 Biofilm control agent (See Note D)	Biofilm removal	3266	8 Corrosive Substances	III	9 m^3 (11 tonne)	Intermittent
Tertiary Amines e.g. Ucarsol AP Solvent	CO_2 removal	See Note B	8 Corrosive Substances	II	10 tonne	
Osmoclean DW Sodium Hydroxide, EDTA	Chemical Clean in Place (CIP)	1824	8 Corrosive Substances	II	1 tonne	Intermittent
Surfactant: Sodium dodecylsulphate	Chemical Clean in Place (CIP)	2926	4.1 Flammable Solid N.O.S Subsidiary risk: 6.1 Toxic Substances	II	0.2 tonne	Intermittent

Note A: *Methane will be present within the pipework and vessels throughout the site, but is not stored in a single location. It is therefore not feasible to determine the exact quantity on site at this stage in the project lifecycle. As the purpose of Risk Screening is to determine if a PHA is required, and a PHA is being conducted anyway, it is not deemed necessary to estimate the exact quantity.*

Note B: *The exact chemical is yet to be determined. The Dangerous Goods Class and Packing Group are expected to be as above.*

Note C: *Various cleaning agents and solvents are expected to be used for maintenance purposes. The quantity is expected to be negligible compared to the thresholds for Risk Screening.*

Note D: *May not be stored on the site at all times.*

For the preliminary risk screening, the total quantity of dangerous goods to be stored at the Leewood facility and the thresholds from SEPP 33 are provided in Table 4-7.

Table 4-7 Dangerous goods screening – Leewood facility

Class	Packing Group	Maximum quantity stored	Threshold
2.1 Flammable Gases	N/A	See Note A (Table 4-6)	Varies depending on quantity – 0.5 T required to be 30 m from boundary assuming the facility has sensitive receivers nearby
2.2 Non-flammable, non-toxic gases	N/A	1 tonne	No limit
3 Flammable Liquids	III	109 tonnes	Storage must 15 m from nearest boundary based on storage quantity and assuming the facility has sensitive receivers nearby
4.1 Flammable Solid N.O.S.	II	0.2 tonne	5 tonne
6.1 Toxic Substances	III	12 tonne (Note B)	2.5 tonne
8 Corrosive Substances	II	113 tonne	25 tonne
8 Corrosive Substances	III	77 tonne	50 tonne

Note A: *Methane will be present within the pipework and vessels throughout the site, but is not stored in a single location. It is therefore not feasible to determine the exact quantity on site at this stage in the project lifecycle. As the purpose of Risk Screening is to determine if a PHA is required, and a PHA is being conducted anyway, it is not deemed necessary to estimate the exact quantity.*

Note B: *Maximum quantity of biocide anticipated to be onsite*

The process equipment containing methane at Leewood central compression facility is greater than 30 metres from the site boundary, however as the exact quantities of gas are not yet known, an assumption has been made to consider Leewood as ‘potentially hazardous industry’ regardless of the proximity of the equipment to the site boundary. This requires a PHA to be conducted to further assess the risk the Class 2.1 Flammable Gas poses to surrounding land users.

A quantity of 109 tonnes of Class 3 Packing Group III Flammable Liquids would be considered ‘potentially hazardous industry’ if it was present 15 metres from the facility boundary in areas where there are sensitive receivers. Hydraulic oil, lubricating oil and corrosion inhibitor storage tanks will be greater than 15 metres from the facility boundary, therefore on the basis of Class 3 Flammable Liquids; the Leewood Compression Facility is not potentially hazardous.

Although the specific biocide used for water treatment has not yet been determined, it may represent a Class 8 Corrosive Substance, with a subsidiary risk Class 6.1 Toxic Substance. It would be present in quantities in excess of the threshold set out in SEPP 33 for Class 6.1 Toxic Substances and therefore is considered potentially hazardous industry. This requires a PHA to further assess the risk to surrounding land users and is contained within Section 4.3 of this report.

The total quantity of Class 8 Corrosive Substances at the Leewood facility are present in quantities in excess of the threshold presented in SEPP 33. This requires a PHA to further assess the risk to surrounding land users and is contained within Section 4.3 of this report.

4.2.4 Dangerous goods - Transportation

During the operational phase, some transport of dangerous goods will be required to support project activities. An estimate of the frequency of dangerous goods transport movements is provided in Table 4-8.

Table 4-8 Estimated transport movements of dangerous goods

Chemical	UN	Class	Packing Group	Movements
Heat Transfer Oils	See Note A	3 Flammable Liquids	III	1 per year
Lubricating Oils	See Note A	3 Flammable Liquids	III	1 per month
Hydrochloric Acid 33% wt / wt	1789	8 Corrosive	II	1 per week
Sulphuric Acid 98% wt / wt	1830	8 Corrosive	II	1 per week
Caustic Soda 30% wt / wt	1824	8 Corrosive	II	1 per week
Aqueous Ammonia 25% wt / wt	2672	8 Corrosive	III	1 per week
Sodium Bisulphite 33% wt / wt	2693	8 Corrosive	III	1 per week

Note A: *The exact hydraulic and lubricating oils will be determined during detailed design, however the Dangerous Goods Class and Packing Group are expected to be as above.*

For the preliminary risk screening, the total quantity of dangerous goods to be transported and the thresholds from SEPP 33 are provided in Table 4-9.

Table 4-9 Dangerous goods screening - Transportation

Class	Packing Group	Minimum Quantity for consideration	Total Annual Movements	Threshold (Cumulative Annual)	Peak Weekly Movements	Threshold (Peak Weekly)
3	III	10 tonnes	246	1000	10	60
8	All	2 tonnes	260	500	10	30

Peak weekly movements have been estimated by adding together two weeks of movements as provided in Table 4-8. The project will not result in movements of dangerous goods in excess of the thresholds presented in SEPP 33. Using SEPP 33 as a guide, a route evaluation study is not recommended.

4.2.5 Dangerous goods – Summary

A summary of the dangerous goods classes at each of the facilities and whether the estimated quantities trigger the requirement for a PHA is provided in Table 4-10. From the dangerous goods screening, Class 2.1 flammable gases (methane), Class 6.1 toxic substances (biocide), and Class 8 corrosives are present in quantities that are above the threshold quantities in SEPP 33 indicating a potentially hazardous industry, and therefore requiring a PHA.

Table 4-10 Dangerous goods screening summary

Facility	Class 2.1	Class 2.2	Class 3	Class 6.1	Class 8
Well pads	Present above threshold	N/A	Present below threshold	Present below threshold	Present below threshold
Bibblewindi	Present above threshold	Present below threshold	Present below threshold when stored away from site boundary	N/A	N/A
Leewood	Present above threshold	Present below threshold	Present below threshold when stored away from site boundary	Present above threshold	Present above threshold

Where (with reference to Table 4-10):

Present below threshold: means that dangerous goods of this Class may be present, however it is anticipated to be below threshold quantities, including distance from site boundary, and therefore does not represent a potentially hazardous industry and a PHA is not required.

Present above threshold: means that dangerous goods of this Class may be present approaching or above threshold quantities; therefore, a PHA is required.

N/A: means that dangerous goods of this Class would not be present.

4.3 Preliminary Hazard Analysis

4.3.1 Hazard identification and risk assessment

Table 4-11 lists hazards that have been identified as having potential for offsite consequences or involving dangerous goods. A complete register is attached in Appendix A that shows:

- potential causes
- potential consequences
- controls including existing field development rules, design standards and operational rules
- an estimate of the likelihood
- an estimate of their severity
- the initial risk of the hazard
- additional mitigation measures and management plans that will be implemented to mitigate the risk
- a revised estimate of their likelihood once the mitigation measures and management plans are implemented
- a revised estimate of their severity once the mitigation measures and management plans are implemented
- the revised (residual) risk of the hazard.

The initial risk is the risk taking into consideration controls that are known to be included in the design of the proposed project and project facilities. These include existing field development rules, design standards and operational procedures.

The residual risk is the risk that remains after additional mitigation measures and management controls have been implemented to reduce the likelihood of the hazard occurring, or to reduce the consequences of the hazard were it to occur.

Table 4-11 Hazards with Potential for Offsite Consequences or involving Dangerous Goods

Unwanted Event	Project Phase	Residual Risk
Sudden loss of containment of significant quantities of water resulting from a catastrophic failure of pond wall	Operation	Very Low
Uncontrolled loss of containment of small quantity (less than 100 L) of liquid chemicals or dangerous goods	Construction & Operation	Very Low
Uncontrolled loss of containment of large quantities (greater than 100 L) of liquid hydrocarbons	Construction & Operation	Low
Uncontrolled loss of containment of large quantities (greater than 100 L) of liquid chemicals or dangerous goods	Construction & Operation	Low
Uncontrolled loss of containment of gas from wellhead and wellhead equipment. Potential for fire or explosion.	Operation	Very Low
Uncontrolled loss of containment of gas from underground gathering lines (low pressure). Potential for fire or explosion.	Operation	Very Low
Uncontrolled loss of containment of gas from underground Bibblewindi to Leewood pipeline (medium pressure). Potential for fire or explosion.	Operation	Low
Uncontrolled loss of containment of gas from facilities (Leewood). Potential for fire or explosion.	Operation	Very Low
Uncontrolled loss of containment of gas from facilities (Bibblewindi). Potential for fire or explosion.	Operation	Very Low

Table 4-11 reports the residual risk only, and for the unwanted events identified the residual risk is either low or very low. As shown in Appendix A, some of the unwanted events have a medium initial risk, taking into consideration controls including inherent design standards and operational practices. The residual risk would be reduced to low or very low by implementation of the recommended site / activity specific mitigation measures / management plans that would be undertaken during the design phase of the project.

These risks can be broadly split into the following three categories.

A sudden loss of containment of significant quantities of water resulting from a catastrophic failure of a pond wall

The risk of a pond bursting or overtopping resulting in an offsite safety consequence was assessed qualitatively as very low on the basis that the ponds are designed to Australian Standards and in accordance with guidelines set by the Australian National Committee on Large Dams (ANCOLD) and NSW Dam Safety Committee procedures and guidelines that would be followed.

The additional design and operational controls would be applied include:

- Leewood Ponds being designed to standard including primary and secondary lining, leak detection and collection and engineered spillway
- Dam Safety Committee to review design and confirm construction to specification
- Multi cell design facilitates, improves maintenance ability and limits volume released in event of failure
- Pond level and collection sump monitoring
- Shallow monitoring bores adjacent to ponds
- Work Permit System / Job Hazard Analysis

- A regular inspection and monitoring program and Dam Safety Emergency Plan to be provided to the Dam Safety Committee in accordance with legislative requirements
- Real time monitoring of collection sump levels with telemetry to a control centre.

An uncontrolled loss of containment of gas leading to a fire or explosion

Risks associated with loss of containment of methane gas have been assessed in the PHA semi-quantitatively by determining the likelihood of gas releases using industry failure data, followed by modelling of the consequences of the fire or explosion if the hazard were to occur. The likelihood and worst case consequence analysis for a release of methane gas is presented in Section 4.3.2. The semi quantitative risk assessment is presented in Section 4.3.3.

The pipelines will be the subject of a Safety Management Study that is compliant to Australian Standard AS 2885.1-2012 *Pipelines – Gas and liquid petroleum Part 1: Design and construction*. The proponent would undertake a preliminary Pipeline Safety Management Study early in the design phase to identify key engineering, design and physical controls, and then a detailed Pipeline Safety Management Study will be completed as part of the detailed design phase.

A conservative approach has been undertaken in this assessment and a PHA has been conducted for the facilities in relation to the release of Class 2.1 Flammable Gas.

An uncontrolled loss of containment of liquid chemicals or dangerous goods

Risks associated with a loss of containment of liquid chemicals were assessed qualitatively. All dangerous goods will be stored and transported in accordance with the Australian Dangerous Goods Code.

As per the preliminary risk screening undertaken in Section 4.2, it was determined that:

- no Class 3 Flammable Liquids stored at the facilities trigger the classification of a ‘potentially hazardous industry’, due to being stored away from the site boundaries; therefore, a Preliminary Hazard Analysis is not required for Class 3 Dangerous Goods
- Class 6.1 Toxic Substances trigger the requirement for a Preliminary Hazard Analysis due to the quantity of biocide to be used at the Leewood water treatment plant. This analysis is presented in Section 4.3.4.
- Class 8 Corrosive Substances are present in quantities in excess of the threshold presented in SEPP 33 therefore a Preliminary Hazard Analysis is required for Class 8 Dangerous Goods. This analysis is presented in Section 4.3.5.
- The project will not result in movements of dangerous goods in excess of the transportation thresholds presented in SEPP 33. Using SEPP 33 as a guide, a route evaluation study is not recommended.

4.3.2 Gas release likelihood and worst case consequence analysis

Gas release likelihood

In order to determine the likelihood of each of the gas release scenarios identified in Section 2.3.7, a semi quantitative analysis was performed by evaluating leak frequencies using generic leak frequency data and ignition probabilities. This frequency data was then used to interpret the risk qualitatively as per the risk matrix in Section 2.3.2.

Generic failure frequencies for above ground piping and equipment were obtained from the UK HSE hydrocarbon release database (UK HSE, 2011). This database contains up-to-date information, as all releases of hydrocarbons from the offshore industry are reported to the HSE

Offshore Division (OSD) as dangerous occurrences under the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995 (RIDDOR).

The Hydrocarbon Releases (HCR) System contains detailed voluntary information on hydrocarbon release incidents supplementary to that provided under RIDDOR and the database contains reports dating from 1 October 1992.

The UK HSE Hydrocarbon release database has been filtered to remove releases associated with exclusively offshore activities. Releases from non-process piping such as open drains were also removed from the data. A summary of generic failure frequencies from the UK HSE hydrocarbon release database is provided in Table 4-12 relating to typical equipment encountered in gas facilities.

Table 4-12 Release frequencies per annum for above ground piping and equipment

Equipment / mm	Equivalent Hole Size 10 mm	Equivalent Hole Size 25 mm	Equivalent Hole Size 50 mm	Equivalent Hole Size 100 mm	Rupture
Vessel	1.65E-3	4.39E-4	3.29E-4	7.32E-5	1.83E-4
ST Heat Exchanger – Shell side	5.04E-3	2.19E-4	2.19E-4	-	-
ST Heat Exchanger – Tube side	3.00E-3	2.40E-4	-	-	1.20E-4
Filter	3.00E-3	3.47E-4	1.73E-4	2.60E-4	-
Atmospheric Tank	1.29E-3	1.61E-4	8.03E-4	-	1.61E-4
Centrifugal Compressor	1.02E-2	1.42E-3	2.37E-4	-	-
Reciprocating Compressor	5.66E-3	1.21E-3	8.08E-4	-	-
Centrifugal Pump	7.47E-3	3.07E-4	5.12E-5	-	-
Manual Valve 20 mm	8.50E-5	1.25E-5	-	-	-
Manual Valve 50 mm	8.50E-5	1.25E-5	4.86E-6	-	-
Manual Valve 100 – 300 mm	8.50E-5	1.25E-5	7.69E-6	-	2.02E-6
Auto Valve 20 mm	7.32E-4	4.13E-5	-	-	-
Auto Valve 50 mm	7.32E-4	4.13E-5	3.26E-5	-	-
Auto Valve 100 – 300 mm	7.32E-4	4.13E-5	3.48E-5	8.69E-6	6.52E-6
Flange 20 mm	2.89E-5	1.88E-6	-	-	-
Flange 50 mm	2.89E-5	1.88E-6	2.63E-6	-	-
Flange 100 – 200 mm	4.54E-5	2.12E-6	1.82E-6	-	1.82E-6
Flange 300 – 500 mm	8.00E-5	2.00E-6	2.00E-6	-	6.00E-6
Pipe 20 mm	1.91E-4	1.79E-5	-	-	-
Pipe 50 mm	1.91E-4	1.79E-5	6.63E-6	-	-
Pipe 100 – 200 mm	5.21E-5	3.76E-6	2.35E-6	4.70E-7	3.99E-6
Pipe 300 – 700 mm	5.11E-5	4.12E-6	8.25E-7	-	3.30E-6

For underground pipelines, the failure frequencies are obtained by multiplying the pipeline length by the per unit length failure rate which directly relates to the extent of risk zones adjacent to the pipelines. Typical causes include:

- external interference
- corrosion, either internal or external
- mechanical failure, including material or weld defects created when the pipe was manufactured or constructed
- ground movement, either natural (e.g. landslide) or artificial (excavation, mining)

- operational, due to overpressure, fatigue or operation outside design limits.

Of the above causes, external interference and ground movement typically dominate pipeline rupture rates, and these have the greatest effect on risk from pipelines.

The failure rate for external interference is influenced by a number of parameters, including the pipeline wall thickness, design factor and material properties, as well as the location class, the pipeline depth of cover and the local installation of pipeline protection such as slabbing.

The failure rate for natural ground movement and for artificial ground movement depends upon the susceptibility to land sliding or subsidence at the specific location. In some cases, other causes might need to be considered in specific locations, such as the quality of girth welds, the potential for Stress Corrosion Cracking (SCC) or Alternating Current (AC) / Direct Current (DC) induced corrosion.

The Australian Pipeline Industry Association (APIA) reported for buried steel pipes an average loss of containment frequency of 0.0025 per 100 km per year (Tuft & Bonar 2009). Of these, 27 per cent represented ruptures and 73 per cent were leaks.

For buried non-steel pipes such as used in the gas gathering lines it was assumed that the same loss of containment frequency as used for buried steel pipelines would apply. This is conservative because the HDPE gathering lines are not subject to the same corrosion mechanisms as would apply to the steel pipelines.

These failure frequencies are considered reasonable assumptions to use for the project at this time on the basis of the protection measures to be adopted by the proponent in reducing the risk of damage to pipelines. Such measures include regular maintenance, pipeline monitoring and appropriate signage to alert landholders to underground infrastructure to ensure pipelines are not ruptured by activities such as excavation work.

The pipelines will be the subject of a Safety Management Study that is compliant to Australian Standard AS 2885.1-2012 *Pipelines – Gas and liquid petroleum Part 1: Design and construction*. The proponent would undertake a preliminary Pipeline Safety Management Study early in the design phase to identify key engineering, design and physical controls, and then a detailed Pipeline Safety Management Study would be completed as part of the detailed design phase.

Ignition probability

In order for a gas release to cause harm to people, the released gas must first ignite. Two scenarios of ignition are possible, immediate ignition resulting in a jet fire or delayed ignition leading to a flash fire or explosion.

The immediate ignition probability is based on the size, phase of the release and the level of reactivity of the material released. The associated probability of immediate ignition for methane (a low reactive gas) is presented in Table 4-13 as given in the Purple Book (TNO 1999).

Table 4-13 Probability of immediate ignition

Source		Ignition probability
Continuous release	Instantaneous release	Low reactive gas
<10 kg/s	<1000 kg	0.02
10-100 kg/s	1000 – 10,000 kg	0.04
> 100 kg/s	>10,000 kg	0.09

Specific point sources are then used when determining the probability of delayed ignition. Examples of these types of ignition sources are provided in Table 4-14, as per (UK HSE 2004).

Table 4-14 Delayed ignition probabilities

Category (strength of source)	Examples of ignition sources	Ignition probability
Certain	Pilot light Open flare	1
Strong	Electric motors Hot work	> 0.5
Medium	Vehicles Faulty wiring	0.5 > p > 0.05
Weak	Electrical appliances Mechanical sparks	< 0.05
Negligible	Intrinsically safe equipment Radio frequency sources	0

In order to minimise the likelihood of ignition, all electrical equipment installed within the gas processing facilities will be certified as appropriate for installation in a flammable / explosive environment. Furthermore, appropriate gas detection, isolation and blowdown systems will be designed as determined by 'safety in design' requirements throughout the project.

Gas release consequence analysis

Consequence modelling was performed for all release scenarios as described in Section 2.3.7 with potential for offsite impacts. The consequence types assessed included:

- jet fires due to immediate ignition of continuous pressurised gas releases
- flash fires due to delayed ignition of vapour clouds formed from gas releases
- fireballs due to immediate ignition from catastrophic vessel ruptures
- explosions due to delayed ignition of accumulated gas in confined areas.

The event tree for a coal seam gas release is outlined in Figure 4-1.

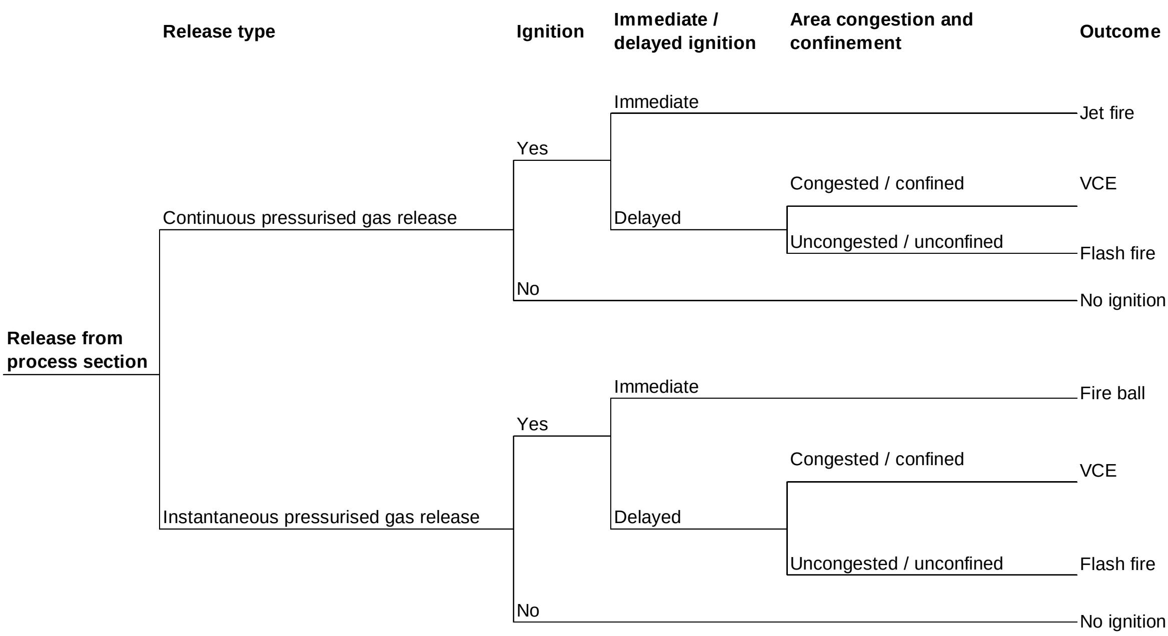

Figure 4-1 Gas release event tree

For the effects associated with each of the consequence types, refer to Section 2.3.5.

The complete results for jet fire, flash fire, fireball and explosion overpressure effect distances are provided in Appendix B. The following discussions summarise the key results from the consequence analysis.

As also noted in Section 2.3.7, the consequence modelling has been undertaken assuming no specific risk mitigation measures have been incorporated into the design. Detailed consequence and risk modelling and consequential design will be undertaken during the detailed design phase.

Weather conditions

Of the three weather conditions used in the consequence analysis, the worst case jet fire and flash fire impacts were produced under weather scenario D (i.e. 3.5 m/s conditions; refer to Table 2-12). This weather category typically represents conditions with little sun and high winds or overcast / windy nights. The higher winds act to fuel the jet flame and increase the extent of the flame, thereby causing higher impact distances compared to calmer, more stable weather conditions. In the area surrounding Bibblewindi and Leewood facilities, D 3.5 m/s conditions are experienced annually around 5 to 10 percent of the time.

Wellhead worst case consequences

A range of consequences were analysed due to releases of gas at the wellheads (refer to Appendix B). A summary of the worst case results at the wellheads is provided in Table 4-15 for jet fires and flash fires. As expected, the worst case consequence results are produced from the largest hole sizes.

Table 4-15 Wellhead Worst Case Consequences

Scenario	Jet fire 35 kW/m^2 effect distance (m)	Jet fire 4.7 kW/m^2 effect distance (m)	Flash fire effect distance (m)
100 mm hole at 620 kPag	35	50	33

The only fireball scenario assessed is a result of the catastrophic failure of a vessel. This results in a 35 kW/m^2 heat radiation effect distance of approximately 2 metres and the 4.7 kW/m^2 effect distance extends 18 metres.

No explosion overpressure analysis was performed at the wellheads as it is assumed the area is open and there is insufficient confinement and congestion to result in an explosion.

On the basis of the consequence analysis performed, consequence effect distances reach up to 50 metres downwind of the release point which is contained within the well pad area of approximately one quarter of a hectare after partial rehabilitation. Therefore, none of the wellhead scenarios analysed in this PHA has off site impacts.

Gathering lines worst case consequences

A range of consequences were analysed due to releases of gas from the gas gathering lines (refer to Appendix B).The largest release scenario from the gathering lines was represented as a full bore rupture (FBR) of the pipeline. From a rupture distance of 5 km downstream in a large diameter pipeline, the worst case jet fire results are produced towards the centre of the pipeline (between 2 and 3 km downstream). A summary of the jet fire and flash fire results at this location is provided in Table 4-16.

Table 4-16 Gathering Line Worst Case Consequences

Scenario	Jet fire 35 kW/m^2 effect distance (m)	Jet fire 4.7 kW/m^2 effect distance (m)	Flash fire effect distance (m)
Rupture of gathering line 5 km downstream at 420 kPag	57	165	79

In order to prevent offsite impact from all jet fire effects, a corridor approximately 165 metres wide would be required along the length of the pipeline. Given that this is not considered practical, it is assumed, that in the unlikely event of a jet fire from a full bore rupture of the gathering line, there will be offsite impacts.

Although effect distances up to 165 metres have been identified, this is considered conservative as the modelling software has limited capabilities for underground pipelines and therefore the safeguards such as depth of cover are not accounted for in the consequence modelling.

No explosion overpressure analysis was performed for the gathering lines as it is assumed the length of the pipelines are in open areas; therefore, there is limited ability for gas accumulation and confinement.

Bibblewindi compression facility worst case consequences

A range of consequences were analysed due to releases of gas at the Bibblewindi compression facility (refer to Appendix B). High and low pressure release scenarios were analysed at the Bibblewindi facility, assuming a low pressure of 172 kPag and a high compressed gas pressure of 2,000 kPag.

A summary of the worst case results at the Bibblewindi compression facility is provided in Table 4-17 for jet fires and flash fires. As expected, the worst case consequence results are produced from the largest hole sizes and higher pressures.

Table 4-17 Bibblewindi Compression Facility Worst Case Consequences

Scenario	Jet fire 35 kW/m^2 effect distance (m)	Jet fire 4.7 kW/m^2 effect distance (m)	Flash fire effect distance (m)
100 mm hole at low pressure of 172 kPag	22	29	16
100 mm hole at high pressure of 2,000 kPag	50	82	61

Fireballs were identified as a potential consequence of catastrophic vessel rupture at the Bibblewindi compression facility. Three volume scenarios were assessed, including 0.5 m^3, 1 m^3 and 2 m^3 vessel sizes under both the low pressure and high pressure conditions. As expected, the highest fireball effects were observed for the high pressure, largest volume vessels (2 m^3 at 2,000 kPag), whereby the 35 kW/m^2 heat radiation contour extends 11 metres and the 4.7 kW/m^2 heat radiation contour extends 49 metres.

Due to the presence of process equipment at the Bibblewindi compression facility, an area of congestion around the compressors was identified, as per Section 2.5.5, with the potential for gas accumulation leading to an explosion. As a result of a high pressure catastrophic 2 m^3 vessel rupture, an explosion overpressure of 35 kPa extends 19 metres and an overpressure of 7 kPa extends 62 metres, which is the worst case scenario analysed. In comparison, a small (0.5 m^3), low pressure vessel has a 35 kPa overpressure effect distance of 6 metres and 7 kPa effect distance of 39 metres.

In order to prevent offsite impacts from all consequences at the Bibblewindi compression facility, a distance of approximately 82 metres would be required between potential release points and the site boundary. The current site layout places the compressors at least 80 metres from the site boundary; therefore, it is possible for some consequences to have minor offsite impacts at the Bibblewindi compression facility, noting that the final location of the facility will be determined following additional modelling and micrositing using the Field Development Protocol.

Bibblewindi to Leewood gas pipeline worst case consequences

A range of consequences were analysed due to releases of gas from the Bibblewindi to Leewood gas pipeline (see Appendix B). The pipeline between Bibblewindi and Leewood compression facilities is assumed to be a length of 16 km and 864 mm diameter at 2,000 kPag.

Similar to the gathering lines, this large bore long pipeline has the largest impact distances towards the centre of the pipeline. A summary of the jet fire and flash fire results at the centre of the pipeline is provided in Table 4-18.

Table 4-18 Intermediate Gas Pipeline Worst Case Consequences

Scenario	Jet fire 35 kW/m^2 effect distance (m)	Jet fire 4.7 kW/m^2 effect distance (m)	Flash fire effect distance (m)
Rupture of Bibblewindi to Leewood intermediate gas line 8 km downstream at 2,000 kPag	139	386	161

The worst case jet fire effect distance is approximately 386 metres wide along the length of the pipeline. However, the pipeline is to be located within the existing Bibblewindi to Leewood infrastructure corridor which runs between the Bibblewindi and Leewood compression facilities through the State forest (refer Figure 1-1). The nearest sensitive receiver is greater than 2,000 metres away; therefore, it is not expected that sensitive receivers will be impacted by releases from the pipeline.

This assessment is also considered conservative as the modelling results represent the unmitigated impacts of underground pipelines and therefore the safeguards such as depth of cover are not accounted for in the consequence modelling.

No explosion overpressure analysis was performed for the Bibblewindi to Leewood gas line as the buried pipeline will be in open terrain, therefore, there is limited ability for gas accumulation and confinement to occur.

Leewood Central Gas Processing and Power Generation Facility worst case consequences

A range of consequences were analysed due to releases of gas from the Leewood central gas processing and power generation Facilities (refer to Appendix B). Two scenarios were assessed for the Leewood central gas compression facility. A pressure of 2,000 kPag was used to represent the inlet pipeline pressure and 6,500 kPag to represent the inlet pipeline pressure at the final stage of compression.

A separate environmental impact assessment for the 15,000 kPag sales gas pipeline will assess the impacts from the discharge pipeline of the final stage compressor onwards, based on the sales gas pipeline's design and operating conditions.

A summary of the worst case results for each pressure is provided in Table 4-19 for jet fires and flash fires. As expected, the worst case consequence results are produced from the largest hole sizes for each pressure.

Table 4-19 Leewood Central Gas Compression and Power Generation Facility Worst Case Consequences

Scenario	Jet fire 35 kW/m^2 effect distance (m)	Jet fire 4.7 kW/m^2 effect distance (m)	Flash fire effect distance (m)
100 mm hole at 2,000 kPag	55	84	68
Full bore rupture of a 250 mm pipeline at 6,500 kPag	183	321	222

Fireball effect distances from ruptures of high pressure (15,000 kPag), large volume (2 m^3) vessels were observed up to 39 metres at 35 kW/m^2 and 130 metres at 4.7 kW/m^2.

Similar to the Bibblewindi gas compression facility, an area of congestion and potential gas accumulation was identified around the TEG and compression facilities at Leewood (refer Section 2.5.5). From the level of confinement in this area, explosion overpressure analysis of the same fireball scenario above resulted in effect distance of 39 metres at 35 kPa and up to 125 metres for 7 kPa.

The maximum modelled effect distance is 321 metres, resulting from a full bore rupture of a 250 mm pipeline at 6,500 kPag. The nearest sensitive receptor is located around 350m to the east of the eastern boundary of the Leewood site, and is therefore, beyond the range of the worst case modelled scenario. Extensive consequence modelling will be undertaken as part of the detailed design process to ensure the final facility design meets all regulatory requirements.

4.3.3 Gas release semi quantitative risk assessment

The risk associated with a gas release is based on the combination of the release frequency, probability of immediate and delayed ignition and associated consequence distance to generate a risk result at sensitive receivers.

An assessment was made of the level of risk to sensitive receivers for the fire and explosion scenarios identified in Section 2.3.7. For this assessment the heat radiation and explosion overpressure criteria outlined in HIPAP 4 (NSW Department of Planning 2011b) was used describe the consequence effects. A semi-quantitative assessment was performed by using the data provided in Section 4.3.2 and the qualitative risk criteria as provided in Section 2.3.2. The resulting risk assessment is summarised in Table 4-20. Only the worst case release scenarios described in Section 4.3.2 are assessed against the heat radiation and explosion overpressure criteria in HIPAP 4.

All risks are assessed as having a remote probability on the basis that combining the release frequencies with ignition probabilities; all scenarios will have a frequency less often than once in 100 years.

The low frequencies estimated in the semi quantitative assessment are due to the combination of low release frequencies and low reactivity of methane. Furthermore, all electrical equipment installed within the gas processing facilities will be certified as appropriate for installation in a flammable / explosive environment resulting in low immediate and delayed ignition probabilities.

Sensitive receivers

The details regarding the location of sensitive receivers in the vicinity of the project area is provided in Section 1.4.

There are no consequences analysed that have the potential to impact sensitive receivers in the vicinity of the wellheads, gathering lines, Bibblewindi in-field gas compression facility or the Bibblewindi to Leewood gas line.

At the Leewood central gas processing facility, the two nearest sensitive receivers are located at approximately 350 metres east and 750 metres west from the facility boundaries. From the consequences assessed, the 4.7 kW/m^2 jet fire impact from a full bore rupture of the high pressure (6,500 kPag), 250 mm pipeline located well-within the facility does not have the potential to impact either of these two sensitive receivers.

The semi quantitative assessment in Table 4-20 estimates the frequency of gas release events to be in the order of 3×10^{-7} p.a., thus below the HIPAP 4 risk criteria that states incident heat flux radiation at residential and sensitive use areas should not exceed 4.7 kW/m^2 at a frequency of more than 5×10^{-5} p.a. Further in-depth assessment of this risk will be undertaken by the proponent as the design progresses and more information is available to assess the likelihood of such an event.

None of the explosion overpressure consequences reach sensitive receivers.

Table 4-20 Semi-quantitative risk assessment of gas release consequences

Location	Description of consequences/impact	Semi quantitative likelihood estimate[1]	Potential Likelihood Category	Potential Consequence for offsite impact[2]	Qualitative Risk Rating
Wellheads	Jet fire from a 100 mm hole with jet fire heat radiation of 4.7 kW/m^2 (representing second degree burns after 30 seconds exposure) extending 50 m downwind.	4.2E-08	Remote	Minor or medically treated injury, lost time injury	Very Low
	Fireball from a catastrophic failure of a vessel with a 4.7 kW/m^2 effect distance of 18 m.	1.6E-05	Remote	Minor or medically treated injury, lost time injury	Very Low
Gas gathering lines	Jet fire from a full bore rupture (FBR) at the centre of the pipeline with jet fire heat radiation of 4.7 kW/m^2 (representing second degree burns after 30 seconds exposure), extending a distance of 165 m downwind.	3.0E-07	Remote	Minor or medically treated injury, lost time injury	Very Low
Bibblewindi in-field gas compression facility	Jet fire from a 100 mm hole with jet fire heat radiation of 4.7 kW/m^2 (representing second degree burns after 30 seconds exposure) extending 82 m downwind.	4.2E-08	Remote	Minor or medically treated injury, lost time injury	Very Low
	Fireball from a catastrophic failure of a 2m^3 vessel with a 4.7 kW/m^2 (representing second degree burns after 30 seconds exposure) effect distance of 49 m.	1.6E-05	Remote	Minor or medically treated injury, lost time injury	Very Low
	Explosion from a catastrophic failure of a high pressure 2m^3 vessel with a 7 kPa overpressure (representing a 10% chance of injury) effect distance of 62 m..	1.6E-05	Remote	Minor or medically treated injury, lost time injury	Very Low
Bibblewindi to Leewood Gas Line	Jet fire from a full bore rupture (FBR) at the centre of the pipeline with jet fire heat radiation of 4.7 kW/m^2 (representing second degree burns after 30 seconds exposure), extending a distance of 386 m downwind.	3.0E-07	Remote	Minor or medically treated injury, lost time injury	Very Low
Leewood Central Gas Compression Facility and	Jet fire from a high pressure full bore rupture (250 mm pipeline at 6,500 kPag) with jet fire heat radiation of 4.7 kW/m^2 (representing second degree burns after 30 seconds exposure) extending 321 m downwind.	3.6E-07	Remote	Minor or medically treated injury, lost time injury	Very Low

Location	Description of consequences/impact	Semi quantitative likelihood estimate[1]	Potential Likelihood Category	Potential Consequence for offsite impact[2]	Qualitative Risk Rating
Power Generation Facility	Fireball from a catastrophic failure of a 2m^3 vessel with a 4.7 kW/m^2 (representing second degree burns after 30 seconds exposure) effect distance of 130 m.	1.6E-05	Remote	Minor or medically treated injury, lost time injury	Very Low
	Explosion from a catastrophic failure of a high pressure 2m^3 vessel with a 7 kPa overpressure (representing a 10% chance of injury) effect distance of 125 m.	1.6E-05	Remote	Minor or medically treated injury, lost time injury	Very Low

1: Semi quantitative estimate calculated by combining the frequency of release and the probability of ignition.

2: At location of sensitive receptors. Maximum consequence of medical treatment injury assumed as there are no sensitive receivers in the impact zone

4.3.4 Class 6.1 Biocide release

Biocide release likelihood

Biocide will be used in the Leewood water treatment process as an additive in the ion exchange stage to prevent the growth of microorganisms that may foul the micro or ultrafiltration membranes.

The exact type of biocide to be used in this process is yet to be determined, however, consistent with SEPP 33, a conservative approach was applied to assume it represents a Class 6.1 Toxic Substance. As determined in the preliminary risk screening (refer Section 4.2.3), the quantities estimated to be used at the Leewood water treatment plant will be in excess of the 2.5 tonne threshold in SEPP 33.

A biocide release may occur due to mechanical damage or equipment failure, for example, impact of the storage facility with a vehicle or degradation of piping.

To minimise the likelihood of biocide release, it will be stored at the water treatment plant in accordance with the requirements of the Australian Dangerous Goods Code.

Similar to hydrocarbon release frequencies provided in Section 4.3.2, release from atmospheric storage facilities as per the biocide has been reported by the UK HSE. Small and medium atmospheric storage tanks (including plastic) containing non-flammable liquids have failure frequencies as provided in Table 4-21 (UK HSE 2012).

Table 4-21 Small atmospheric tank failure frequencies per annum

Type of release	Failure rate (p.a.)
Catastrophic	8×10^{-6}
Large	5×10^{-5}
Small	5×10^{-4}

For biocide to pose an offsite risk, a significant (catastrophic) release must first occur, followed by vaporisation of toxic components from the biocide with subsequent dispersion of the toxic gas to sensitive receivers in concentrations that may cause injury or irritation.

Taking into consideration the engineering and operational controls, the combination of all these events leading to a biocide release which would result in injury or irritation has an unlikely probability of occurrence, in the order of less than 1 in a million chances.

Biocide release consequence analysis

Injury due to exposure to the toxic components of biocide occurs due to ingestion of the solution or inhalation of gases if misting occurs. Irritation may occur due to contact with the skin. For injury or irritation to occur, exposure must be above the designated levels as described on the chemicals safety data sheet.

Toxic and corrosive fumes of bromine gas, hydrogen bromide, and nitrogen oxides may be emitted from the biocide when heated to decomposition (above 70°C).

To measure the consequence of injury and irritation risks, the well-established Emergency Response Planning Guideline (ERPG) (AIHA 2016) values for airborne chemicals is used. The different levels are explained in Table 4-22. The injury risk is determined using ERPG 3 levels; whilst the irritation risk uses ERPG 2 levels.

To assess the consequence of a biocide release, an example is taken of a large biocide release that has been heated to produce a toxic gas of nitrogen dioxide. The ERPG values for nitrogen dioxide are also included in Table 4-22.

Table 4-22 Emergency Response Planning Guideline Levels

ERPG value	Description	Level of NO_2 (ppm, based on 60 minute exposure)
1	The maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing or developing other than mild, transient adverse health effects or without perceiving a clearly defined objectionable odour.	1
2	The maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair an individual's ability to take protective action.	15
3	The maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.	30

If 100 kg of nitrogen dioxide is produced, consequence modelling indicates that the gas will disperse to a distance of 100 metres in ERPG 2 (irritation) concentrations and to a distance of 70 metres in ERPG 3 (injury) concentrations.

As the closest sensitive receiver is over 350 metres away from the Leewood facility there is no release scenario that would generate consequences that reach sensitive receivers.

4.3.5 Class 8 Corrosives release

Corrosives release likelihood

Class 8 corrosives, Packaging Groups II are used for CO_2 removal in the Leewood central gas processing facility and Packaging Groups II and III are used as water treatment chemicals and chemical CIP in the Leewood water treatment plant. As determined in the preliminary risk screening (refer Section 4.2.3), the quantities estimated to be used at Leewood will be in excess of the 25 tonnes for Packaging Group II and 50 tonnes for Packaging Group III thresholds in SEPP 33. Consistent with SEPP 33, a conservative approach will be taken to provide facilities that treat all Class 8 Corrosives as the higher risk Packaging Group II category.

A release involving corrosives may occur due to mechanical damage, corrosion or equipment failure; for example, impact of the storage facility with a vehicle or degradation of piping.

To minimise the likelihood of a release of corrosives, each will be stored in accordance with the requirements of the Australian Dangerous Goods Code, which considers secondary containment, separation of incompatible chemicals etc. There will be separate storages for the central gas processing facility and the water treatment plant to eliminate the potential for cross mixing of the different chemicals.

As already noted in Section 4.3.4, releases from small and medium atmospheric storage tanks (including plastic) containing non-flammable liquids have failure frequencies as provided in Table 4-21 (UK HSE 2012).

For corrosives to pose an offsite risk, a significant (catastrophic) release must first occur, followed by vaporisation of toxic components from the corrosive with subsequent dispersion of the toxic gas to sensitive receivers in concentrations that may cause injury or irritation. Taking into consideration the engineering and operational controls, the combination of all these events leading to a corrosives release which would result in injury or irritation has an unlikely probability of occurrence, in the order of less than 1 in a million chances.

Corrosives release consequence analysis

Injury due to exposure to the corrosives occurs due to ingestion of the solution or inhalation of gases if misting occurs. Irritation may occur due to contact with the skin. For injury or irritation to occur, exposure must be above the designated levels as described on the chemicals safety data sheets.

In the central gas processing facility, toxic and corrosive ammonia fumes may be emitted from the amines when heated. With appropriate design and controls it is unlikely that it would be heated during storage, the proponent would follow vendors' guidelines and follow good engineering practice in design of the storage systems.

In the water treatment plant, toxic and corrosive chlorine gas may be emitted from the mixing of acids with the sodium hypochlorite solution. The proponent would ensure appropriate separation distances are established and would also make sure that sodium hypochlorite would be stored in a separate bunded area such that in the most unlikely event that there was leakage of two chemicals they could not mix in the same bunded area. Standard design procedures would be employed for ensuring that cross connection of acid to the sodium hypochlorite solution tank would be avoided by the use of different connection nozzles for transfer lines used in bulk chemical unloading.

It is considered that sensitive receivers are unlikely to be exposed to injury or irritation risks from corrosive release due to the closest sensitive receiver being more than 350 metres away from the Leewood facility, and that there are no credible release scenarios that would generate consequences that reach the closest sensitive receiver.

4.3.6 Compliance with HIPAP 4 risk criteria

The NSW HIPAP 4 risk criteria suggests that:

- Incident heat flux radiation at residential and sensitive use areas should not exceed 4.7 kW/m^2 at a frequency of more than 50 chances in a million per year (5 x 10^{-5} p.a.)
- Incident explosion overpressure at residential and sensitive use areas should not exceed 7.0 kPa at frequencies of more than 50 chances in a million per year (5 x 10^{-5} p.a.)
- Toxic concentrations in residential and sensitive use areas should not exceed a level which would be seriously injurious to sensitive members of the community following a relatively short period of exposure at a maximum frequency of 10 in a million per year (1 x 10^{-5} p.a.)
- Toxic concentrations in residential and sensitive use areas should not cause irritation to eyes or throat, coughing or other acute physiological responses in sensitive members of the community over a maximum frequency of 50 in a million per year (5 x 10^{-5} p.a.).

From the gas release consequence analysis performed in Section 4.3.2 for the wellheads, gathering lines, the Bibblewindi in-field gas compression facility, the Bibblewindi to Leewood gas line, and the Leewood central gas compression and power generation facility there is no release scenario with the potential to reach a sensitive receptor at the 4.7 kW/m^2 incident heat flux radiation level.

Therefore, the HIPAP 4 risk criteria of 5 x 10^{-5} p.a. is met at the location of sensitive receivers for the 4.7 kW/m^2 heat flux radiation levels.

There are no explosion overpressure consequences that have the potential to reach sensitive receivers, therefore the HIPAP 4 risk criteria is met for explosion overpressure.

Section 4.3.4 describes the likelihood and consequences of toxic releases due to Class 6.1 biocide, where it is a remote likelihood or occurrence of release and toxic injury and irritation consequence effects will not reach sensitive receivers. On this basis, the HIPAP 4 risk criteria are met for both toxic injury and toxic irritation risk.

Section 4.3.5 describes the likelihood and consequences of toxic releases due to Class 8 Corrosive Substances, where it is a remote likelihood or occurrence of release and toxic injury and irritation consequence effects will not reach sensitive receivers. On this basis, the HIPAP 4 risk criteria are met for both toxic injury and toxic irritation risk.

The conclusions regarding loss of containment and the assessment of the offsite risk associated with those releases is based on the assumption of mitigation measures that are planned to be incorporated into the design and operation of the facilities.

These mitigation measures have been identified throughout the report, however a summary of some the key mitigation controls to be implement through the project include:

- all facilities would be designed and operated under the applicable Australian safety standards and protocols, this includes:
  - incorporation of all new facilities into an operational safety management system including permit to work requirements, emergency shutdown, isolation and blowdown protocols, emergency response plan etc.
  - appropriate signage would be installed in accordance with Australian standards to alert landholders to underground infrastructure
  - electrical equipment installed within the gas processing facilities to be certified as appropriate for installation in a flammable / explosive environment
- safety in design would be incorporated into the design and construction of all facilities and infrastructure, for example Hazard and Operability (HAZOP), Quantitative Risk Assessment (QRA), Safety Management Study (SMS) of the pipelines (as per AS 2885.1-2012)
- all dangerous goods to be stored and transported in accordance with the Australian Dangerous Goods Code
- all Class 3 Packing Group III Flammable Liquids would be stored 10 m from the facility boundary at Leewood and 15 metres from the boundary at Bibblewindi.

4.4 Bushfire Risk Assessment

The risk of a bushfire igniting from a project related activity and impacting on life and property has been assessed for both the construction and operational stages of the project. Project related activities which, if not mitigated, may have the potential to generate an ignition that would result in a bushfire. Examples could include untended vegetation around pilot flares, hotworks, vehicles /machinery driving through long grass and / or accidental ignitions (such as from cigarettes).

These potential ignitions would need to coincide with a period of elevated fire danger (such as a hot dry windy day) and would have to be initiated in contravention of current process, procedures and contract requirements.

4.4.1 Bushfire Context

The following background information is to provide context to the bushfire risk assessment for the project.

Bushfire History

High intensity bushfires have occurred within the forested parts of the project area on approximately a decadal basis. High intensity destructive fires have occurred in 1951 / 2, 1957 / 8, 1974, 1978, 1982 / 3, 1997 and 2006. Some of these fires burnt across large areas at high intensity and very quickly.

For example, the 1997 fire burnt nearly 100,000 hectares of the 140,000 hectares burnt over a short period. The 2006 fires burnt more than 74,000 hectares (740 km^2) in a single day. Other very destructive fires have occurred within the region, but outside of what would be the project area. Such fires include the 2013 Wambelong fire near Coonabarabran, which resulted in large scale property losses.

Landscape bushfire potential

The project area and surrounding landscape contain large areas of near-contiguous forest or woodland vegetation cover that can potentially support large, high intensity bushfires. A fire starting within the project area has a higher risk of becoming a large landscape level fire, where continuous landscape vegetation cover is located nearby, particularly on the western to southern boundaries and when adverse fire weather (hot north to westerly wind) is present.

The fuel hazard risk in the surrounding landscape is the responsibility of the land managers (such as Forestry Corporation of NSW, NSW National Parks and Wildlife Service and private landholders).

Proximity of woody / forested vegetation on adjoining lands

Assets located in close proximity to fire-prone vegetation may experience direct flame contact, radiant heat or ember attack. The Australian Standard AS3959:2009 identifies that assets located within 100 metres of fire prone forest or woodland vegetation (and within 50 metres of unmanaged grassland vegetation) may be exposed to radiant heat fluxes of at least $12kW/m^2$ (i.e. enough to ignite exposed timbers and break standard glass) or greater.

By comparison, a radiant heat flux of $7kW/m^2$ is likely to be fatal to exposed persons, and at 4.7 kW/m^2, a fire fighter wearing protective clothing will feel pain after one minute of exposure (NSWRFS 2006). Therefore, the separation distance between the vegetation hazard and an asset in which a person may work or reside (or which has important financial or capability, i.e. production) value, is an important risk factor for consideration. Areas where people work, congregate or sleep are particularly susceptible.

This vegetation proximity risk to Santos' current assets is recognised in the local Bush Fire Management Committees *Bush Fire Risk Management Plan* (BFCC 2010) where (now) Santos assets are identified as follows:

- Eastern Star Gas Wells Sites – Extreme Risk – Treatment T16
- Eastern Star Gas Wilga Park Power – Medium Risk – Treatment T16
- Economic Asset (No. 26) - Eastern Star Gas well sites throughout the Pilliga Forest Complex - Extreme Risk.

The intensity and rate of spread of a bush or grass fire is significantly influenced by the amount of fuel present.

Spotting and ember attack (100-250 metres) potential of vegetation

Ember attack occurs when windborne burning or smouldering vegetative matter such as leaves or bark settles on, and in turn sets fire to, vulnerable buildings. The burning or smouldering vegetative matter causes fire by penetrating gaps or openings in buildings, accumulating in corners, or through burning exposed timbers.

Spotting occurs when a piece of loose bark or leaf catches fire and, under the influence of convective wind at the front of the fire, travels ahead of a bushfire (sometimes many kilometres) and starts a new fire. It is to be noted that certain vegetation groups and species are more likely to create embers and spotting materials. Fire sensitive communities such as white cypress pine (*Callitris glauca*) stands also have lower levels of embers and ground fuels, and may be retained as a 'green-break' in areas.

In the event of a bushfire, vegetation with fibrous bark (known to generate spotting and ember attack) may generate ember attack on project assets, where people work or sleep or escape routes / refuges. Where assets are not appropriately prepared this may result in structure loss where embers are able to penetrate structures.

Topography and access within and surrounding the site

Gentle to flat surrounding topography and good site access surrounding a site will increase control options for fire fighters in suppressing bushfires through direct or indirect means. Where site access is restricted there can be delays to fire control, thereby requiring indirect suppression strategies to cover larger areas (such as burning out to prepared containment lines).

Restricted access can also create enhanced risk for emergency access and egress, particularly if they have to traverse large vegetated areas.

Potential ignition sources within and surrounding the site

Potential ignitions from project related activities include ignitions from hot works. This may range from welding, mulching and other activities that may introduce an ignition source. Other potential risks include where there is inadequate mitigation and protection measures incorporated around and in the operation of gas flares.

Historically on adverse fire days, ignitions have the potential to develop into very large fires and involve large areas very quickly.

Potential ignitions from project related activities include ignitions from hot works or heavy plant used on days of elevated fire danger (if mandatory mitigation and prohibition measures were not adhered to), vegetation contact with powerlines (where not buried) or accidental ignitions.

Ignition sources in the surrounding landscape that may result in bushfire include arson (typically along the Newell Highway corridor), lightning, escaped agricultural burns, accidental (including vehicle accidents) and powerline ignitions.

Detection of new ignitions

Due to the large expanses of forest, low population within the landscape and generally flat topography, fires may develop unnoticed for some period. Fires starting next to or near the Newell Highway may be informally reported by motorists.

Initial and sustained attack capacity

The location and number of fire suppression resources will directly influence the success of initial attack while the fire is small. These factors will also influence the ability of an ignition to develop and grow into a large uncontrollable fire. Historically, the number of fire suppression resources in the landscape has declined with the consolidation of farms and an aging farm workforce (i.e. resulting in less firefighting volunteers). In addition, there has also been a decline in the forestry sector, thereby resulting in fewer net fire fighters and equipment being available for the management of public forests.

Project staff and contractors do not undertake initial or sustained attack, which is the responsibility of external firefighting authorities. Although project resources such as dozers may, under the direction of a fire authority, assist in control. The time taken for an external fire authority to ready, dispatch and travel to a fire on the project area is likely to exceed one hour.

Santos has provided information on the nature and location of project infrastructure to the NSW Rural Fire Service (RFS) to include on its maps during fire incidents; however, Santos has no expectation that RFS resources would be used in preventing fire damage to project infrastructure.

4.4.2 Bushfire risk activity analysis

A large-scale high intensity bushfire during the life of the project, whether starting from project related activities or burning into the project area, has the potential to generate the following consequences:

- People – a bushfire (originating within or coming from outside the project area) spreading at high intensity, cutting off access and egress to parts of the site, and impacting buildings where people work and sleep is a credible threat which may generate serious injury and / or loss of life. Based on the Santos corporate risk matrix this falls into the category of single fatality and / or severe irreversible disability to multiple people.
- Assets and capability – bushfires may significantly impact site operations and capability, thereby potentially impacting gas supply for a considerable period (possibly weeks or months). A bushfire burning into adjoining private property areas, State forest or conservation reserves may impact assets, tourist infrastructure or primary production values.
- Environment – if the gas production facilities are damaged by a bushfire the potential consequence / potential for impact from the facilities on the environment is low.

Due to the long period of construction (i.e. for gas wells and linear infrastructure) throughout the project's assessed life, it is considered to have a similar risk profile to project operations. This is due to drilling being classified as a construction activity for the purposes of EIS assessment.

A range of mitigation measures are in place (see below) which reduce the likelihood of project activities causing a bushfire to the lowest level of 'remote'. This is defined as 'requires exceptional circumstances, is unlikely even in long term, 100-year event'. The recommended additional mitigation measures (see below) further reduce the risk to as low as reasonably practicable, although still within the 'remote' classification band; which is the lowest classification possible under the risk matrix.

While mitigation actions can be used to reduce the likelihood risk factor, there are no actions which can be applied to change the potential worst case consequence of a bushfire event, which is a single fatality and / or severe irreversible disability to multiple people.

Existing Mitigation Actions

The risk assessment has assumed that the project would adopt the following risk mitigation initiatives as business as usual, thereby lowering the initial risk to as low as is reasonably practicable within the 'remote' likelihood category:

- Contractors to have details of operational activities which are permissible, hot works restrictions, and mandatory procedures and preparedness actions required. This may include permissible locations of plant and personnel on days of elevated fire danger, ignition control, and job safety and environment hazard analysis.

- Hot works permits which identify for project personnel and contractors those requirements to adjust, modify or cease activities which may cause ignitions in response to escalating fire danger. Limited hot work permits to be issued between October and February. The presence of a fire unit at hot work areas during periods of elevated fire danger.
- Staff and contractor induction regarding bushfire awareness, mitigation, ignition control and response actions which apply to all proponent managed activities.

The proponent currently is able to modify vegetation within the area under its management to reduce potential direct flame, radiant heat and ember attack impacts. This includes:

- Identification of specific asset protection zones (APZ) and strategic fire advantage zones (SFAZ) around assets where vegetation management is required.
- Preparation of an annual works mitigation schedule to identify works required to prepare asset protection and SFAZ (see NSWRFS 2006 for definitions) around assets, and maintenance to the assets themselves to improve their resilience to bushfires. This may include sealing gaps, installing shielding (such as colorbond fencing or window shutters) and using thicker materials in the walls, doors and windows.

The local BFCC Bush Fire Risk Management Plan (BFCC 2010) identifies the following mitigation measures to be applied to current gas assets within the project area:

- 'Maintain sites as fuel free areas. Eastern Star Gas (ESG) (i.e. now Santos) maintains all sites as fuel free areas, complete with gravel bases. Regular inspections are conducted to ensure no re-growth occurs. Whilst not a member of the local Bush Fire Management Committee (BFMC), ESG have to maintain these sites as per legislative requirements.'
- Pilot flares incorporate shielding and a hardened asset protection zone to reduce the potential for accidental ignitions (designed to reduce the likelihood of an ignition to as low as reasonably practicable).
- The proponent currently maintains emergency response and safety plans for current operations.

Proponent proposed mitigation actions

The proponent would prepare a Bushfire Management Plan, informed by the proponent's participation in the Resource Industry Fire Management Group and consultation with relevant stakeholders including the Rural Fire Service, Forestry Corporation of NSW and landholders. The plan, and related digital data, would be provided to these stakeholders once produced and thereafter reviewed annually, in consultation with those same stakeholders. The plan would:

- Include formal preparedness procedures for staff and contractors to monitor fire danger ratings, and disseminate these to staff and contractor to enable them to adjust their activities
  - details of operational activities which require fire units to be on site
  - identification of appropriate work practices to prevent accidental fire ignition by project personnel and contractors
  - hot works restrictions, and
  - preparedness actions required (such as the location of plant and personnel)
- Specifically identify the risks which staff, contractors, visitors and fire fighters may be exposed to.
- Detail procedures to respond to a formal bushfire warning being issued by emergency services.

- Identify actions in the event of a fire outbreak (such as remotely shutting off wells) including incident command and control structure and responsibilities.
- Identify areas where asset protection zones and fuel reduced areas are to be established and maintained. The proponent is unable to modify the fuel hazard risk in the surrounding landscape which are the responsibility of other land managers (such as farmers or Forestry Corporation of NSW).
- Provide evacuation procedures which provide for orderly evacuations well in advance of bushfire impacts, including nominating and mapping access and egress routes that are suitable for use in an emergency. Fire trails identified and mapped as escaped routes should be constructed and maintained in accordance with NSW Rural Fire Service specifications (BFCC 2007, NSWRFS 2006). Maps and details of areas suitable for use as refuge areas and safer places to assemble are also to be included. Areas identified as refuges of last resort must be appropriately prepared (structure and setbacks) and of sufficient size (may exceed 100 metres) for the personnel which may assemble there.
- Identify the requirements for and timing of annual refresher or fire awareness drills for project staff and contractors, including evacuation exercises and planned mitigation activities.
- Document communication procedures, links and 'black-spots'.
- Detail formal fire reporting and response procedures (including command and control structure) and the required frequency and means by which these arrangements are communicated to all staff and contractors.
- Confirm fire reporting and response actions.
- Identify refuge areas which are clearly identified and mapped.

The proponent is to establish and maintain bushfire mitigation measures on assets located within or adjoining areas of bushfire hazard. New assets would also incorporate requirements for the establishment of asset protection zones, as detailed in the Bushfire Management Plan. For example, infrastructure at the Bibblewindi site would be set back from the fence line to act as an asset protection zone.

In addition, the following features are incorporated in the design and construction of wells, gathering systems, and for electrical and instrumentation equipment installed within the project area, and will be included in a Bushfire Management Plan:

- Wells. Infrastructure can be managed remotely, by an operator in the field and in the event of a bushfire, if neither can be completed there are a number of controls in place for the safe operation of the unit. The unit is programmed so that differences in operating parameters outside the operating envelope (band within the alarm set points) triggers a response based on the risk associated with that parameter and typically escalates in response, starting with opening / closing of valving to its fail safe position. The pipe standard to be used (ASME B313 process piping, referenced in Australian standard AS 4041-2006 Pressure Piping) is that the pipe must withstand 650°C for 30 minutes and maintain integrity.
- Gathering systems. Buried, valves above ground are metal and locked closed unless opened by an operator. If wells are shut in as above, pressure in gathering system will decline. If a pipeline is compromised, the pressure will decline in gathering systems, sensor will close the fail safe valve at wellheads. In addition, the gas compression units will continue to extract gas from the gathering system, while the gas source (wells) is shut off, the compressors will draw the remaining gas out of the system.

- Electrical and instrumentation equipment within the project area. All electrical and instrumentation equipment installed in locations where there would potentially be a flammable atmosphere present would be hazardous area rated in accordance with AS / NZS 60079: Electrical Apparatus for Explosive Gas Atmospheres, and as such, would not act as an ignition source.

Following a fire, inspections will examine the integrity of all pipelines and equipment. This may require purging all gas through to the flare to ensure the site is gas free prior to inspection.

The proponent is not a fire authority and fires occurring on or near proponent managed land will be under the incident control authority of one of the NSW Fire Authorities (NSW Rural Fire Service, Forestry Corporation of NSW, NSW National Parks and Wildlife Service or Fire and Rescue NSW). To assist in the coordination of fire response actions the proponent will provide a Liaison Officer to a NSW Rural Fire Service, Forestry Corporation of NSW or NSW National Parks and Wildlife Service incident management team to provide local knowledge and advice during fire incidents. Santos personnel have participated and will continue to participate in bushfire emergency preparedness exercises with fire authorities. The details, timing and frequency of these arrangements will be documented in the Bushfire Management Plan prepared for the project.

It should be noted the allocation of external resources to respond to a fire will be dependent on the risk a fire poses relative to the risk from other fires which may also be running at the same time, availability of resources and the safety and effectiveness in deploying resources. Fire response and mitigation measures applied to the project need to ensure that the assets and staff are well prepared and able to respond (i.e. evacuate or seek shelter) to a bushfire. These arrangements, including the locations of firefighting resources and fire control advantages (such as potential water points at Leewood and Bibblewindi), are to be documented in the Bushfire Management Plan.

4.4.3 Risk Factor Summary

A risk ranking of ‘medium’ is recorded for the risk of a bushfire igniting from a project related activity and impacting on life and property during construction or operation of the project.

The proponent is able to apply mitigation measures to reduce the potential for fires to start as a result of project related activities. These existing mitigation measures reduce the likelihood for the bushfire risk above to ‘remote’, the lowest likelihood classification.

The proposed additional mitigation measures will reduce the risk further (that is, as low as reasonably practicable for the proponent to apply); however, is still assessed as being within the lowest ‘remote’ likelihood class.

The overall residual risk ranking remains ‘medium’, which is the lowest possible risk category that can be achieved because the potential consequence includes the possibility that a fatality could occur from bushfire impact,

The proponent, as with other activities located in similar bushfire prone environments, and despite comprehensive current and proposed mitigation measures, is unable to influence the consequence of a bushfire event. Based risk matrix used in this risk assessment, the residual consequence falls into the category of ‘single fatality and / or severe irreversible disability to multiple people’, and despite being of remote likelihood, results as a ‘medium’ overall residual risk.

5. Conclusion

5.1 Preliminary risk screening

The preliminary risk screening exercise determined all project facilities to be 'potentially hazardous industry' as defined by SEPP 33 based on the presence of large volumes of Class 2.1 Flammable Gases (methane) and at Leewood only, Class 6.1 Toxic Substances (biocide) and Class 8 Corrosive Substances.

Class 3 Packing Group III Flammable Liquids stored at the various facilities were not deemed to trigger the classification of 'potentially hazardous industry' on the basis that they are stored within the required distances from the site boundaries.

As the facilities have been considered as potentially hazardous, a PHA was conducted to further assess the risk that the methane, biocide and corrosive substances poses to surrounding land users.

5.2 Preliminary Hazard Analysis

A summary of the outcomes of the PHA is provided below for the dangerous goods classes that triggered the potentially hazardous industry threshold based on the preliminary risk screening.

An uncontrolled loss of containment of gas leading to a fire or explosion

The overall residual risk from fires or explosions from methane has been assessed qualitatively as being low or very low.

The Preliminary Hazard Analysis of the loss of containment of Class 2.1 Flammable Gases (methane) assessed the risk of fires and explosions in further detail using a semi quantitative approach.

It was determined the risk of 4.7 kW/m^2 heat radiation exposure meets the HIPAP 4 risk criteria as it would not exceed 50 chances in a million per year (5×10^{-5} p.a.) at sensitive receivers.

It was determined the risk of 7 kPa explosion overpressure meets the HIPAP 4 risk criteria as it would not exceed 50 chances in a million per year (5×10^{-5} p.a.) at sensitive receivers.

An uncontrolled loss of containment of liquid chemicals or dangerous goods

All risks associated with the loss of containment of liquid chemicals or dangerous goods were assessed qualitatively as having a low residual risk with regards to offsite consequences.

The Preliminary Hazard Analysis of the loss of containment of Class 6.1 Toxic Substances (biocide) assessed the risk of exposure to toxic chemicals from the biocide in further detail using a semi quantitative approach. It was determined the risk of injury and irritation at sensitive receivers meets the HIPAP 4 risk criteria.

The Preliminary Hazard Analysis of the loss of containment of Class 8 Corrosive Substances assessed the risk of exposure to toxic gases resulting from the heating or chemical reaction of the chemicals and determined that the risk of injury and irritation at sensitive receivers meets the HIPAP 4 risk criteria.

Mitigation measures

The above conclusions regarding loss of containment and the assessment of the offsite risk associated with those releases is based on the assumption of mitigation measures that are planned to be incorporated into the design and operation of the facilities.

These mitigation measures have been identified throughout the report, however a summary of high level mitigation controls to be implemented through the project include:

- appropriate signage would be installed in accordance with Australian standards to alert landholders to underground infrastructure
- all facilities would be designed and operated under the applicable Australian safety standards and protocols
- safety in design would be incorporated into the design and construction of all facilities and infrastructure
- all dangerous goods to be stored and transported in accordance with the Australian Dangerous Goods Code
- all Class 3 Packing Group III Flammable Liquids would be stored 10 metres from the Leewood facility boundary and 15 metres from the Bibblewindi facility based on anticipated quantities.

5.3 Bushfire Risk Factor Summary

Based on the factors identified in Section 4.4, it is possible that a large scale high intensity bushfire may occur over the life of the project. The proponent is able to apply fire prevention and mitigation measures to reduce the potential for fires to start as a result of project related activities. These existing fire prevention and mitigation measures reduce the likelihood of the project potentially starting a fire to ‘remote’, which is the lowest likelihood.

Additional mitigation measures are proposed by the proponent to further reduce the risks (as low as reasonably practicable for the proponent to apply). This includes the development of effective strategies and enhancement of existing procedures to mitigate bushfire risk during the construction and operation of the project. These arrangements, systems and processes are to be formalised in a Bushfire Management Plan which would be prepared in conjunction with landholders and the NSW Rural Fire Service, with components under the proponents control implemented for the project to mitigate this risk.

This document would include:

- description of the bushfire risks to which staff, contractors and visitors may be exposed, and the process used to communicate these risks to these persons
- formal preparedness procedures for staff and contractors to maintain awareness of and respond to escalating forecast fire danger
- formal pre-rehearsed procedures for staff and contractors to respond to respond to a formal bushfire warning being issued by emergency services, including identification of escape routes and refuge areas
- identification of specific asset protection zones and strategic fire advantage zones around assets where vegetation management is required
- identification of appropriate construction standards for buildings and refuge areas. This may include measures to retrofit existing structures (such as fitting of ember screens and improved glazing) to improve the potential for structures to survive bushfire impacts
- preparation of an annual works mitigation schedule to identify works required to be implemented to prepare asset protection and strategic fire advantage zones around assets, maintenance to the assets themselves to improve their resilience to bushfires, and maintenance requirements for emergency access and egress routes.

These additional measures further consolidate the likelihood risk within the lowest ‘remote’ likelihood class.

Despite comprehensive current and additional proposed mitigation measures the proponent, as with other activities located in similar bushfire prone environments, is unable to influence the consequence of a bushfire event. The residual consequence falls into the category of ‘single fatality and / or severe irreversible disability to multiple people’, and despite being of ‘remote’ likelihood, results as a ‘medium’ overall residual risk for the construction and operation stages of the project.

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Appendices

Appendix A – Register of risks with potential for offsite harm

Risk	Potential causes	Risk assessment scenario	Project Phases (Construction, Operation)	Inherent design standards and operational practices applied	Initial risks			Site / activity specific mitigation measures / management plans applied to reduce risk	Residual risks		
					Likelihood	Consequence	Risk rating		Likelihood	Consequence	Risk rating
Sudden loss of containment of significant quantities of water resulting from catastrophic failure of pond wall	Improper design Erosion Operation outside design limits Poor maintenance	For offsite safety impacts to occur, a catastrophic failure would be required. Safety risk assessment conducted on the basis of major dam burst causing damage to offsite infrastructure and injury to off-site persons.	Operation	Leewood Ponds designed to standard including primary and secondary lining, leak detection and collection and engineered spillway. Dam Safety Committee reviewed design and confirmed construction to specification. Multi cell design facilitates maintenance and limits volume released in event of failure. Pond level and collection sump monitoring. Shallow monitoring bores adjacent to ponds. Work Permit System / Job Hazard Analysis Regular inspection and monitoring program and Dam Safety Emergency Plan provided to Dam Safety Committee in accordance with legislative requirements.	Remote	Injury requiring medical treatment or minor medical / first aid with no LTI	**Very Low**	Real time monitoring of collection sump levels with telemetry to control centre.	Remote	Injury requiring medical treatment or minor medical / first aid with no lost time injury	**Very Low**
An uncontrolled loss of containment of a small quantity (<100L) of liquid chemicals or dangerous goods	Equipment failure Loading or handling error Operator error Impact to equipment	Offsite safety impacts are not expected due to a release of small quantities of chemicals or dangerous goods.	Construction Operation	Storage and transport of chemicals and goods in accordance with Australian standards and codes Bunding of equipment Spill response kits	Unlikely	Injury requiring medical treatment or minor medical / first aid with no LTI	**Very Low**	Inspections/audits Contractor audits	Unlikely	Injury requiring medical treatment or minor medical / first aid with no lost time injury	**Very Low**
An uncontrolled loss of containment of liquid chemicals or dangerous goods (>100L)	Vehicle rollover or collision Loading or handling error Operator error Tank or equipment failure	Safety risk assessment conducted on the basis of a release of dangerous goods causing a toxic emission and off-site persons being exposed.	Construction Operation	Storage and transport of chemicals and goods in accordance with Australian standards and codes Bunding of storage areas Emergency response systems Spill response kits Evacuation alarms, points and procedures	Unlikely	Medium term reversible disability to one or more persons. Significant medical treatment, disabling or lost time injury.	**Low**	Inspections/audits Contractor audits	Unlikely	Medium term reversible disability to one or more persons. Significant medical treatment, disabling or lost time injury.	**Low**
An uncontrolled loss of containment of gas at a wellhead leading to a fire or explosion.	Impact from mobile equipment Equipment failure Operational error Uncontrolled excavation Overpressure Corrosion/erosion Bushfire Lightning strike	Uncontrolled Loss of Containment of gas from wellhead & wellhead equipment during operation. Potential for fire. Potential offsite impact includes heat radiation exposure from jet fire, fireball or flash fire. Safety risk assessment conducted on the basis of fire exposure from a large hole gas release impacting offsite personnel in the area. Single fatality considered maximum worst case due to gas pressure and location of potential release.	Construction Operation	Removal of ignition source Automatic closure of failsafe valve on depressurisation Consideration of potential for radiant heat from bushfires in wellhead material selection and design Telemetry installed to allow ongoing monitoring and remotely operated shut in of wells Blow Out Preventer on wellhead Electrical and instrumentation equipment is hazardous area rated in accordance with AS / NZS 60079: Electrical Apparatus for Explosive Gas Atmospheres Emergency Shutdown and Manual Isolations Well heads are fenced Contractor Management Systems Work Permit System / Job Hazard Analysis Emergency Response Plan Evacuation alarms, points & procedures	Remote	Single fatality and/or severe irreversible disability to multiple people	**Medium**	Ensure separation distance to unrestricted areas outside fence is > 40 m (consequence modelling indicates this will reduce severity of injury to minor burns) to prevent public exposure to a loss of containment event at the wellhead.	Remote	Medium term reversible disability to one or more persons. Significant medical treatment, disabling or lost time injury.	**Very Low**

Risk	Potential causes	Risk assessment scenario	Project Phases (Construction, Operation)	Inherent design standards and operational practices applied	Initial risks			Site / activity specific mitigation measures / management plans applied to reduce risk	Residual risks		
					Likelihood	Consequence	Risk rating		Likelihood	Consequence	Risk rating
An uncontrolled loss of containment of gas from underground gathering lines leading to a fire or explosion (low pressure).	Equipment failure Operational error Third party excavation Uncontrolled excavation Overpressure Corrosion/erosion Bushfire	Potential impact includes heat radiation exposure from jet fire or flash fire. Safety risk assessment conducted on the basis or fire exposure from a large hole gas release impacting off-site personnel in the area. Single fatality considered maximum worst case due to gas pressure and location of potential release.	Operation	Design and operation in accordance with Australian Standards and relevant guidelines. Automatic closure of failsafe valve on depressurisation . Telemetry installed to allow ongoing monitoring and remote operation to shut down wells. Buried gas gathering lines with above ground valves that are metal and locked closed unless opened by an operator Signage along gathering line route Increased depth of cover where required Work Permit System / Job Hazard Analysis Emergency Response Plan Evacuation alarms, points & procedures Emergency shutdown and manual isolation	Remote	Single fatality and/or severe irreversible disability to multiple people	**Medium**	Gathering line network is buried reducing risk Community/landholder awareness programs	Remote	Medium term reversible disability to one or more persons. Significant medical treatment, disabling or lost time injury.	**Very Low**
An uncontrolled loss of containment of gas from underground Bibblewindi to Leewood pipeline leading to a fire or explosion (medium pressure).	Equipment failure Operational error Ineffective isolation Bushfire Third party excavation Uncontrolled excavation Overpressure Corrosion/erosion	Potential offsite impact includes heat radiation exposure from jet fire or flash fire. Safety risk assessment conducted on the basis of fire exposure from a large hole gas release impacting off-site personnel in the area. Single fatality considered maximum worst case due to gas pressure and location of potential release.	Operation	Design and operation in accordance with Australian standards and relevant guidelines. Automatic closure of failsafe valve on depressurisation. Telemetry installed to allow ongoing monitoring and remote operation of isolation points. Signage along gathering line route Increase depth of cover where required. Contractor Management Systems. Trained, competent & inducted personnel. Standard Operating Procedures Work Permit System / Job Hazard Analysis. Emergency Response Plan. Evacuation alarms, points and procedures. Emergency shutdown and manual isolation.	Remote	Single fatality and/or severe irreversible disability to multiple people	**Medium**	Pipeline is buried reducing risks. Gates and barriers installed at public road crossing points. Significant distance between pipeline corridor and nearest sensitive receivers.	Remote	Extensive injuries or irreversible disability or impairment to one person.	**Low**
An uncontrolled loss of containment of gas at Leewood gas processing facility. Potential for fire or explosion.	Impact from mobile equipment Equipment failure Operational error Overpressure Corrosion/erosion	Potential offsite impact includes heat radiation exposure from jet fire, fireball or flash fire or explosion overpressure. Safety risk assessment conducted on the basis of fire exposure from a large hole gas release impacting offsite personnel in the area. Single fatality considered maximum worst case due to location of potential release.	Operation	Design and operation in accordance with Australian and international standards Electrical and instrumentation equipment is hazardous area rated in accordance with AS / NZS 60079: Electrical Apparatus for Explosive Gas Atmospheres Emergency relief and depressurisation system (including flare) Emergency shutdown and manual isolation Fenced site, access control Continuous operations monitoring Work Permit System / Job Hazard Analysis Personal protective equipment Emergency Response Plan Ignition control Evacuation alarms, points & procedures	Remote	Single fatality and/or severe irreversible disability to multiple people	**Medium**	Confirm during detailed design that the separation distances are sufficient to minimise risk of offsite impact from loss of containment to as low as reasonably practicable.	Remote	Injury requiring medical treatment or minor medical / first aid with no lost time injury	**Very Low**

Risk	Potential causes	Risk assessment scenario	Project Phases (Construction, Operation)	Inherent design standards and operational practices applied	Initial risks: Likelihood	Initial risks: Consequence	Initial risks: Risk rating	Site / activity specific mitigation measures / management plans applied to reduce risk	Residual risks: Likelihood	Residual risks: Consequence	Residual risks: Risk rating
A loss of containment of gas at Bibblewindi leading to a fire or explosion	Impact from mobile equipment Equipment failure Operational error Overpressure Corrosion/erosion	Potential offsite impact includes heat radiation exposure from jet fire, fireball or flash fire or explosion overpressure. Safety risk assessment conducted on the basis of fire exposure from a large hole gas release impacting offsite personnel in the area. Single fatality considered maximum worst case due to location of potential release.	Operation	Design and operation in accordance with Australian and international standards. Electrical and instrumentation equipment is hazardous area rated in accordance with AS / NZS 60079: Electrical Apparatus for Explosive Gas Atmospheres Emergency relief and depressurisation system (including flare) Emergency shutdown and manual isolation Fenced site, access control Continuous operations monitoring Work Permit System / Job Hazard Analysis Contractor Management Systems Personal protective equipment Emergency Response Plan Ignition control Evacuation alarms, points & procedures	Remote	Single fatality and/or severe irreversible disability to multiple people	**Medium**	Confirm during detailed design that the separation distances are sufficient to minimise risk of offsite impact from loss of containment to as low as reasonably practicable.	Remote	Injury requiring medical treatment or minor medical / first aid with no lost time injury	**Very Low**
A bushfire igniting from project related activities and impacting life and property	Ignition source from project related activities (e.g. 'hot work' activities or processes that can be a source of ignition or fire hazard.)	Safety risk assessment conducted on the basis of fire causing fatality or damage to assets.	Construction / Operation	Annual works mitigation to maintain asset protection and strategic fire advantage zones around assets, asset maintenance to ensure plant and equipment operated in a proper and efficient condition Electrical and instrumentation equipment is hazardous area rated in accordance with AS / NZS 60079: Electrical Apparatus for Explosive Gas Atmospheres Hot work permit system for staff and contractors Staff and contractor induction for bushfire awareness and mitigation Ignition Control Work Permit System / Job Hazard Analysis Personal Protective Equipment Emergency Response Plan Evacuation alarms, points & procedures	Remote	Single fatality and/or severe irreversible disability to multiple people	**Medium**	Modification of work activities (including hot work) based on bushfire risk rating and operating environment. Preparation and implementation of project bushfire management plan incorporating bushfire risk, preparedness, awareness , mitigation , reporting, response (fire fighting, evacuation, refuge areas) and recovery actions and procedures. Active involvement in bushfire response planning with local authorities, including the Rural Fire Service.	Remote	Single fatality and/or severe irreversible disability to multiple people	**Medium**

Appendix B – Consequence modelling results

Jet Fire Analysis

Wellheads	10	620	H		A 1 m/s	4.7	4.4	4.2	4.1
	10	620	H		D 3.5 m/s	4.5	4.3	4.1	4.0
	10	620	H		F 1 m/s	4.7	4.4	4.2	4.1
Wellheads	100	620	H		A 1 m/s	49.3	18.3	16.7	16.7
	100	620	H		D 3.5 m/s	49.6	41.2	37.3	34.7
	100	620	H		F 1 m/s	49.3	18.3	16.7	16.7
Wellheads	50	620	H		A 1 m/s	24.2	20.4	18.7	17.3
	50	620	H		D 3.5 m/s	24.3	20.9	19.4	18.4
	50	620	H		F 1 m/s	24.2	20.4	18.7	17.3
Gathering Lines	10	420	HI	Any	A 1 m/s	Not Reached	Not Reached	Not Reached	Not Reached
Gathering Lines	10	420	HI	Any	D 3.5 m/s	Not Reached	Not Reached	Not Reached	Not Reached
Gathering Lines	10	420	HI	Any	F 1 m/s	Not Reached	Not Reached	Not Reached	Not Reached
Gathering Lines	50	420	HI	Any	A 1 m/s	11.0	7.3	6.2	5.6
Gathering Lines	50	420	HI	Any	D 3.5 m/s	10.7	7.3	6.4	5.8
Gathering Lines	50	420	HI	Any	F 1 m/s	11.0	7.3	6.2	5.6
Gathering Lines	100	420	HI	Any	A 1 m/s	25.8	15.5	12.7	11.2
Gathering Lines	100	420	HI	Any	D 3.5 m/s	25.7	15.4	13.2	12.0
Gathering Lines	100	420	HI	Any	F 1 m/s	25.8	15.5	12.7	11.2
Gathering Lines	FBR	420	HI	0	A 1 m/s	126.6	77.5	55.4	43.2
Gathering Lines	FBR	420	HI	0	D 3.5 m/s	127.3	78.3	56.7	44.2
Gathering Lines	FBR	420	HI	0	F 1 m/s	126.6	77.5	55.4	43.2
Gathering Lines	FBR	420	HI	500	A 1 m/s	136.0	83.3	59.7	46.4
Gathering Lines	FBR	420	HI	500	D 3.5 m/s	136.7	84.2	61.1	47.5
Gathering Lines	FBR	420	HI	500	F 1 m/s	136.0	83.3	59.7	46.4
Gathering Lines	FBR	420	HI	1000	A 1 m/s	149.0	90.8	64.5	50.7
Gathering Lines	FBR	420	HI	1000	D 3.5 m/s	150.3	92.5	67.0	52.0
Gathering Lines	FBR	420	HI	1000	F 1 m/s	149.0	90.8	64.5	50.7
Gathering Lines	FBR	420	HI	1500	A 1 m/s	156.8	95.6	68.0	53.3
Gathering Lines	FBR	420	HI	1500	D 3.5 m/s	158.1	97.4	70.6	54.9
Gathering Lines	FBR	420	HI	1500	F 1 m/s	156.8	95.6	68.0	53.3
Gathering Lines	FBR	420	HI	2000	A 1 m/s	161.7	98.8	70.5	55.1
Gathering Lines	FBR	420	HI	2000	D 3.5 m/s	162.9	100.5	73.0	56.8
Gathering Lines	FBR	420	HI	2000	F 1 m/s	161.7	98.8	70.5	55.1

Jet Fire Analysis

Gathering Lines	FBR	420	HI	2500	A 1 m/s	163.3	99.8	71.3	55.7
Gathering Lines	FBR	420	HI	2500	D 3.5 m/s	164.5	101.5	73.7	57.4
Gathering Lines	FBR	420	HI	2500	F 1 m/s	163.3	99.8	71.3	55.7
Gathering Lines	FBR	420	HI	3000	A 1 m/s	161.7	98.7	70.5	55.1
Gathering Lines	FBR	420	HI	3000	D 3.5 m/s	162.9	100.5	72.9	56.8
Gathering Lines	FBR	420	HI	3000	F 1 m/s	161.7	98.7	70.5	55.1
Gathering Lines	FBR	420	HI	3500	A 1 m/s	156.7	95.5	67.9	53.3
Gathering Lines	FBR	420	HI	3500	D 3.5 m/s	158.0	97.3	70.5	54.8
Gathering Lines	FBR	420	HI	3500	F 1 m/s	156.7	95.5	67.9	53.3
Gathering Lines	FBR	420	HI	4000	A 1 m/s	148.8	90.6	64.4	50.6
Gathering Lines	FBR	420	HI	4000	D 3.5 m/s	150.0	92.4	66.9	51.9
Gathering Lines	FBR	420	HI	4000	F 1 m/s	148.8	90.6	64.4	50.6
Gathering Lines	FBR	420	HI	4500	A 1 m/s	135.5	83.0	59.5	46.2
Gathering Lines	FBR	420	HI	4500	D 3.5 m/s	136.3	84.0	60.9	47.3
Gathering Lines	FBR	420	HI	4500	F 1 m/s	135.5	83.0	59.5	46.2
Gathering Lines	FBR	420	HI	5000	A 1 m/s	125.4	76.7	55.0	42.8
Gathering Lines	FBR	420	HI	5000	D 3.5 m/s	126.0	77.5	56.1	43.9
Gathering Lines	FBR	420	HI	5000	F 1 m/s	125.4	76.7	55.0	42.8
Bibblewindi	10	2000	H		A 1 m/s	7.7	7.4	7.4	7.4
	10	2000	H		D 3.5 m/s	7.6	7.4	7.4	7.4
	10	2000	H		F 1 m/s	7.7	7.4	7.4	7.4
Bibblewindi	10	172	H		A 1 m/s	2.5	Not Reached	Not Reached	Not Reached
	10	172	H		D 3.5 m/s	2.4	Not Reached	Not Reached	Not Reached
	10	172	H		F 1 m/s	2.5	Not Reached	Not Reached	Not Reached
Bibblewindi	50	2000	H		A 1 m/s	41.3	33.8	30.2	27.4
	50	2000	H		D 3.5 m/s	41.5	34.8	31.7	29.6
	50	2000	H		F 1 m/s	41.3	33.8	30.2	27.4
Bibblewindi	50	172	H		A 1 m/s	14.0	12.3	11.5	11.0
	50	172	H		D 3.5 m/s	14.0	12.5	11.8	11.4
	50	172	H		F 1 m/s	14.0	12.3	11.5	11.0
Bibblewindi	100	2000	H		A 1 m/s	81.2	64.0	55.7	49.8
	100	2000	H		D 3.5 m/s	81.6	66.1	58.9	53.9
	100	2000	H		F 1 m/s	81.2	64.0	55.7	49.8

Jet Fire Analysis

Bibblewindi	100	172	H		A 1 m/s	29.0	24.3	22.0	20.2
	100	172	H		D 3.5 m/s	29.2	24.9	22.9	21.6
	100	172	H		F 1 m/s	29.0	24.3	22.0	20.2
Intermediate Line	10	2000	HI	Any	A 1 m/s	3.1	1.8	0.8	Not Reached
Intermediate Line	10	2000	HI	Any	D 3.5 m/s	2.9	1.5	0.8	Not Reached
Intermediate Line	10	2000	HI	Any	F 1 m/s	3.1	1.8	0.8	Not Reached
Intermediate Line	50	2000	HI	Any	A 1 m/s	26.6	15.9	13.0	11.5
Intermediate Line	50	2000	HI	Any	D 3.5 m/s	26.4	15.8	13.6	12.3
Intermediate Line	50	2000	HI	Any	F 1 m/s	26.6	15.9	13.0	11.5
Intermediate Line	100	2000	HI	Any	A 1 m/s	55.0	33.3	24.4	20.3
Intermediate Line	100	2000	HI	Any	D 3.5 m/s	55.0	33.3	25.6	22.3
Intermediate Line	100	2000	HI	Any	F 1 m/s	55.0	33.3	24.4	20.3
Intermediate Line	FBR	2000	HI	0	A 1 m/s	394.2	240.9	174.0	138.7
Intermediate Line	FBR	2000	HI	0	D 3.5 m/s	396.9	246.9	180.3	143.1
Intermediate Line	FBR	2000	HI	0	F 1 m/s	394.2	240.9	174.0	138.7
Intermediate Line	FBR	2000	HI	500	A 1 m/s	319.8	195.6	140.4	112.0
Intermediate Line	FBR	2000	HI	500	D 3.5 m/s	322.1	200.1	146.1	115.6
Intermediate Line	FBR	2000	HI	500	F 1 m/s	319.8	195.6	140.4	112.0
Intermediate Line	FBR	2000	HI	1000	A 1 m/s	343.2	210.0	150.9	120.7
Intermediate Line	FBR	2000	HI	1000	D 3.5 m/s	345.5	214.8	156.8	124.2
Intermediate Line	FBR	2000	HI	1000	F 1 m/s	343.2	210.0	150.9	120.7
Intermediate Line	FBR	2000	HI	1500	A 1 m/s	361.2	221.0	159.3	127.3
Intermediate Line	FBR	2000	HI	1500	D 3.5 m/s	363.6	226.1	165.1	130.8
Intermediate Line	FBR	2000	HI	1500	F 1 m/s	361.2	221.0	159.3	127.3
Intermediate Line	FBR	2000	HI	2000	A 1 m/s	371.8	227.5	164.3	131.2
Intermediate Line	FBR	2000	HI	2000	D 3.5 m/s	374.1	232.7	170.0	134.8
Intermediate Line	FBR	2000	HI	2000	F 1 m/s	371.8	227.5	164.3	131.2
Intermediate Line	FBR	2000	HI	2500	A 1 m/s	377.8	231.2	167.1	133.4
Intermediate Line	FBR	2000	HI	2500	D 3.5 m/s	380.2	236.5	172.8	137.1
Intermediate Line	FBR	2000	HI	2500	F 1 m/s	377.8	231.2	167.1	133.4
Intermediate Line	FBR	2000	HI	3000	A 1 m/s	381.0	233.1	168.6	134.5
Intermediate Line	FBR	2000	HI	3000	D 3.5 m/s	383.4	238.5	174.3	138.3
Intermediate Line	FBR	2000	HI	3000	F 1 m/s	381.0	233.1	168.6	134.5

Jet Fire Analysis

Intermediate Line	FBR	2000	HI	3500	A 1 m/s	382.5	234.0	169.3	135.1
Intermediate Line	FBR	2000	HI	3500	D 3.5 m/s	384.9	239.4	175.0	138.9
Intermediate Line	FBR	2000	HI	3500	F 1 m/s	382.5	234.0	169.3	135.1
Intermediate Line	FBR	2000	HI	4000	A 1 m/s	383.3	234.5	169.7	135.4
Intermediate Line	FBR	2000	HI	4000	D 3.5 m/s	385.7	239.9	175.3	139.2
Intermediate Line	FBR	2000	HI	4000	F 1 m/s	383.3	234.5	169.7	135.4
Intermediate Line	FBR	2000	HI	4500	A 1 m/s	383.4	234.6	169.7	135.4
Intermediate Line	FBR	2000	HI	4500	D 3.5 m/s	385.8	240.0	175.4	139.2
Intermediate Line	FBR	2000	HI	4500	F 1 m/s	383.4	234.6	169.7	135.4
Intermediate Line	FBR	2000	HI	5000	A 1 m/s	383.3	234.6	169.7	135.4
Intermediate Line	FBR	2000	HI	5000	D 3.5 m/s	385.7	240.0	175.4	139.2
Intermediate Line	FBR	2000	HI	5000	F 1 m/s	383.3	234.6	169.7	135.4
Intermediate Line	FBR	2000	HI	5500	A 1 m/s	383.1	234.4	169.6	135.3
Intermediate Line	FBR	2000	HI	5500	D 3.5 m/s	385.5	239.8	175.3	139.1
Intermediate Line	FBR	2000	HI	5500	F 1 m/s	383.1	234.4	169.6	135.3
Intermediate Line	FBR	2000	HI	6000	A 1 m/s	382.8	234.2	169.5	135.2
Intermediate Line	FBR	2000	HI	6000	D 3.5 m/s	385.2	239.6	175.1	139.0
Intermediate Line	FBR	2000	HI	6000	F 1 m/s	382.8	234.2	169.5	135.2
Intermediate Line	FBR	2000	HI	6500	A 1 m/s	382.5	234.0	169.3	135.1
Intermediate Line	FBR	2000	HI	6500	D 3.5 m/s	384.9	239.4	175.0	138.9
Intermediate Line	FBR	2000	HI	6500	F 1 m/s	382.5	234.0	169.3	135.1
Intermediate Line	FBR	2000	HI	7000	A 1 m/s	382.2	233.9	169.2	135.0
Intermediate Line	FBR	2000	HI	7000	D 3.5 m/s	384.6	239.3	174.8	138.8
Intermediate Line	FBR	2000	HI	7000	F 1 m/s	382.2	233.9	169.2	135.0
Intermediate Line	FBR	2000	HI	7500	A 1 m/s	381.9	233.7	169.0	134.9
Intermediate Line	FBR	2000	HI	7500	D 3.5 m/s	384.3	239.1	174.7	138.7
Intermediate Line	FBR	2000	HI	7500	F 1 m/s	381.9	233.7	169.0	134.9
Intermediate Line	FBR	2000	HI	8000	A 1 m/s	381.6	233.5	168.9	134.8
Intermediate Line	FBR	2000	HI	8000	D 3.5 m/s	384.0	238.9	174.5	138.5
Intermediate Line	FBR	2000	HI	8000	F 1 m/s	381.6	233.5	168.9	134.8
Intermediate Line	FBR	2000	HI	8500	A 1 m/s	381.2	233.2	168.7	134.6
Intermediate Line	FBR	2000	HI	8500	D 3.5 m/s	383.6	238.6	174.4	138.4
Intermediate Line	FBR	2000	HI	8500	F 1 m/s	381.2	233.2	168.7	134.6

Jet Fire Analysis

Intermediate Line	FBR	2000	HI	9000	A 1 m/s	380.6	232.9	168.4	134.4
Intermediate Line	FBR	2000	HI	9000	D 3.5 m/s	383.0	238.2	174.1	138.2
Intermediate Line	FBR	2000	HI	9000	F 1 m/s	380.6	232.9	168.4	134.4
Intermediate Line	FBR	2000	HI	9500	A 1 m/s	380.2	232.6	168.2	134.2
Intermediate Line	FBR	2000	HI	9500	D 3.5 m/s	382.5	238.0	173.9	138.0
Intermediate Line	FBR	2000	HI	9500	F 1 m/s	380.2	232.6	168.2	134.2
Intermediate Line	FBR	2000	HI	10000	A 1 m/s	379.7	232.3	168.0	134.1
Intermediate Line	FBR	2000	HI	10000	D 3.5 m/s	382.1	237.7	173.7	137.8
Intermediate Line	FBR	2000	HI	10000	F 1 m/s	379.7	232.3	168.0	134.1
Intermediate Line	FBR	2000	HI	10500	A 1 m/s	379.2	232.0	167.8	133.9
Intermediate Line	FBR	2000	HI	10500	D 3.5 m/s	381.6	237.4	173.5	137.6
Intermediate Line	FBR	2000	HI	10500	F 1 m/s	379.2	232.0	167.8	133.9
Intermediate Line	FBR	2000	HI	11000	A 1 m/s	378.7	231.7	167.5	133.7
Intermediate Line	FBR	2000	HI	11000	D 3.5 m/s	381.1	237.0	173.2	137.4
Intermediate Line	FBR	2000	HI	11000	F 1 m/s	378.7	231.7	167.5	133.7
Intermediate Line	FBR	2000	HI	11500	A 1 m/s	378.1	231.3	167.2	133.5
Intermediate Line	FBR	2000	HI	11500	D 3.5 m/s	380.4	236.6	172.9	137.2
Intermediate Line	FBR	2000	HI	11500	F 1 m/s	378.1	231.3	167.2	133.5
Intermediate Line	FBR	2000	HI	12000	A 1 m/s	377.2	230.8	166.8	133.2
Intermediate Line	FBR	2000	HI	12000	D 3.5 m/s	379.6	236.1	172.5	136.9
Intermediate Line	FBR	2000	HI	12000	F 1 m/s	377.2	230.8	166.8	133.2
Intermediate Line	FBR	2000	HI	12500	A 1 m/s	375.7	229.9	166.1	132.6
Intermediate Line	FBR	2000	HI	12500	D 3.5 m/s	378.1	235.2	171.8	136.3
Intermediate Line	FBR	2000	HI	12500	F 1 m/s	375.7	229.9	166.1	132.6
Intermediate Line	FBR	2000	HI	13000	A 1 m/s	373.2	228.3	164.9	131.7
Intermediate Line	FBR	2000	HI	13000	D 3.5 m/s	375.6	233.6	170.7	135.3
Intermediate Line	FBR	2000	HI	13000	F 1 m/s	373.2	228.3	164.9	131.7
Intermediate Line	FBR	2000	HI	13500	A 1 m/s	369.1	225.8	163.0	130.2
Intermediate Line	FBR	2000	HI	13500	D 3.5 m/s	371.5	231.0	168.8	133.8
Intermediate Line	FBR	2000	HI	13500	F 1 m/s	369.1	225.8	163.0	130.2
Intermediate Line	FBR	2000	HI	14000	A 1 m/s	362.1	221.5	159.7	127.6
Intermediate Line	FBR	2000	HI	14000	D 3.5 m/s	364.4	226.6	165.5	131.2
Intermediate Line	FBR	2000	HI	14000	F 1 m/s	362.1	221.5	159.7	127.6

Jet Fire Analysis

Intermediate Line	FBR	2000	HI	14500	A 1 m/s	350.0	214.2	154.1	123.2
Intermediate Line	FBR	2000	HI	14500	D 3.5 m/s	352.4	219.1	160.0	126.7
Intermediate Line	FBR	2000	HI	14500	F 1 m/s	350.0	214.2	154.1	123.2
Intermediate Line	FBR	2000	HI	15000	A 1 m/s	329.1	201.4	144.6	115.6
Intermediate Line	FBR	2000	HI	15000	D 3.5 m/s	331.4	206.0	150.4	119.1
Intermediate Line	FBR	2000	HI	15000	F 1 m/s	329.1	201.4	144.6	115.6
Intermediate Line	FBR	2000	HI	15500	A 1 m/s	305.3	186.6	133.8	106.5
Intermediate Line	FBR	2000	HI	15500	D 3.5 m/s	307.6	191.0	139.4	110.1
Intermediate Line	FBR	2000	HI	15500	F 1 m/s	305.3	186.6	133.8	106.5
Intermediate Line	FBR	2000	HI	16000	A 1 m/s	274.0	167.7	120.5	95.6
Intermediate Line	FBR	2000	HI	16000	D 3.5 m/s	276.0	171.3	125.1	98.7
Intermediate Line	FBR	2000	HI	16000	F 1 m/s	274.0	167.7	120.5	95.6
Leewood	10	2000	H		A 1 m/s	8.0	7.6	7.6	7.6
	10	2000	H		D 3.5 m/s	7.8	7.6	7.6	7.6
	10	2000	H		F 1 m/s	8.0	7.6	7.6	7.6
Leewood	10	6500	H		A 1 m/s	14.3	12.5	11.7	11.1
	10	6500	H		D 3.5 m/s	14.2	12.6	11.9	11.5
	10	6500	H		F 1 m/s	14.3	12.5	11.7	11.1
Leewood	50	2000	H		A 1 m/s	42.7	34.8	31.1	28.2
	50	2000	H		D 3.5 m/s	42.9	35.9	32.6	30.5
	50	2000	H		F 1 m/s	42.7	34.8	31.1	28.2
Leewood	50	6500	H		A 1 m/s	73.7	58.4	51.1	45.8
	50	6500	H		D 3.5 m/s	74.1	60.3	53.9	49.5
	50	6500	H		F 1 m/s	73.7	58.4	51.1	45.8
Leewood	100	2000	H		A 1 m/s	83.7	65.8	57.2	51.3
	100	2000	H		D 3.5 m/s	84.1	68.0	60.5	55.4
	100	2000	H		F 1 m/s	83.7	65.8	57.2	51.3
Leewood	100	6500	H		A 1 m/s	139.2	105.8	89.6	81.2
	100	6500	H		D 3.5 m/s	139.3	109.1	95.1	84.0
	100	6500	H		F 1 m/s	139.2	105.8	89.6	81.2
Leewood	250	6500	FBR		A 1 m/s	438.2	317.3	272.8	245.4
	250	6500	FBR		D 3.5 m/s	443.5	329.3	275.9	251.5
	250	6500	FBR		F 1 m/s	438.2	317.3	272.8	245.4

CR = Catastrophic Rupture, size of rupture vessel given
H = Horizontal (above ground) leak, size of hole given
HI = Horizontal Impinging (below ground) leak, size of hole given
FBR = Full Bore Rupture

Flash Fire Analysis

Section Description	Equivalent Hole Size (mm)	Volume (m3)	Pressure (kPa)	Release Type & Direction	Rupture Location along pipe (m)	Distance to UFL contour (m)	Distance to LFL contour (m)	Distance to UFL contour (m)	Distance to LFL contour (m)	Distance to UFL contour (m)	Distance to LFL contour (m)
						Weather					
						A 1 m/s		D 3.5 m/s		F 1 m/s	
Wellheads		0.5	620	CR		1.0	1.9	1.0	2.2	1.0	1.9
Wellheads	10		620	H		No Hazard	No Hazard	No Hazard	No Hazard	No Hazard	No Hazard
Wellheads	50		620	H		No Hazard	9.2	No Hazard	8.6	No Hazard	11.6
Wellheads	100		620	H		No Hazard	30.0	No Hazard	28.5	No Hazard	32.9
Gathering Lines	10		420	HI	Any	No Hazard	No Hazard	No Hazard	No Hazard	No Hazard	No Hazard
Gathering Lines	50		420	HI	Any	No Hazard	25.3	No Hazard	30.0	8.4	10.8
Gathering Lines	100		420	HI	Any	16.1	22.3	No Hazard	60.7	13.1	15.5
Gathering Lines	FBR		420	HI	0	39.5	51.7	48.9	70.2	35.4	43.0
Gathering Lines	FBR		420	HI	500	41.8	56.6	52.6	74.4	38.5	48.2
Gathering Lines	FBR		420	HI	1000	41.0	53.7	50.5	71.2	38.1	47.6
Gathering Lines	FBR		420	HI	1500	42.1	56.6	52.4	73.4	39.8	49.6
Gathering Lines	FBR		420	HI	2000	44.3	59.5	54.8	77.5	41.9	51.1
Gathering Lines	FBR		420	HI	2500	45.4	60.5	55.9	78.9	42.8	51.7
Gathering Lines	FBR		420	HI	3000	44.3	59.4	54.8	77.4	41.8	51.1
Gathering Lines	FBR		420	HI	3500	42.0	56.4	52.3	73.1	39.7	49.5
Gathering Lines	FBR		420	HI	4000	41.0	53.5	50.4	71.1	38.0	47.4
Gathering Lines	FBR		420	HI	4500	41.7	56.5	52.5	74.5	38.4	48.1
Gathering Lines	FBR		420	HI	5000	39.8	52.0	49.5	70.9	35.7	43.1
Bibblewindi		0.5	2000	CR		1.5	2.7	1.5	3.0	1.5	2.7
Bibblewindi		0.5	172	CR		0.6	1.3	0.7	1.7	0.7	1.3
Bibblewindi		1.0	2000	CR		1.9	3.6	2.0	3.9	2.0	3.5
Bibblewindi		1.0	172	CR		0.9	1.8	1.0	2.3	0.9	1.7
Bibblewindi		2.0	2000	CR		2.5	4.6	2.6	5.1	2.6	4.6
Bibblewindi		2.0	172	CR		1.2	2.3	1.3	3.0	1.3	2.3

Flash Fire Analysis

Section Description	Equivalent Hole Size (mm)	Volume (m3)	Pressure (kPa)	Release Type & Direction	Rupture Location along pipe (m)	Distance to UFL contour (m)	Distance to LFL contour (m)	Distance to UFL contour (m)	Distance to LFL contour (m)	Distance to UFL contour (m)	Distance to LFL contour (m)
						Weather					
						A 1 m/s		D 3.5 m/s		F 1 m/s	
Bibblewindi	10		2000	H		No Hazard	57.3	No Hazard	57.9	7.4	61.2
Bibblewindi	10		172	H		No Hazard	No Hazard	No Hazard	No Hazard	No Hazard	No Hazard
Bibblewindi	50		2000	H		No Hazard	22.8	No Hazard	21.4	No Hazard	25.4
Bibblewindi	50		172	H		No Hazard	No Hazard	No Hazard	No Hazard	No Hazard	No Hazard
Bibblewindi	100		2000	H		No Hazard	57.3	No Hazard	57.9	7.4	61.2
Bibblewindi	100		172	H		No Hazard	13.0	No Hazard	12.0	No Hazard	15.5
Intermediate Line	10		2000	HI	Any	No Hazard	No Hazard	No Hazard	No Hazard	No Hazard	No Hazard
Intermediate Line	100		2000	HI	Any	25.9	35.4	41.1	117.2	21.4	25.5
Intermediate Line	50		2000	HI	Any	16.6	23.5	No Hazard	63.7	13.6	16.7
Intermediate Line	FBR		2000	HI	0	94.6	125.6	114.8	161.3	106.3	137.9
Intermediate Line	FBR		2000	HI	500	80.9	106.3	98.4	138.6	88.3	113.8
Intermediate Line	FBR		2000	HI	1000	85.3	116.2	104.9	145.7	95.5	121.2
Intermediate Line	FBR		2000	HI	1500	89.1	121.1	109.4	152.0	99.6	125.9
Intermediate Line	FBR		2000	HI	2000	91.5	123.3	111.8	156.2	102.0	132.0
Intermediate Line	FBR		2000	HI	2500	93.0	124.5	113.2	158.9	103.8	134.8
Intermediate Line	FBR		2000	HI	3000	93.6	124.9	113.8	160.0	104.7	136.0
Intermediate Line	FBR		2000	HI	3500	93.9	125.1	114.1	160.5	105.2	136.6
Intermediate Line	FBR		2000	HI	4000	94.0	125.2	114.3	160.9	105.4	136.9
Intermediate Line	FBR		2000	HI	4500	94.1	125.2	114.3	160.9	105.4	136.9
Intermediate Line	FBR		2000	HI	5000	94.1	125.3	114.3	160.9	105.4	136.9
Intermediate Line	FBR		2000	HI	5500	94.0	125.2	114.3	160.8	105.4	136.9
Intermediate Line	FBR		2000	HI	6000	93.9	125.1	114.2	160.8	105.3	136.7
Intermediate Line	FBR		2000	HI	6500	93.9	125.1	114.2	160.6	105.2	136.7
Intermediate Line	FBR		2000	HI	7000	93.8	125.0	114.1	160.5	105.1	136.5
Intermediate Line	FBR		2000	HI	7500	93.8	125.0	114.0	160.3	105.0	136.4

Flash Fire Analysis

Section Description	Equivalent Hole Size (mm)	Volume (m3)	Pressure (kPa)	Release Type & Direction	Rupture Location along pipe (m)	Distance to UFL contour (m)	Distance to LFL contour (m)	Distance to UFL contour (m)	Distance to LFL contour (m)	Distance to UFL contour (m)	Distance to LFL contour (m)
						Weather					
						A 1 m/s		D 3.5 m/s		F 1 m/s	
Intermediate Line	FBR		2000	HI	8000	93.7	124.9	113.9	160.2	104.9	136.3
Intermediate Line	FBR		2000	HI	8500	93.6	124.9	113.9	160.1	104.8	136.2
Intermediate Line	FBR		2000	HI	9000	93.5	124.8	113.7	159.8	104.6	135.8
Intermediate Line	FBR		2000	HI	9500	93.4	124.7	113.7	159.9	104.5	135.8
Intermediate Line	FBR		2000	HI	10000	93.3	124.7	113.5	159.5	104.4	135.6
Intermediate Line	FBR		2000	HI	10500	93.2	124.6	113.4	159.3	104.2	135.4
Intermediate Line	FBR		2000	HI	11000	93.1	124.6	113.3	159.1	104.1	135.2
Intermediate Line	FBR		2000	HI	11500	93.0	124.4	113.2	158.9	103.8	134.9
Intermediate Line	FBR		2000	HI	12000	92.8	124.3	113.0	158.6	103.6	134.5
Intermediate Line	FBR		2000	HI	12500	92.5	124.1	112.7	158.0	103.1	133.7
Intermediate Line	FBR		2000	HI	13000	91.9	123.6	112.1	156.9	102.4	132.7
Intermediate Line	FBR		2000	HI	13500	90.9	122.8	111.3	155.4	101.4	130.5
Intermediate Line	FBR		2000	HI	14000	89.3	121.3	109.6	152.2	99.8	126.4
Intermediate Line	FBR		2000	HI	14500	86.4	118.3	106.7	147.3	97.1	122.6
Intermediate Line	FBR		2000	HI	15000	83.0	110.7	101.0	142.0	91.8	118.0
Intermediate Line	FBR		2000	HI	15500	76.5	102.9	93.7	131.7	82.9	103.5
Intermediate Line	FBR		2000	HI	16000	71.7	98.0	89.0	123.9	77.2	98.7
Leewood		0.5	15000	CR		3.1	5.7	3.2	6.3	3.1	5.7
Leewood		0.5	2000	CR		1.5	2.9	1.6	3.2	1.6	2.9
Leewood		0.5	6500	CR		2.3	4.2	2.4	4.6	2.3	4.2
Leewood		1.0	15000	CR		4.0	7.3	4.2	8.1	4.0	7.3
Leewood		1.0	2000	CR		2.0	3.7	2.1	4.1	2.0	3.7
Leewood		1.0	6500	CR		3.0	5.4	3.1	5.9	3.0	5.4

Flash Fire Analysis

Section Description	Equivalent Hole Size (mm)	Volume (m3)	Pressure (kPa)	Release Type & Direction	Rupture Location along pipe (m)	Distance to UFL contour (m)	Distance to LFL contour (m)	Distance to UFL contour (m)	Distance to LFL contour (m)	Distance to UFL contour (m)	Distance to LFL contour (m)
						Weather					
						A 1 m/s		D 3.5 m/s		F 1 m/s	
Leewood		2.0	15000	CR		5.1	9.4	5.3	10.3	5.2	9.4
Leewood		2.0	2000	CR		2.6	4.8	2.7	5.4	2.7	4.8
Leewood		2.0	6500	CR		3.8	7.0	4.0	7.6	3.9	7.0
Leewood	10		2000	H		No Hazard	No Hazard	No Hazard	No Hazard	No Hazard	No Hazard
Leewood	10		6500	H		No Hazard	No Hazard	No Hazard	No Hazard	No Hazard	No Hazard
Leewood	50		2000	H		No Hazard	24.0	No Hazard	22.7	No Hazard	26.9
Leewood	50		6500	H		No Hazard	52.9	No Hazard	51.6	No Hazard	56.2
Leewood	100		2000	H		No Hazard	64.2	No Hazard	63.1	8.1	67.8
Leewood	100		6500	H		18.9	98.8	18.7	111.8	20.7	107.2
Leewood	250		6500	FBR		108.9	209.2	103.0	275.5	112.5	238.6

CR = Catastrophic Rupture, size of rupture vessel given
H = Horizontal (above ground) leak, size of hole given
HI = Horizontal Impinging (below ground) leak, size of hole given
UFL = Upper Flammability Limit (16.5%)
LFL = Lower Flammability Limit (4.4%)
FBR = Full Bore Rupture

Fireball Analysis

Section Description	Volume (m3)	Pressure (kPa)	Release Type & Direction	Distance to 4.7 kW/m2 contour (m)	Distance to 12.6 kW/m2 contour (m)	Distance to 23 kW/m2 contour (m)	Distance to 35 kW/m2 contour (m)
Wellheads	0.5		CR	17.9	9.7	5.6	2.2
Bibblewindi	0.5	172	CR	10.7	5.6	2.8	Not Reached
Bibblewindi	1.0	172	CR	13.6	7.0	3.1	Not Reached
Bibblewindi	2.0	172	CR	17.3	8.7	3.6	Not Reached
Bibblewindi	0.5	2000	CR	30.3	17.2	11.0	6.9
Bibblewindi	1.0	2000	CR	38.6	21.9	14.0	8.6
Bibblewindi	2.0	2000	CR	49.3	28.0	17.9	11.1
Leewood	0.5	2000	CR	31.6	17.9	11.5	7.1
Leewood	1.0	2000	CR	40.3	22.9	14.6	9.0
Leewood	2.0	2000	CR	51.5	29.2	18.7	11.7
Leewood	0.5	6500	CR	55.5	32.6	22.2	15.8
Leewood	1.0	6500	CR	70.8	41.6	28.4	20.3
Leewood	2.0	6500	CR	90.2	53.2	36.4	26.0

CR = Catastrophic Rupture

Overpressure Analysis

Section Description	Volume (m3)	Pressure (kPa)	Release Type & Direction	3.5 kPa	7 kPa	14 kPa	21 kPa	35 kPa
Bibblewindi	0.5	172	CR	37.8	20.4	11.7	8.8	6.4
Bibblewindi	1.0	172	CR	47.6	25.7	14.7	11.1	8.0
Bibblewindi	2.0	172	CR	59.9	32.4	18.6	13.9	10.1
Bibblewindi	0.5	2000	CR	72.2	39.1	22.4	16.8	12.2
Bibblewindi	1.0	2000	CR	91.0	49.2	28.2	21.2	15.4
Bibblewindi	2.0	2000	CR	114.6	62.0	35.5	26.7	19.4
Leewood	0.5	2000	CR	76.7	41.5	23.8	17.8	12.9
Leewood	1.0	2000	CR	96.6	52.3	29.9	22.5	16.3
Leewood	2.0	2000	CR	121.7	65.8	37.7	28.3	20.6
Leewood	0.5	6500	CR	109.1	59.0	33.8	25.4	18.4
Leewood	1.0	6500	CR	137.5	74.4	42.6	32.0	23.2
Leewood	2.0	6500	CR	173.2	93.7	53.7	40.3	29.2

CR = Catastrophic Rupture

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