25. PRELIMINARY HAZARD AND RISK

This chapter provides a summary of the potential hazards associated with the project during the construction, operation and decommissioning phases of the project and an assessment of their risks to people and property. Risk management objectives have been developed and the avoidance, mitigation and management measures to achieve these objectives identified. The residual impact assessment assumes that the proposed avoidance, mitigation and management measures have been applied.

The assessment of potential hazards and risks associated with the project infrastructure included consideration of coal seam gas production wells, gathering systems and production facilities. Production facilities are assumed to comprise a combination of gas compression facilities, water treatment facilities and power generation. The preliminary assessment of hazard and risk for the project was undertaken by Planager and is included as Appendix S, Preliminary Hazard and Risk Assessment. The findings of the study are summarised herein.

25.1 Legislative Context and Standards

The following legislation and associated regulations, standards and guidance documents are relevant to identifying hazards and risk, and to provide guidance on avoiding, mitigating and managing impacts through all phases of the project. Project facilities will need to comply with Australian laws, regulations, standards, codes and guidelines and/or internationally recognised standards as described below.

Environmental Protection Act 1994 **(Qld) (EP Act).** The objective of the EP Act is to protect Queensland's environment by promoting ecologically sustainable development. The Environmental Protection Regulation 2008 provides a mechanism to enforce the EP Act and allows for an assessment of the risk that an environmentally relevant activity poses to environmentally sensitive areas. Several environmentally sensitive areas exist within the proposed project development area. The EP Act monitors the storage and handling of dangerous chemicals on site and the potential risks to human health and the environment.

Petroleum and Gas (Production and Safety) Act 2004 **(Qld) (P&G Act).** The P&G Act regulates the natural gas and petroleum industry (including coal seam gas) in Queensland. The aim of the act is to facilitate and regulate responsible petroleum activities and the expansion of the industry in a safe, efficient and viable manner. The act aims to minimise land-use conflicts and encourage responsible land-use management.

Petroleum and Gas (Production and Safety) Regulation 2004 (Qld). The regulation sets the requirements for safe operations of petroleum installations under the P&G Act, as well as the obligations of operators. Under the P&G Act, operators of an operating plant are obligated to prepare and submit a suitable safety management plan that is appropriate to the level of the plant.

Dangerous Goods Safety Management Act 2001 **(Qld).** The act sets out requirements and obligations that relate to the storage and handling of dangerous goods and combustible liquids. The act aims to protect humans against harm or injury and property and the environment from matters arising from explosion, fire and harmful reaction.

***Workplace Health and Safety Act 1995* (Qld).** The act applies to most construction activities and establishes a framework for preventing or minimising workers' exposure to risks. This is done by imposing safety obligations on certain persons and establishing benchmarks for industry.

***Electrical Safety Act 2002* (Qld).** The act establishes a legislative framework for electrical safety in Queensland to prevent injury or fatality to people and the destruction or damage to property from electricity. The principles of the Electrical Safety Act are applicable when electrical works are conducted under the Petroleum and Gas (Production and Safety) Regulation 2004 (Qld).

National Standard for Occupational Noise (Cwlth) (NOHSC, 2000). The aim of this standard is to provide advice to reduce the number of incidence and the severity of occupational noise-induced hearing loss. This standard applies to all workplaces where there is potential for exposure to excessive noise, the facilities, processes in those workplaces, and all persons in those workplaces with potential for exposure to excessive noise.

Other codes and standards that are relevant to the project include, but are not necessarily limited to, the following:

- AS/NZS ISO31000-2009: Risk Management – Principles and Guidelines (Standards Australia, 2009a). This document provides principles and generic guidelines for evaluating potential hazards and reducing the risk through risk management.
- AS/NZS 2885.1-2007: Pipelines – Gas and Liquid Petroleum, Part 1 (Standards Australia, 2007). Risks have been classified using Arrow's risk matrix that is compatible with the risk matrix found in this document.
- Hazardous Industry Planning Advisory Paper No 4 – Risk Criteria for Land Use Planning (NSW) (DPI, 2011a). This guideline follows internationally recognised practices for hazard and risk assessments and has been adopted for this preliminary hazard and risk assessment as no formal risk assessment guideline have been published in Queensland.
- Hazardous Industry Planning Advisory Paper No 6 – Guidelines for Hazard Analysis (NSW) (DPI, 2011b). This guideline follows internationally recognised practices for hazard and risk assessments and has been adopted for this preliminary hazard assessment as no formal risk assessment guideline have been published in Queensland.
- State Planning Policy 1/03, Mitigating the Adverse Impacts of Flood, Bushfire and Landslide (Qld). Under the *Integrated Planning Act 1997*, this policy requires that the potential impact on people, property, economic activity and the environment from floods, bush fire and landslide are minimised.
- SafeOP for Petroleum and Gas - A Guide to Legislative Requirements for Operating Plant (DNRM, 2005). This document provides guidance to operators on the matters they must include in a safety management plan.
- Locational Guidelines – Development in the Vicinity of Operating Coal Seam Methane Wells (DIPNR, 2004). These NSW guidelines have been referred to in the present risk analysis and adapted for the local Surat Gas Project conditions and for the Arrow well design.

25.2 Assessment Methods

The preliminary hazard and risk assessment was completed in accordance with ISO 31000:2009 Risk Management – Principles and Guidelines (Standards Australia, 2009a), both qualitatively

and quantitatively. The assessment considered risks to people and property, including the public, in the vicinity of the proposed project facilities.

The risk assessment process involved identification of the possible hazards, the causes or initiating factors of the hazardous event, the consequences of the event and the associated risks of those consequences occurring. The risks associated with a hazardous event are commonly defined as a function of the following four elements:

- The likelihood of the event (such as a loss-of-containment event).
- The consequences associated with the event (such as the thermal damage or level of injury from a fire).
- The effects of the event (such as thermal radiation from a fire due to release).
- The effectiveness of systems for preventing the event or mitigating hazards and consequences (such as safety and security systems).

Overall, the risk assessment comprised:

- A hazard identification process.
- A quantitative risk assessment.
- A qualitative risk assessment.

25.2.1 Hazard Identification

The hazard identification process involved the following desktop reviews:

- Assessment of the hazardous properties inherent to gas extraction, processing and handling.
- Conceptual hazard and risk operational study (Conceptual HAZOP). The Conceptual HAZOP was completed by a multidisciplinary team from design, operations, safety, environment and maintenance functions.
- Review of other relevant hazard identification studies.
- Review of similar facilities and the historical incidents and near misses associated with them.
- Assessment of location-specific threats and issues.
- Definition of relevant hazardous incident scenarios.

25.2.2 Quantitative Risk Assessment

The quantitative risk assessment was carried out for the operational stage of the proposed development in order to determine appropriate buffer zones between the production facilities and neighbouring land uses. The quantitative risk assessment focused on the production wells, gathering systems, field compression facilities, central gas processing facilities and integrated processing facilities.

The risk assessment generally included:

- Consequence calculations on credible incident scenarios using industry-recognised software for consequence modelling.

- Likelihood estimations of historical accident and equipment failure rate data from a number of recognised sources. The following four factors were considered in determining the likelihood of consequences:
  - The basic failure rate for each type of identified failure.
  - The overall failure rate applicable to the type of equipment to be used.
  - The probability of ignition of flammable gas that would be released upon failure.
  - Probability of the realisation of certain effects (e.g., fatality, injury, or property damage).
- A risk evaluation combining the event frequency (likelihood) and hazard consequence data to produce estimates of risk and generate risk curves.

The quantitative risk assessment was developed with consideration of:

- The flammability of the coal seam gas
- The inventory of gas available to be released
- The nature of the release and the pressure under which the gas could be released.

It must be noted that safety features, including but not limited to emergency shutdown and isolation valves, are designed into gas infrastructure. These have the specific purpose of limiting the volume of gas released. Facilities are designed so that emergency isolation and shutdown valves operate automatically or manually. As such, an emergency situation, such as a leak around the compressors at a production facility, would result in isolation valves automatically closing around the compressors in order to minimise the amount of gas released. The quantitative risk assessment assumes that safety features such as these are designed and built into the facilities and that they are effective.

The results of the risk analysis are presented as:

- Individual fatality risk, i.e., the likelihood (or frequency) of fatality to notional individuals at locations around the site, as a result of any of the events. The units for individual risk are probability (of fatality) per million per year.
- Injury and propagation risk, i.e., the likelihood of injury or propagation to individuals or plant at locations around the site as a result of the same events used to calculate individual fatality risk (above). The units for injury and propagation risk are probability (of injury/propagation) per million per year.

The calculated risk results were compared with the relevant risk criteria as summarised in Table 25.1.

Table 25.1 Risk criteria

Land Use	**Criteria ($\times 10^{-6}$ per year)**
Individual Fatality Risk	
Sensitive developments (hospitals, schools, child-care facilities, old-age housing)	0.5
Residential (and hotels, motels, tourist resorts)	1
Business (commercial developments including retail centers, offices and entertainment areas)	5
Active open space (including sporting complexes)	10

Table 25.1 Risk criteria (cont'd)

Land Use	Criteria ($\times 10^{-6}$ per year)
Individual Fatality Risk (cont'd)	
Industrial	50
Injury and Propagation Risk	
Injury risk criteria (4.7 kilowatts per square metre (kW/m^2), 7 kPa)	50
Propagation risk criteria (23 kW/m^2, 14 kPa)	50

All aspects of the assessment were completed with consideration of the hazardous properties of coal seam gas. Coal seam gas is composed predominately of methane, which is a buoyant, flammable gas that is lighter than air (relative density of 0.6). On release in the open air, methane tends to disperse rapidly at altitude if not ignited. Coal seam gas will displace oxygen in confined spaces and, if an ignition source is present, will ignite and/or explode if accumulated.

The following scenarios were considered to be possible and were accordingly modelled in the quantitative risk assessment:

- Jet fires, resulting from the ignition of a continuous release of coal seam gas producing a long, stable, high-temperature flame. In case of a low-pressure, low-velocity or intermittent release, the resulting fire may be much shorter and less stable than in the case of a jet fire and generally would not result in equipment damage or injury.
- Flash fires, occurring when a cloud of coal seam gas vapour is ignited, resulting in a flame travelling through the cloud.
- Vapour cloud explosion, occurring when a large cloud of coal seam gas vapour is ignited. Vapour cloud explosions associated with lighter-than-air gases (such as coal seam gas) generally require confinement (such as in a building or enclosure) for the cloud to accumulate. Because of the requirement for gas to be confined, vapour cloud explosions are considered credible at compression facilities but not at wells or on gathering lines.

The effects of these events on people depend on the duration of exposure and their distance from the fire or explosion.

25.2.3 Qualitative Risk Assessment

A qualitative risk assessment was undertaken for those risks that could not be assessed quantitatively . The assessment was carried out across phases of the project for credible hazard events with potential risks to people and property. The risks were classified using a 'five by five risk matrix' compatible with AS 2885.1: Pipelines – Gas and Liquid Petroleum, Part 1 (Standards Australia, 2007).

25.2.4 Consultation with Emergency Services

Emergency Management Queensland and representatives of the various emergency services responsible for the project development area were consulted to determine potential response measures to be considered in the risk assessments

Arrow will continue consultation with emergency services and the local disaster management groups as field development progresses and the locations of infrastructure are better understood.

25.3 Existing Environment and Environmental Values

This section provides a description of the environment and community that may be affected by the proposed Surat Gas Project activities. The project development area is primarily composed of rural areas used for sheep, cattle grazing and cultivation, but includes isolated areas of bushland and state forests. Population is widely dispersed, except for townships such as Dalby, Chinchilla, Cecil Plains, Wandoan and Goondiwindi.

This dispersed population, large amount of open land and the widely distributed extent of the coal seam gas resource allows the Surat Gas Project to develop facilities in locations that maintain distance from centres of population and residential locations. This, and the inherent flexibility in the location of project infrastructure, contributes to the safety of people and property through adequate separation.

The existing environment contains areas of natural bushland and grassland. The hot summers and prolonged cycle of drought and drought-breaking rains mean that the project development area may be affected by bushfires as well as floods. The natural environment is also host to potentially hazardous wildlife, such as snakes, spiders, ticks and disease vectors such as mosquitoes. The environmental values attributable to these aspects include:

- The health, safety and wellbeing of people, property and the wider community.
- The ecosystems in and surrounding the project development area that potentially could be affected by the development.

25.4 Issues and Potential Impacts

The potential issues associated with hazard and risk relate to the exposure of people (the public and the project workforce) and property to hazards that are inherent to coal seam gas development. Hazards and risks have been identified through the life of the development from construction to decommissioning. There are significant safety features integral in the design of the project infrastructure as a matter of normal engineering standards, therefore the assessment of premitigated impacts and residual impacts is not necessary. Accordingly, this section presents an assessment of impacts based on the premise that infrastructure will be designed, constructed and operated with safety controls in place.

25.4.1 Issues Identified Through Quantitative Risk Assessment

The quantitative risk assessment identified the potential hazards and risks from the operation phase of the project. Issues associated with the operation of the production wells, gathering systems, processing facilities and high-pressure pipelines relate to fire and thermal radiation and over pressure as described in Table 25.2.

Table 25.2 Quantitative impact potential for coal seam gas

Hazard	Potential Outcome	Method of Estimation
Thermal radiation from jet fire.	Fatality.	The probability of fatality from exposure to a jet fire is calculated with consideration of the heat radiation (kW/m^2) at the target or receptor and the duration of exposure to the jet fire (in minutes).
Thermal radiation from flash fire.	Fatality.	The probability of fatality from exposure to a flash fire assumes the fatality of 100% of persons located within a flame envelope where the flame envelope is the area where flammable gas is physically combusted.
Overpressure effects from explosion of a gas/vapour cloud.	Fatality.	The probability of fatality from exposure to overpressure waves assumes 100% fatality of all persons exposed to overpressure waves of greater than 30 kPa and that overpressures of less than 30 kPa are not considered potentially lethal.

The calculated risks from these operational hazards are described below for the production wells, gathering systems, processing facilities and high-pressure pipelines.

Production Wells

The risk associated with production wells is best represented as risk transects, whereby the risk is shown as a function of the receptor distance from the centre of the wellhead. Risk reduces with increasing distance from the wellhead and it is assumed that the transect can be applied equally in all directions from the wellhead. The risk transect for production wells is shown in Figure 25.1. The risk transect informs the buffer that is required around the wellhead for the protection of people and property. The buffer is dependent on the type of adjacent land use and the acceptability of risk for persons occupying that type of land use (generally dependant on the amount of time spent in that land use). The buffers for each land-use type (i.e., industrial, active open space, business, residential and sensitive) ensure that persons using the land-use types beyond those buffer zones are not exposed to unacceptable risk. The buffer is not designed to be protective of personnel involved in wellhead works. Where multiple land uses are located in the vicinity of a well, the largest of the applicable buffers would be considered appropriate. The minimum buffer distances around production wells are presented in Table 25.3.

Table 25.3 Minimum buffer distances required around production wells

Wells	Minimum Buffer Distance (m)				
	Industrial Buffer (50×10^{-6}/yr)	**Active Open Space (10×10^{-6}/yr)**	**Business (5×10^{-6}/yr)**	**Residential Development (1×10^{-6}/yr)**	**Sensitive Development (0.1×10^{-6}/yr)**
Production well with flexible connections	10 m	25 m	30 m	30 m	35 m

The injury and propagation risk contours to offsite populations from a production well incident indicate very low risk and that the risks are contained within the well site boundary thereby meeting the criteria as shown in Figure 25.2.

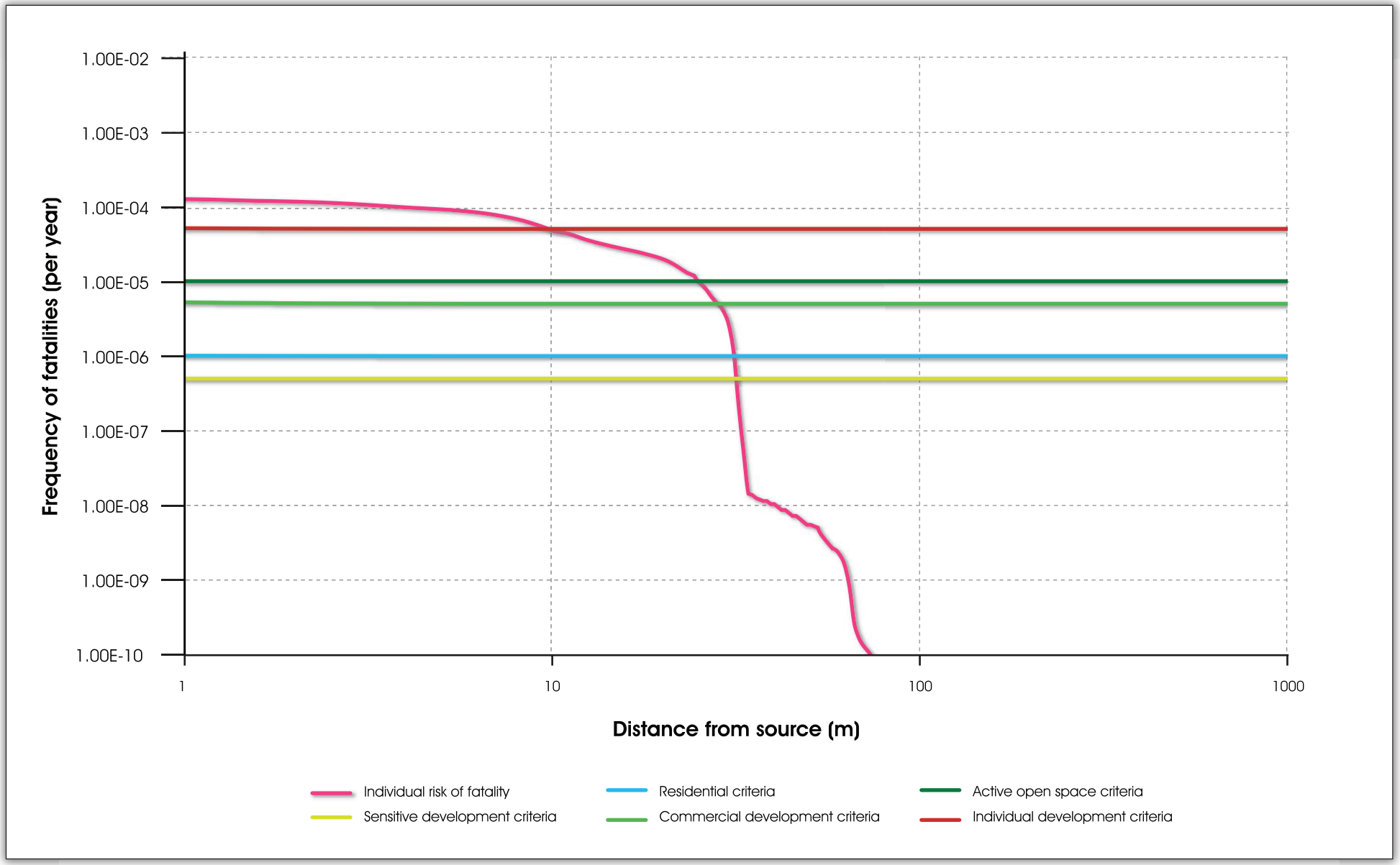
Gathering Systems

The risks associated with gathering lines are represented as risk transects, showing the risk as a function of the distance away from the centreline of a gathering. This is represented for both low and medium-pressure gathering lines in Figure 25.3.

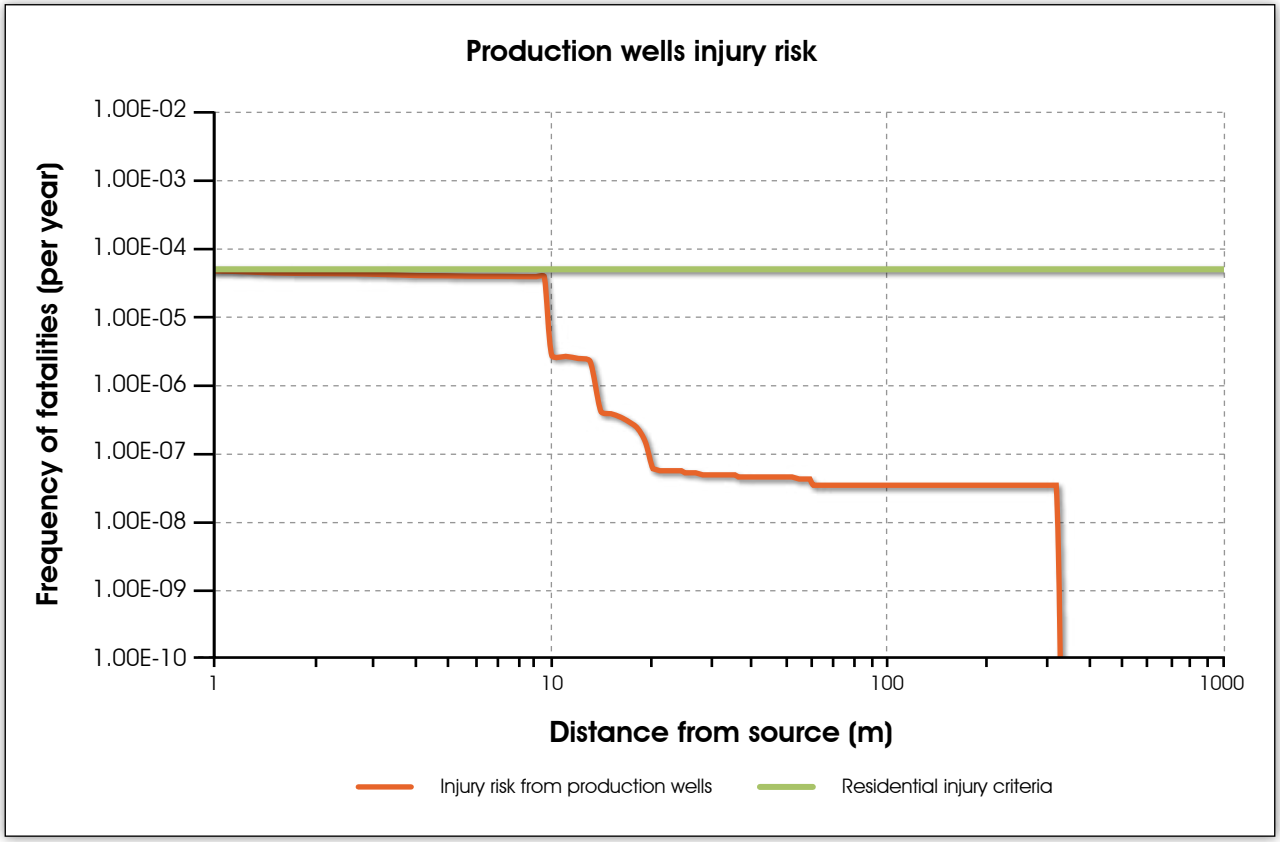
The injury and propagation risk from low and medium pressure gathering lines (100 mm and 630 mm diameter) are shown in Figure 25.4.

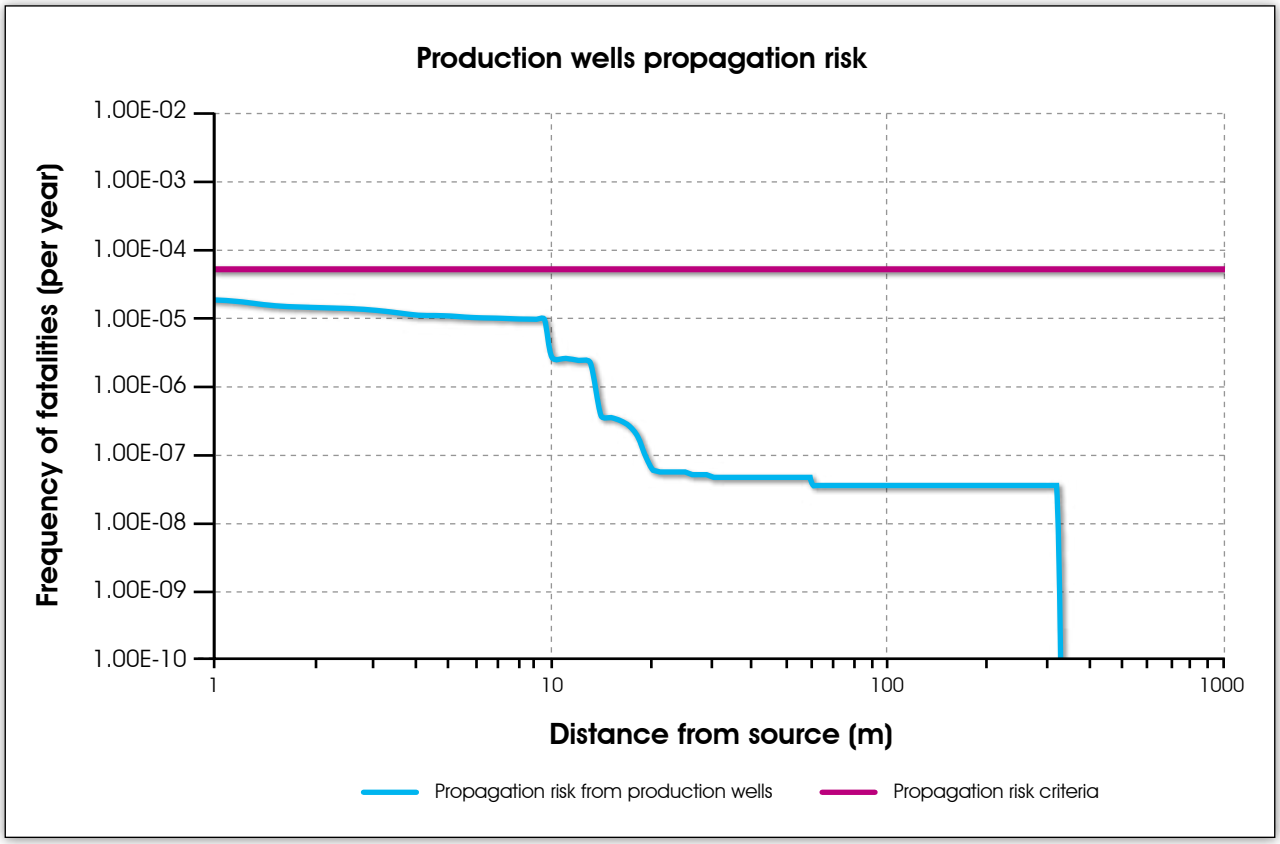
Field Compression Facilities

The primary hazardous activity associated with field compression facilities is the compression of gas. A hazardous incident with compressed gas could potentially result in risk beyond the facility boundary. Conceptually, a field compression facility will include two compressors but could have a maximum of eight. The quantitative risk assessment was developed based on a conservative site model that comprised eight compressors. The minimum buffer distances calculated around field compression facilities are presented in Table 25.4.

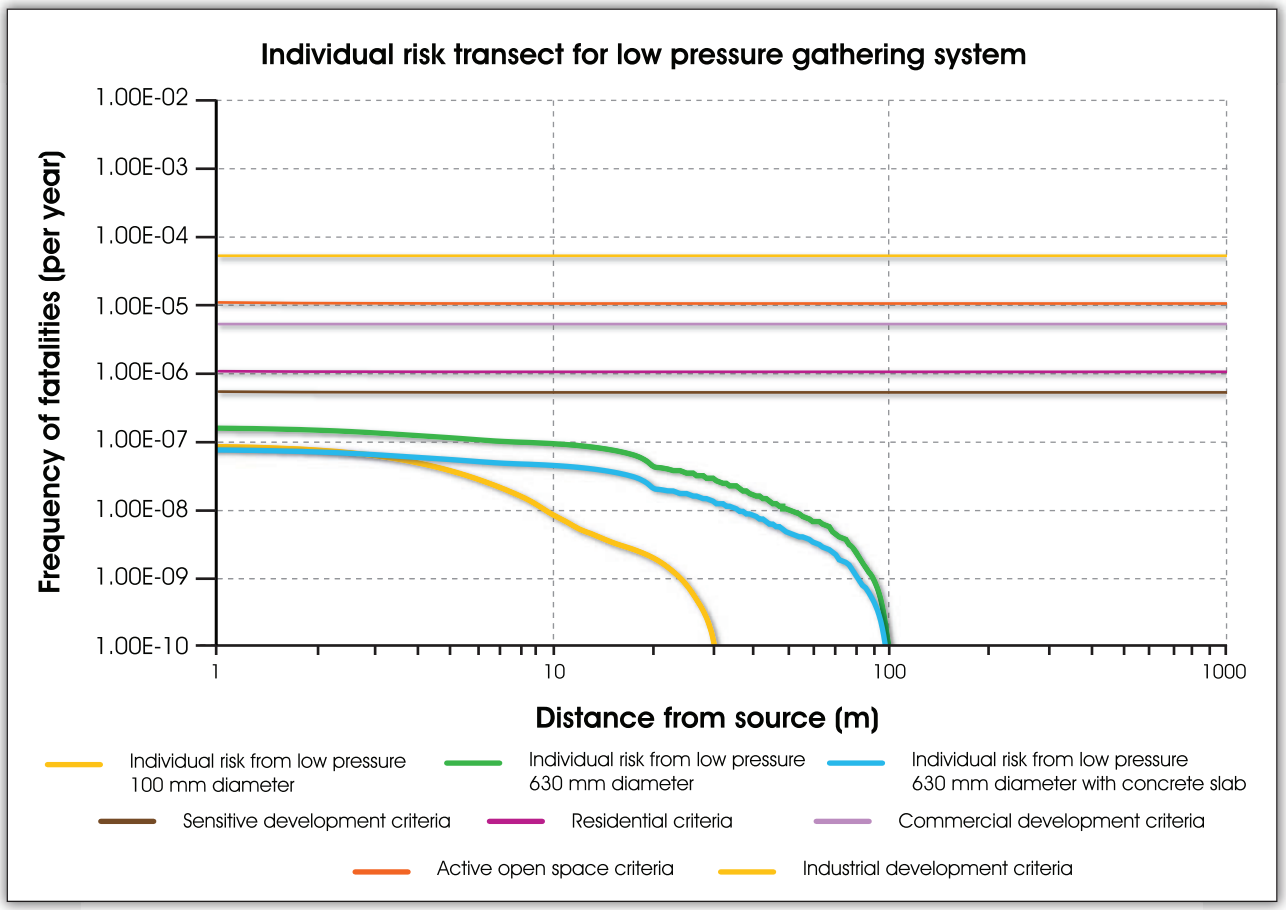


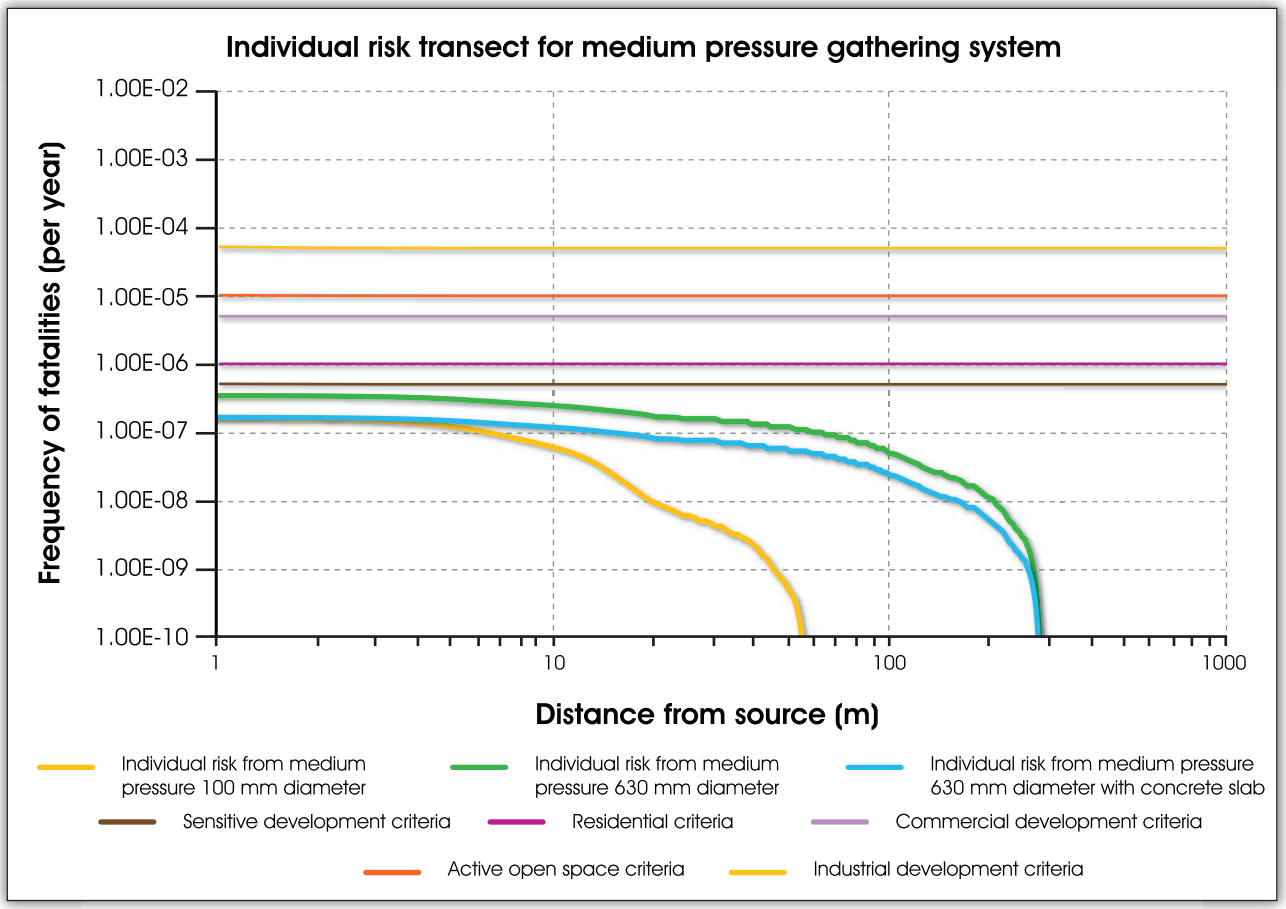
	coffey environments	Job No: 7040	Arrow Energy	arrow energy go further	Individual fatality risk transect for production wells
		File Name: 7040_04_F25.01_GL	Surat Gas Project		Figure No: 25.1



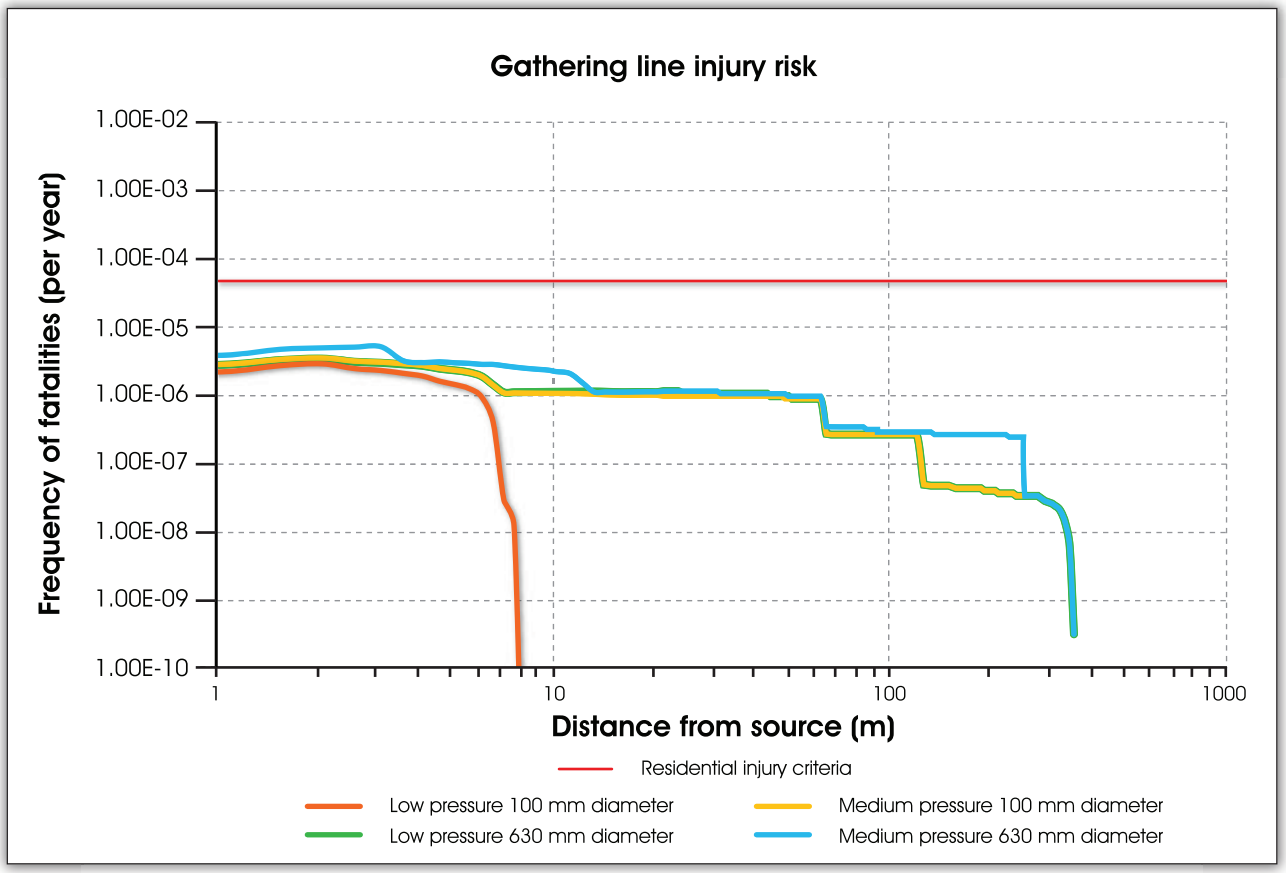


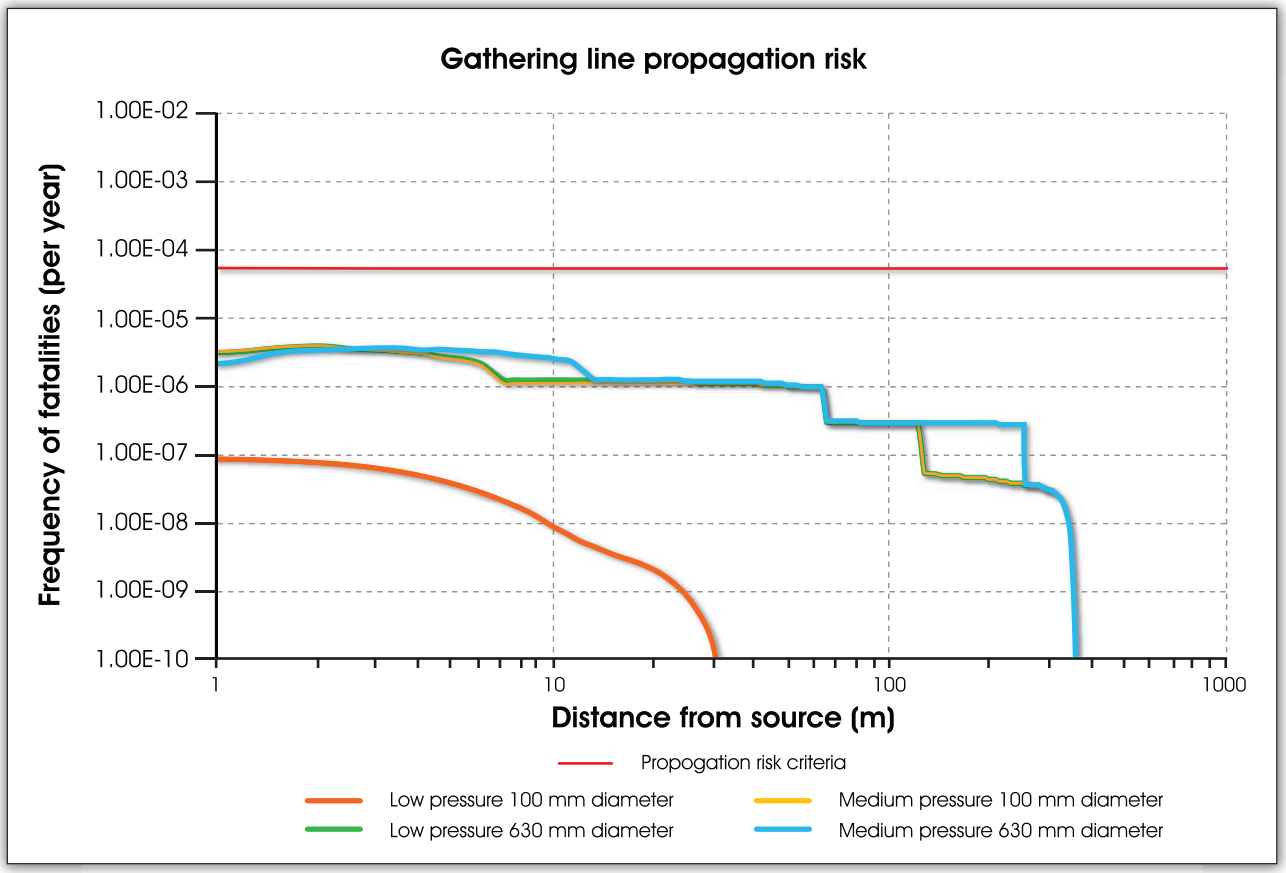
coffey environments	Job No: 7040 File Name: 7040_04_F25.02_FT	Arrow Energy Surat Gas Project	arrow energy go further	Production well injury and propagation risk	Figure No: 25.2





coffey environments	Job No: 7040 File Name: 7040_04_F25.03_FT	Arrow Energy Surat Gas Project	arrow energy go further	Individual risk transects for low and medium pressure gathering systems	Figure No: 25.3





coffey environments	Job No: 7040 File Name: 7040_04_F25.04_FT	Arrow Energy Surat Gas Project	arrow energy go further	Gathering line injury and propagation risk	Figure No: 25.4

Table 25.4 Minimum buffer distance around field compression facilities

Field Compression Facility	Minimum buffer distance (m)				
	Industrial Buffer (50×10^{-6} /yr)	Active Open Space (10×10^{-6} /yr)	Business (5×10^{-6} /yr)	Residential Development (1×10^{-6}/yr)	Sensitive Development (0.1×10^{-6}/yr)
Up to eight compressors	Site boundary	20 m from outer edge of compressors	30 m from outer edge of compressors	50 m from outer edge of compressors	100 m from outer edge of compressors

The risk of injury and propagation from a field compression facility (incident involving jet fire, flash fire, overpressure event) comprising two compressors is low with an acceptable risk level being achieved within the site boundary. For the largest conceivable field compression facility, the acceptable risk level is achieved 30 m from the outer edge of the compressors as shown in Figure 25.5.

Central Gas Processing Facility and Integrated Processing Facility

The gas handling and compression equipment is similar for central gas processing facilities and integrated processing facilities. The main difference between these facilities is the addition of water treatment facilities at the integrated processing facilities, which do not significantly affect risk and hence the assessment is applicable to both.

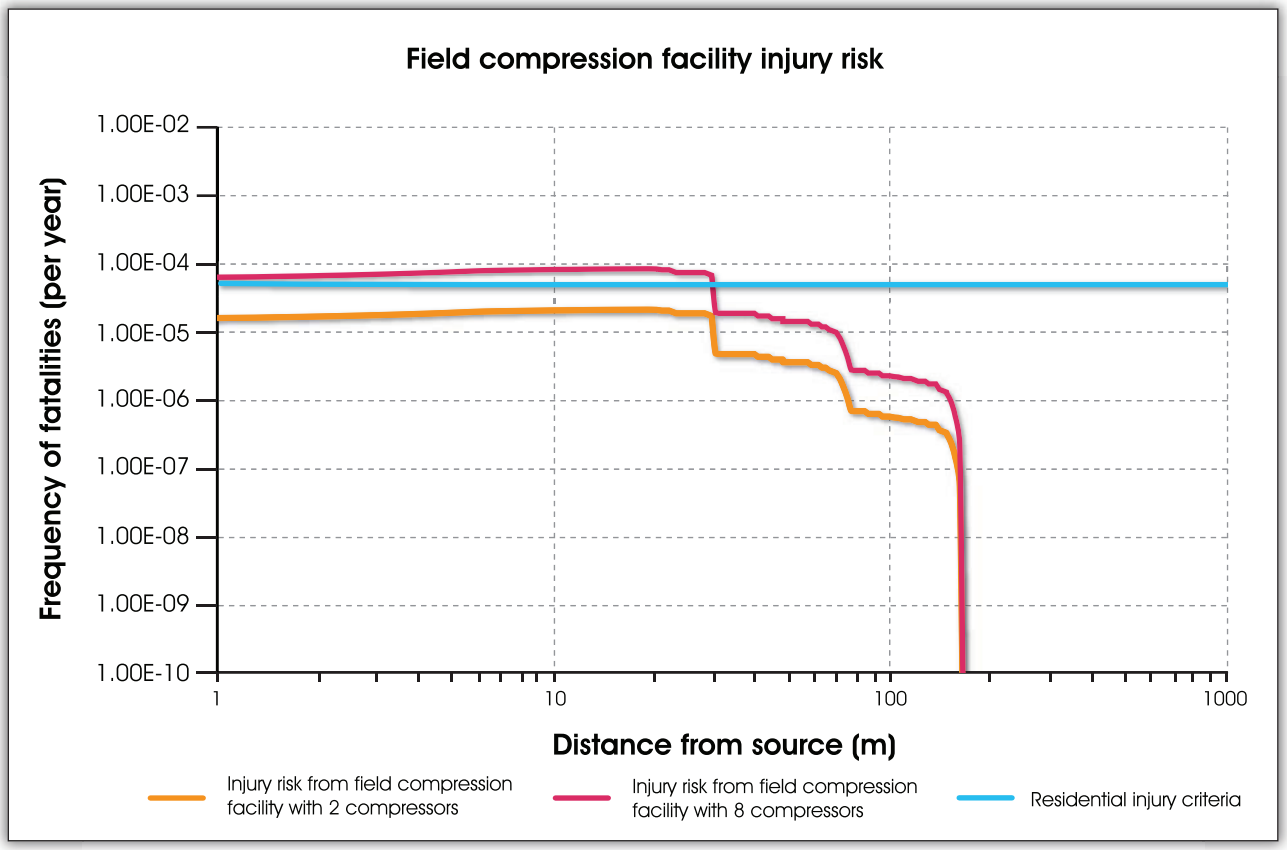
Individual fatality risks associated with central gas and integrated processing facilities relate to the compression of gas and incidents involving jet fire, flash fire or overpressure events that have the potential to affect people or property beyond the facility boundary. Central gas and integrated processing facilities typically include 14 compressors, all which have been modelled to establish appropriate buffer zones. The minimum buffer distances around central gas and integrated processing facilities are presented in Table 25.5.

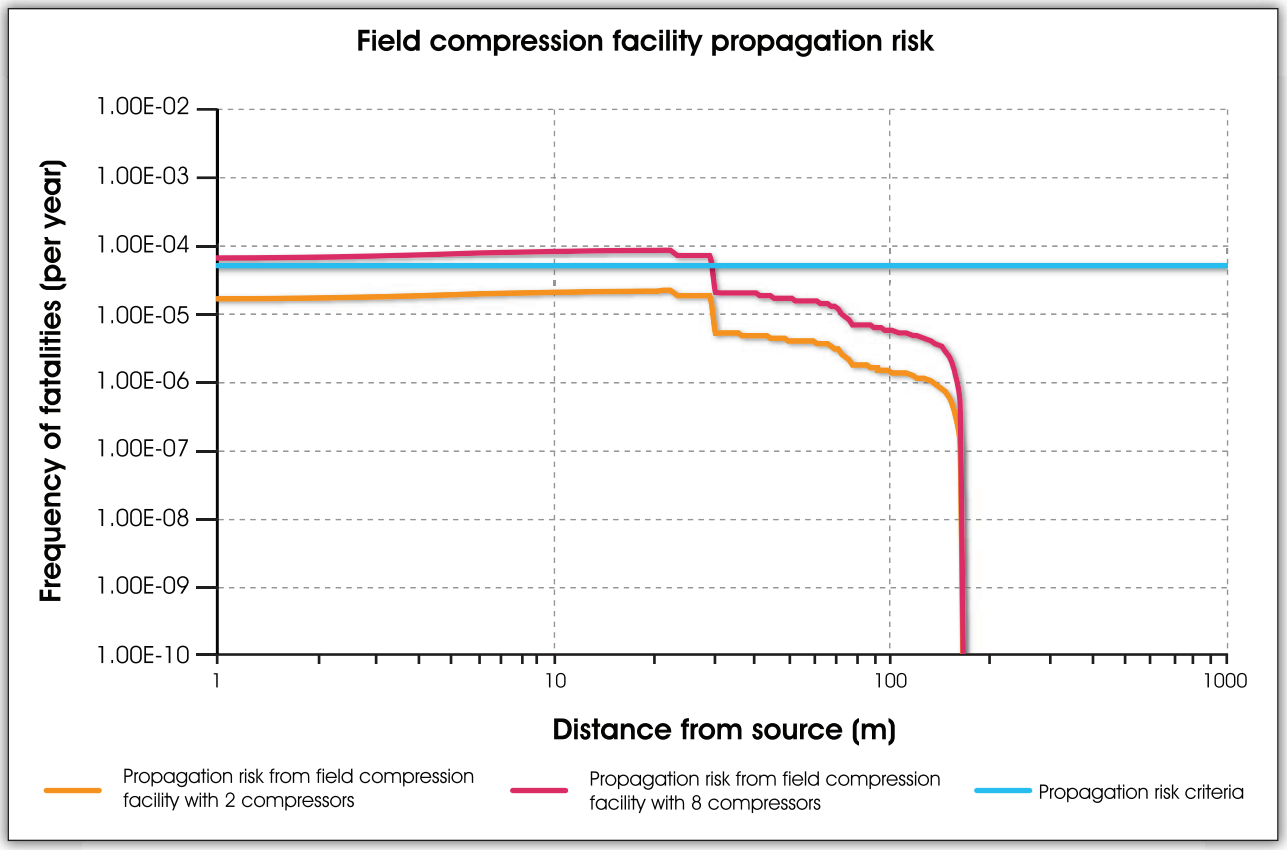
Table 25.5 Minimum buffer distance for central gas processing and integrated processing facilities

Central gas and integrated processing facilities	Minimum buffer distance (metres)				
	Industrial Buffer (50×10^{-6} /yr)	Active Open Space (10×10^{-6} /yr)	Business (5×10^{-6} /yr)	Residential Development (1×10^{-6}/yr)	Sensitive Development (0.1×10^{-6}/yr)
Up to 14 compressors	Site boundary	55 m from outer edge of compressors	75 m from outer edge of compressors	210 m from outer edge of compressors	290 m from outer edge of compressors

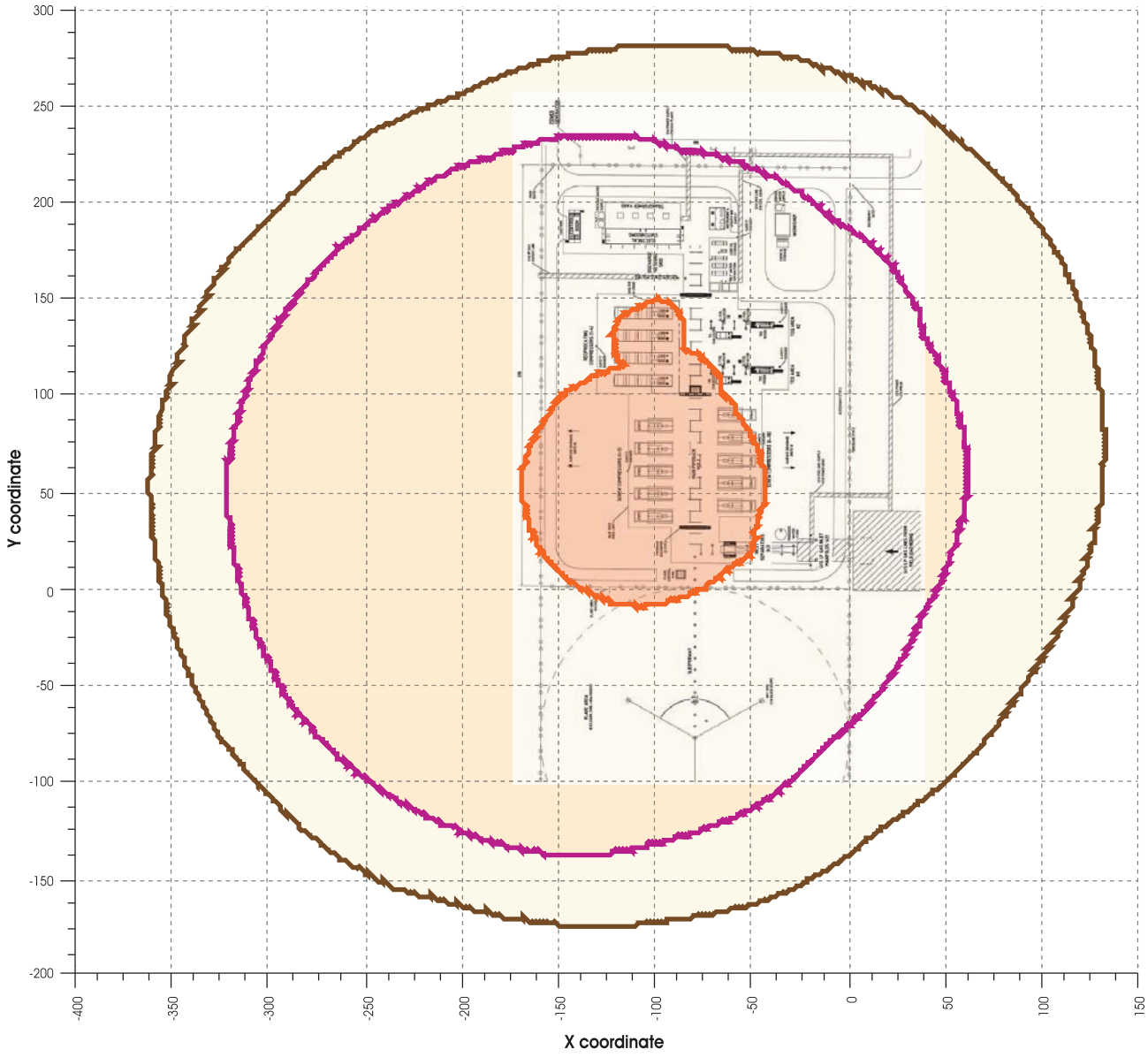
The risk of fatality associated with production wells, production facilities, assuming application of the residential buffer, is three times lower than the risk of fatality by a falling object or electrocution in a non-industrial environment and approximately 145 times lower than the risk of fatality in a car accident in Australia. The level of risk associated with the operation of the central gas and integrated processing facilities is therefore considered low with buffers in place and is 'tolerable' for adjacent residential development.

Given the typical layout of central gas processing and integrated processing facilities and the distance from compression equipment to fence lines, the risk contours associated with these types of facility are not expected to extend significantly beyond the site boundary. The risk contours for these facilities are shown in Figure 25.6.





coffey environments	Job No: 7040	Arrow Energy	arrow energy go further	Field compression facility injury and propagation risk	Figure No: 25.5
	File Name: 7040_04_F25.05_GL	Surat Gas Project			



Key

- Active open space
- Residential development
- Sensitive development

Note: Grid resolution 3.0 x 3.0 meters (233 x 233 grid points)

Source: Individual risk contours from Planager

coffey environments	Job No: 7040	Arrow Energy	arrow energy go further	Individual risk contours at a central gas processing or integrated processing facility	Figure No: 25.6
	File Name: 7040_04_F25.06_FT	Surat Gas Project			

The risk of injury and propagation from a central gas and integrated processing facility extends up to 30 m from the outer edge of the compressors. Given a typical site layout, it is unlikely that this distance would extend beyond the site boundary as shown in Figure 25.7. The risk of injury and propagation for this type of facility is considered to be **low**.

High-pressure Gas Pipelines

Hazards associated with the high-pressure gas transmission pipelines are identical to those that have been previously identified for the high-pressure Arrow Surat Pipeline. For each location where the high-pressure gas pipeline will be installed, a risk assessment study will be conducted in accordance with the requirements in the Australian high-pressure pipelines code AS 2885 (Standards Australia, 2007). The study will identify the many variations and types of locations through which the pipelines will pass, and the types of threats to and from the pipelines. The study will ensure that all possible threats at each location are identified, evaluated and appropriately planned for and managed during pipeline construction and operation. The widths of the corridors in which high-pressure pipelines will be located are prescribed in AS 2885.

25.4.2 Issues Identified Through Qualitative Risk Assessment

The qualitative assessment identified the potential hazards and risks from the construction, operation and decommissioning phases of the project. Preliminary hazard and risk issues associated with the project relate to the:

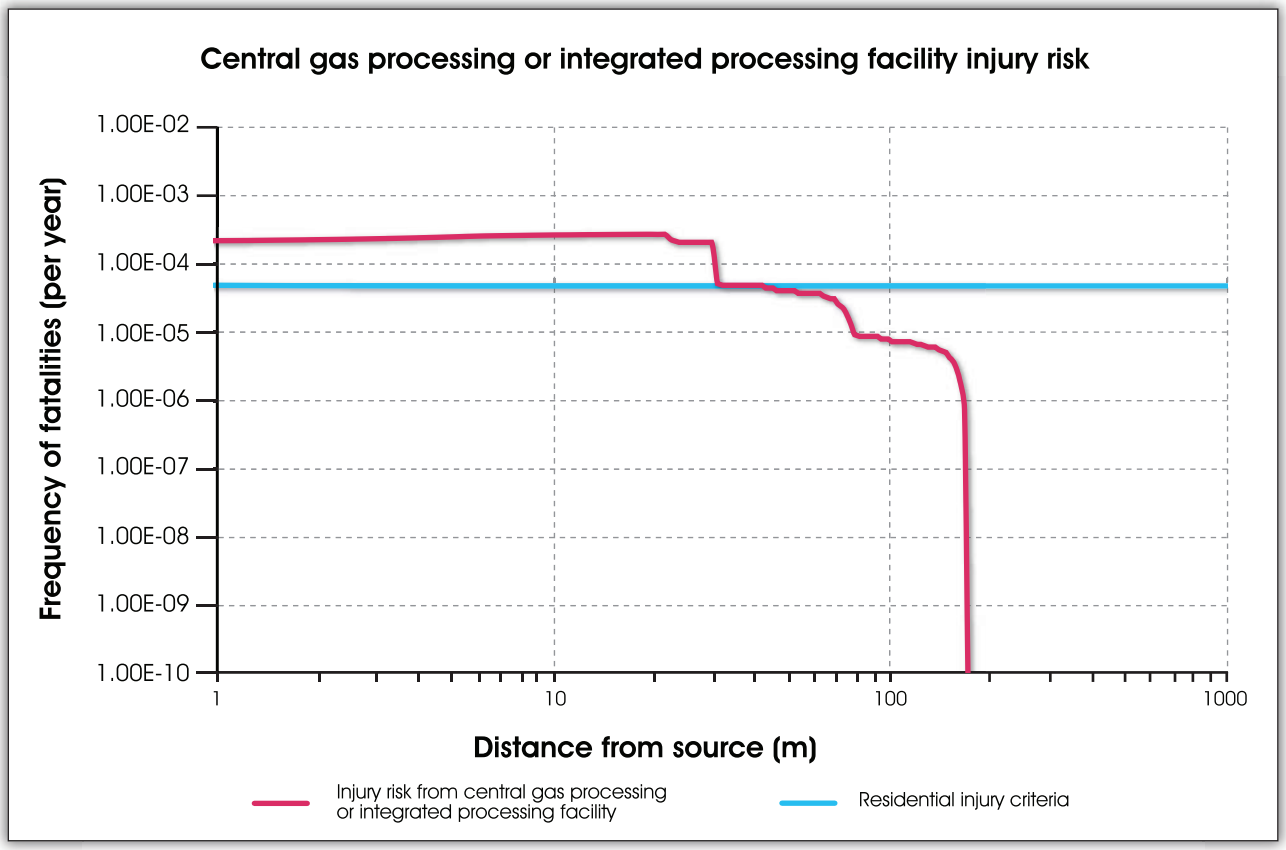
- Risk of human injury or fatality.
- Propagation of an incident to neighbouring facilities.
- Damage to property.

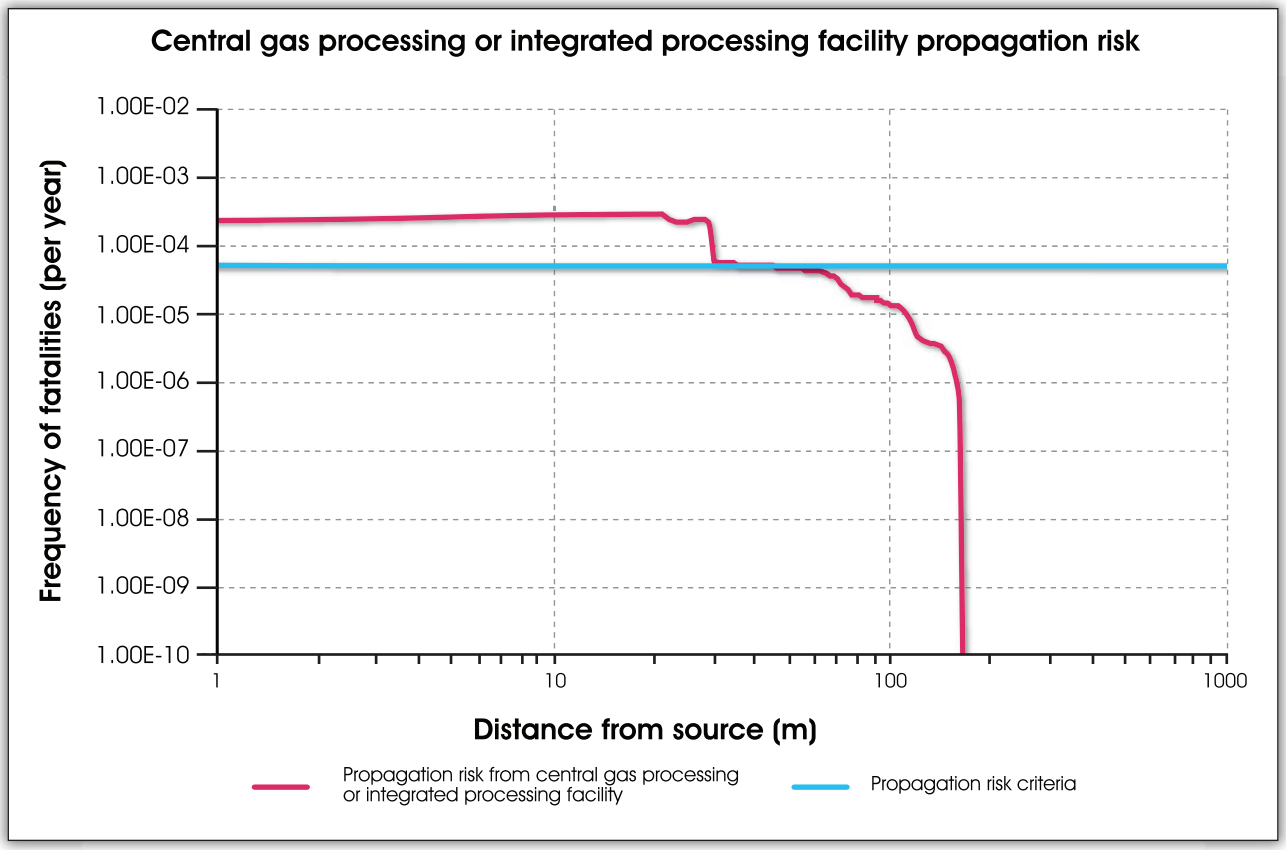
Hazards identified mainly relate to personal safety of the workforce, major accident hazards and hazardous substances as further described below.

Personal Safety Hazards

The following types of personal safety hazards were identified as having the potential to injure persons, predominantly on work sites, but also including persons who may live or work in the immediate vicinity of work sites:

- Project-related vehicular travel and transportation.
- Light, heavy and rotating machinery.
- Fire ignited by vehicles accessing wells and facilities located in dry grassland.
- Electricity.
- Confined spaces.
- Working at heights.
- Waterbodies with engineered/unnatural banks (risk of drowning).
- Rigging up or down of drilling rig or during well tests and wellhead completions.
- Loss of containment of liquid hazardous materials under pressure.
- Bites from snakes, spiders, or ticks on or in the vicinity of facilities.





coffey environments	Job No: 7040 File Name: 7040_04_F25.07_FT	Arrow Energy Surat Gas Project	arrow energy go further	Central gas processing facility injury and propagation risk	Figure No: 25.7

- Exposure to harmful materials and liquids (e.g., diesel, hydraulic oil, drilling fluids, very saline water and water treatment chemicals).
- Uneven terrain.

Major Hazards

The following types of major accident hazards were identified as having the potential to injure multiple persons.

- Pressure release and/or gas release due to physical damage to wellheads.
- Pressure release and/or gas release due to physical damage to pipelines and operational facilities.
- Pressure release and/or gas release due to failure of pipelines and operational facilities.
- Release of gas during a blowdown event.
- Ignition of combustible or flammable material.
- Dam failure.

Hazardous Substances

Several hazardous substances will be used during the construction and operation of the field facilities and associated infrastructure. These substances have the potential to cause injury or exposure to people and the environment. The management of land contaminated through project activities is discussed in Chapter 12, Geology, Landform and Soils. Hazardous materials used during construction, operations, water treatment and brine treatment are summarised in Tables 25.6 to 25.11.

Table 25.6 Chemicals used during construction and their typical volumes

Hazardous Materials Product Name	Hazchem/UN Number	Production Well	Field Compression Facility	Central Gas Processing Facility	Integrated Processing Facility
Petrol	3YE/1203	160 L	NA	NA	NA
Diesel	NA	NA	<40,000L	<40,000L	<40,000L
Alclean corrosive liquids N.O.S. (phosphoric acid) 5032	2X/1760	200 kg	NA	NA	NA
Superglue (environmentally hazardous substance, liquid N.O.S biphenolaepichlorohydrin epoxy resin)	3YE; no UN number available	32 L	NA	NA	NA
Squirts (aerosol) range	2YE/1950	<10 kg	NA	NA	NA
Pine-o-Clean and other aerosols	2Y/1950	<3 kg	NA	NA	NA
Performance surface spray aerosols	2Y/1950	<3 kg	NA	NA	NA
Various solvents and thinner	2YE or 3YE/various	<100 L/kg	NA	NA	NA
Battery terminal protector	2Y/1950	NA	13.5 L	13.5 L	13.5 L
Triethylene glycol	None allocated	NA	NA	10,800 L	10,800 L

Table 25.7 Chemicals used during operations and their typical volumes

Hazardous Materials Product Name	Hazchem/UN Number	Production Well	Field Compression Facility	Central Gas Processing Facility	Integrated Processing Facility
Petrol	3YE/1203	160 L	NA	NA	NA
Diesel	NA	NA	<40,000L	<40,000L	<40,000L
Aerosols	2Y/1950	<3 kg	<3 kg	<3 kg	<3 kg
Various solvents and thinners	2YE or 3YE	<100 L/kg	<100 L/kg	<100 L/kg	<100 L/kg
Triethylene glycol	None allocated	NA	NA	10,800 L	10,800 L

Table 25.8 Chemicals used during water treatment and their typical volumes

Hazardous Materials Product Name	Hazchem/UN Number	Production Well	Field Compression Facility	Central Gas Processing Facility	Integrated Processing Facility
Sodium hypochlorite	2X/1791	0	0	0	100 kL
Sodium metabisulfite	None	0	0	0	30 kL
Sulphuric acid	2P/1830	0	0	0	30 kL
Caustic soda	2R/1824	0	0	0	30 kL
DBNPA	2X/3082	0	0	0	5 kL
EDTA	None	0	0	0	5 kL
Antiscalant	TBA	0	0	0	15 kL
Coagulant (PAC)	None	0	0	0	10,000 kg
Flocculant	TBA	0	0	0	3,000 kg
Hydrochloric acid	2R/1789	0	0	0	30 kL
Ammonium hydroxide	2P/2672	0	0	0	30 kL
Citric acid	None	0	0	0	5 kL
Gypsum	None	0	0	0	30,000 kg
Polymer	TBA	0	0	0	3,000 kg
Glutaraldehyde	2R/3265	0	0	0	30 kL

Table 25.9 Chemicals used during brine treatment and their typical volumes

Hazardous Materials Product Name	Hazchem/UN Number	Production Well	Field Compression Facility	Central Gas Processing Facility	Integrated Processing Facility
Sodium hypochlorite	2X/1791	0	0	0	30 kL
Sodium metabisulfite	None	0	0	0	30 kL
Sulphuric acid	2P/1830	0	0	0	30 kL
Caustic soda	2R/1824	0	0	0	30 kL
EDTA	None	0	0	0	15 kL

Table 25.9 Chemicals used during brine treatment and their typical volumes (cont'd)

Hazardous Materials Product Name	Hazchem/UN Number	Production Well	Field Compression Facility	Central Gas Processing Facility	Integrated Processing Facility
Antiscalant	TBA	0	0	0	30 kL
Coagulant (PAC)	None	0	0	0	3,000 kg
Flocculant	TBA	0	0	0	3,000 kg
Hydrochloric acid	2R/1789	0	0	0	30 kL
Ammonium bifluoride	2X/1727	0	0	0	30 kL

25.5 Environmental and Social Protection Objective

The environmental and social protection objective for hazard and risk is to minimise the potential risk to people, the environment and property from activities associated with the Surat Gas Project.

25.6 Avoidance, Mitigation and Management Measures

This section summarises the measures proposed to avoid, mitigate and manage the potential risks of the project. Tiered management of safety hazards will be implemented through the application of site and technology selection, engineering controls, followed by procedural and behavioural controls. In this manner, the most severe impacts are engineered out with 'hard barriers' leaving little margin for human error. Arrow recognises a balance between engineering, procedural and behavioural controls as all three are necessary for ongoing safe operations. The application of these types of controls is discussed in broad categories below.

25.6.1 Site Selection and Engineering Controls

Arrow will select locations for project infrastructure with full consideration of and allowance for the minimum buffer zones indicated by the quantitative risk assessment. [C419] This approach will minimise the interaction between project infrastructure and the public. The approach that will be undertaken for selection of sites is discussed further in Chapter 8, Environmental Framework.

Arrow will implement the following engineering control measures to minimise the risks:

- Design and construct project infrastructure and facilities in accordance with applicable codes and standards [C420].
- Establish overflow and operational controls in accordance with the dam operating plan. [C215]
- Install manual isolation valves at the production well and skid edge. [C484]
- Consider remote control isolation on gas and water lines. [C427]
- Fit pumps with automatic pump shutdown or other safety devices to prevent leak in case of pumping against a blockage. [C448]
- Consider installing flow and pressure instrumentation to transmit upset conditions and plant shutdown valves status, where necessary. [C432]
- Implement security controls, e.g., fencing and locked gates. [C450]
- Certify all equipment for drilling, where applicable. [C463]

- Conduct pressure testing and inspection of equipment and pipelines in accordance with relevant legislative requirements and standards. [C443]
- Where applicable, establish blowout preventer and other well control measures. [C462]
- Perform blowout of pipes and equipment, to remove construction debris, using well-established procedures and under strict controls, including those detailed in risk assessments. [C438]
- Install isolation valves on pipelines in accordance with relevant standards and industry practices. [C445]
- Purge equipment after shutdowns. [C467]
- Design all pipes and vessels to cope with maximum expected pressure. [C425]
- Install pressure transmitters that remotely monitor high- and low-pressure alarms. [C426]

The engineering controls in combination with site selection measures will minimise the interaction between the public and project activities and ensure that public risks remain as low as reasonably practicable. Additional details of the engineering design standards that will be applied are presented in Appendix S, Preliminary Hazard and Risk Assessment.

25.6.2 Procedural and Behavioural Controls

Arrow's health, safety and environment management system is designed to manage hazard and risk through policy, standards and procedural controls. An integrated risk management plan (developed in accordance with the relevant NSW DPI hazardous industry planning advisory paper) will be built into the system and become a core component of normal operations.

Arrow will also ensure that all personnel are familiar with Arrow's 12 life-saving rules, which embed safe practices in the day-to-day activities of the workforce. The rules encompass the following controls: [C480]

- All staff to work with a valid permit where required.
- Gas tests to be conducted where required.
- Verification of isolation prior to work commencing and use of specified life-protecting equipment.
- Authorisation to be obtained prior to entering a confined space.
- Authorisation to be obtained prior to overriding or disabling critical safety equipment.
- All persons to protect themselves against a fall when working at a height.
- No walking under a suspended load.
- No smoking outside designated areas.
- No alcohol or drugs while working or driving.
- No phones to be used while driving and speed limits not to be exceeded.
- Seat belts to be worn at all times.
- Prescribed journey management plan to be followed.

The life-saving rules are rules under which all employees and contractors are engaged and Arrow will ensure all personnel are familiar with the rules. Disciplinary action is applicable for non-compliance with the life-saving rules. The rules clearly apply practices that protect life and the personal safety of the workforce on a day-to-day basis and set the precedent for a safe work culture.

As part of Arrow's commitment to the health and safety of personnel, Arrow will:

- Implement a permit to work system that includes a job safety analysis process. [C456]
- Develop and implement safety training programs for personnel and contractors, including induction training of new starters. Include supervision requirements for drilling and construction activities. [C442]
- Conduct pre-job safety meetings prior to the start of and during construction activities. [C437]
- Barricade fall points and use personal fall-arrest equipment and wrist straps and lanyards to secure tools when working at heights. [C459]
- Use whip check or safety chain and tie downs (or equivalent) on all high-pressure lines and pressurised air hoses. [C460]
- Implement transport-related safety programs including driver training, journey management plans, and preventive maintenance programs of vehicles. [C441]
- Ensure equipment and vehicle operators are licensed. [C464]
- Establish lone-worker protocols and communication. [C471]
- Provide escape ropes and ladders at strategic locations within a dam. [C477]
- Machine guard all rotating equipment in accordance with Australian standards. [C452]
- Develop rig move plans. [C488]
- Implement management of change processes, including protocols for communication of changes to appropriate levels of management. [C457]
- Prepare a risk control action plan as part of the safety assessment process for pipelines. [C465]
- Consider non-static protective clothing for operations personnel. [C470]
- Wear appropriate personal protective equipment on a site- and duty-specific basis. [C461]
- Conduct systematic risk assessments (which include hazard identification, assessment, treatment and monitoring) in accordance with relevant legislation and standards during design, construction and operations. [C455]
- Implement Arrow's health, safety and environmental management system for all activities and phases of development. [C417]
- Develop an integrated risk management plan (in alignment with the relevant NSW Department of Primary Industries hazardous industry planning advisory paper). [C439]
- Prepare project safety management plans for the construction, operations and decommissioning of the infrastructure that form part of the present development. [C416]

- Develop and implement incident reporting, emergency response and corrective action systems or procedures. Include systems for reporting, investigation and communications of lessons learned. [C171]
- Consider the Australian Pipeline Industry Association Construction Health and Safety Guidelines (APIA, 2008) for pipeline construction and development of Construction Health and Safety Plan. [C436]
- Register pipelines and below-ground electrical services with Dial Before You Dig. [C430]
- Minimise enclosed spaces where flammable gas may accumulate. [C431]
- Conduct appropriate safety reviews during design of new and modified facilities, including the use of hazard and risk assessment processes. Base safety reviews on well-recognised methodologies, e.g., hazard and operability studies and AS 2885 (Standards Australia, 2007) risk assessment (safety management studies). [C418]
- Where necessary, automate emergency shutdown systems at production facilities and, if necessary, include remote monitoring and control. [C453]
- Use suitably trained and supervised staff or contractors to carry out depressurising and purging activities. [C479]
- Implement an in-vehicle monitoring system for project vehicles. [C288]

Arrow will develop emergency response plans in consultation with emergency services organisations that includes a list of required equipment, training and other resources, and foreseeable emergency and crisis situations (including escapes, blowouts, gas fire, bushfire, critical equipment failure, trapped or missing people, flooding, cyclones, power failure, security incidents and threats, and transport incidents). The plans should include safe evacuation procedures, communication protocols (internal and to emergency services including the Petroleum and Gas Inspectorate), accounting for personnel and visitors, roles and responsibilities and requirements for training. [C424]

25.6.3 Specific Controls

There are unique aspects to the construction and operation of coal seam gas developments that require specific controls to be implemented to minimise risk. The following sections address those aspects that have been identified in the EIS terms of reference or through the preliminary hazard and risk study.

Production wells will be designed and constructed so that the well is cased or concreted through aquifers other than the coal seam to prevent transmission of water and gas between strata. [C537] Issues associated with the process of fraccing (or hydraulic fracturing) of the gas-bearing strata have been identified as potentially causing co-mingling flammable gas with a water source elsewhere in the petroleum and gas industry. Arrow will enforce a no hydraulic fracturing (fraccing) policy in the project development area. [C079]

Fire Risk

Fire poses a risk both onsite and in the surrounding environment. The project facilities are located within an area that is subject to bushfires and requires specific controls to mitigate the impact of bushfires on the project workforce and assets. Exposure of gas infrastructure to an uncontrollable ignition source such as a bushfire is the primary risk. As the project development area is

categorised as a medium to low bushfire risk, the State Planning Policy 1/03 for mitigating the adverse impact of flood, bushfire and landslide (DCS, 2003) will be taken into regard. [C538]

The following management measures and controls will be implemented in the design, planning and construction phase of the project to minimise the risk to people and assets from fire:

- Facilities will be designed with the ability to shut down and be isolated in preparation for impending bushfires. [C421]
- Design and install combustion sources (such as generators and gas-fired compressors) on Arrow facilities in accordance with engineering codes and standards, thus ensuring they will have safety mechanisms built-in. [C422]
- Design equipment to withstand considerable heat load, e.g., through use of heat-resistant (fire-safe) isolation valves on production facilities. [C428]
- Commission fire-safety equipment in the early phase of the construction period. [C446]
- Install fire and gas detection system to shutdown compressors. [C449]
- Fit all buildings and production facilities smoke or fire alarms. [C447]
- Install, inspect and service fire-fighting equipment in accordance with risk assessments and relevant legislation and standards. [C440]
- Develop protocols for the control of construction activities during extreme fire danger periods. [C423]
- Develop protocols for the control of operational activities during extreme fire danger periods, e.g., flaring or shutdowns. [C468]
- Develop fire plans for production facilities. [C223]
- Design radiation zones around flares according to API standard. [C429]
- Install lightning mast and earthing grid to minimise risk of lightning strike at production facilities. [C451]

Measures implemented during the operations phase of the project include:

- Vegetation surrounding production facilities and wellheads will be maintained in a manner that limits the amount of combustible material in the area. The size of the cleared area will be determined on a site-by-site basis with consideration of the site-specific risk of bushfire. [C483]
- Bury gathering lines at a minimum depth of 600 mm. Where gathering lines are present above the ground (at wellheads and at vents or drains), maintain a clear area. The size of the cleared area will be determined on a site-by-site basis with consideration of the site-specific risk of bushfire. [C444]
- Keep access tracks to well sites clear of dry grass and combustible material wherever practicable and where there is a higher risk of bushfire (to minimise the risk of dry grass being ignited by hot components of vehicles accessing the sites). [C486]
- Daily operations will be managed with consideration of the fire danger current at that time. [C487]

- Conduct regular patrols and inspections of pipeline easements, including status of signposting, subsidence and of fire breaks. [C472]
- Maintain facilities so that flammable and combustible material does not accumulate on site. [C485]
- Purge equipment of oxygen prior to introducing flammable gas. [C466]
- Depressurise and degas all plant and equipment in flammable-gas use prior to decommissioning. [C489]

Flooding and Dam Safety

Arrow will manage flooding risk through site location, drainage, etc., particularly for production facilities. [C433] Dam safety is heavily controlled through dam safety guidelines and the application of the State Planning Policy 1/03 for mitigating the adverse impact of flood, bushfire and landslide, which will apply for all facilities forming part of the project development. Arrow will design and size dams to account for predicted flood conditions. [C211]

The following mitigation measures specific to dam safety include:

- Subject each dam to separate approvals by the regulating authority. Each approval will require the incorporation of general and specific controls to avoid, mitigate or manage threats associated with flooding. [C206]
- Develop the construction, design and monitoring requirements for new dams (either raw water, treated water or brine dams) and determine the hazard category of the dam in accordance with the requirements of the most recent version of Manual for Assessing Hazard Categories and Hydraulic Performance of Dams (DERM, 2011a). Construct the dams under the supervision of a suitably qualified and experienced person in accordance with the relevant DERM schedule of conditions relating to dam design, construction, inspection and mandatory reporting requirements. [C141]
- Implement the dam operating plan. [C207]
- Line banks of dam with an impervious lining. [C213]
- Use an independent suitably qualified, third party to certify that dams meet the dam design plan. [C209]
- Inspect and maintain dam integrity. [C216]
- Apply dam safety guidelines, which will apply for all facilities forming part of the project development. [C435]
- Implement a decommissioning and rehabilitation plan in accordance with the dam design plan. [C074]

Hazardous Materials

Arrow will implement the following measures to reduce the hazards associated with hazardous materials:

- Apply appropriate international, Australian and industry standards and codes of practice for the design and storage of hazardous materials (such as chemicals, fuels and lubricants). [C048]

- Apply appropriate international, Australian and industry standards and codes of practice for the handling of hazardous materials (such as chemicals, fuels and lubricants). [C035]
- Implement internal and external (independent) hazard audit programs. Communicate results from audit to management. [C458]
- Automate the chemical dosage system for water treatment at integrated processing facilities. [C474]
- Consider the use of non-toxic gases for water treatment if gases are used. [C475]
- Design appropriate drainages for waste spills within buildings. [C434]
- Ensure operator supervision for unloading of hazardous materials at production facilities. [C476]

Hazardous Wildlife

Project personnel will likely encounter hazardous wildlife such as snakes, spiders and ticks. Arrow will train relevant personnel in the identification and avoidance of potentially hazardous wildlife and will use qualified handlers to move wildlife from project areas when encountered. [C481]

The project development will involve the installation of a number of dams at production facilities. The provision of large bodies of water in the environment could facilitate an increase in mosquitoes. Generally, coal seam gas water dams represent a habitat that is of low value to mosquitoes as brine dams are often too saline and treated water dams are often too sterile to support mosquitoes. To reduce mosquito breeding in dams, dams and dam inner banks will be maintained so that they are as free of vegetation as practicable. [C208]

25.7 Residual Impacts

Avoidance, mitigation and management measures will reduce the consequence of an event or the likelihood of it occurring. Site selection and engineering controls will be implemented in project design and planning whereas procedural and behavioural controls will be implemented throughout the construction, operation and decommissioning phases. The specific control measures described above apply to all phases of the project.

A summary of the risk assessment, including credible hazard scenarios, possible causes and avoidance, mitigation and management measures is presented in Tables 25.10 to 25.13. Hazard scenarios and mitigations have been grouped in terms of:

- Gas or pressure release and/or fire and explosion.
- External events such as bushfire and flooding.
- The storage and handling of hazardous materials.
- The personal safety of the project workforce.

The majority of the residual risks were assessed as either low or medium. A high residual risk was associated with road accidents involving project vehicles.It is widely recognised that road traffic crashes are commonplace and the risk associated with travel by light vehicles carries a significant risk which can be attributed to the increased frequency and volume of traffic on roads. Arrow has proposed mitigation measures to reduce the residual risks.

Table 25.10 Summary of impact assessment – gas or pressure releases

Hazard Scenario	Potential Causes	Project Phase	Project Component	Summary of Mitigation Measures	Consequence	Likelihood	Residual Risk
Hazard scenarios and potential impacts involving gas or pressure release or fire and explosion							
Fire or explosion due to ignition of flammable or combustible material resulting in injury, fatality or destruction of property.	Incident involving gas released during well blowdown.	Construction	Production wells	• Implement Arrow's health, safety and environment management system. • Develop an integrated risk management plan. • Prepare project safety management plans. • Develop and implement incident reporting, emergency response and corrective action systems or procedures. • Select locations for project infrastructure will full consideration of and allowance for the minimum buffer zones. • Design and construct project infrastructure and facilities in accordance with applicable codes and standards. • Design and install combustion sources in accordance with engineering codes and standards. • Consider the Australian Pipeline Industry Association Construction Health and Safety Guidelines for pipeline construction and development of Construction Health and Safety Plan. • Depressurise and degas all plant and equipment in flammable-gas use prior to decommissioning. • Perform blowout of pipes and equipment. • Conduct appropriate safety reviews during design of new and modified facilities.	Severe	Rare	Medium
Fire or explosion due to ignition of flammable or combustible material resulting in injury or destruction of property.	Incident involving maintenance 'hot works'.	Operations	Production facilities		Major	Unlikely	Medium
Pressure burst resulting in operator injury or equipment damage.	Physical damage to wellhead equipment. Failure of well pressure control or blow out. Encountering free gas in wellbore during drilling due to blockage in existing well or laterals. Encountering free gas in wellbore due to encountering gas pocket. Failure of circulation piping during pressure testing.	Construction Operations	Production wells Gathering systems Medium- and high-pressure pipelines Production facilities		Moderate	Rare to Possible	Low to Medium

Table 25.10 Summary of impact assessment – gas or pressure releases (cont'd)

Hazard Scenario	Potential Causes	Project Phase	Project Component	Summary of Mitigation Measures	Consequence	Likelihood	Residual Risk
Hazard scenarios and potential impacts involving gas or pressure release or fire and explosion							
Pressure burst due to failure of integrity of plant and equipment resulting in operator injury or equipment damage with potential for propagation to fire and explosion.	Failure of the integrity of plant and equipment due to physical damage, deterioration, erosion or corrosion.	Operations	Production facilities	• Bury gathering lines at a minimum depth of 600 mm and where above ground, maintain a clear area. • Conduct systematic risk assessments. • Develop emergency response plans. • Develop fire plans for production facilities. • Implement management of change processes. • Certify all equipment for drilling, where applicable. • Conduct pressure testing and inspection of equipment and pipelines. • Where applicable, establish blowout preventer and other well control measures. • Prepare a risk control action plan for pipelines. • Install isolation valves on pipelines, and well and skid edge. • Commission fire-safety equipment. • Fit buildings and production facilities with smoke or fire alarms. • Purge equipment of oxygen prior to introducing flammable gas. • Purge equipment after shutdowns. • Develop protocols for the control of operational activities during extreme fire danger periods. • Consider non-static protective clothing for operations personnel.	Moderate	Rare	Low
Ignition of dry grass/brush on access tracks caused by vehicle resulting in a grass or bushfire and injury or damage to property and equipment.	Construction vehicles and machinery traffic on the access track.	Construction Operations	Production wells Gathering systems Medium- and high-pressure pipelines Production facilities		Moderate	Rare to Possible	Medium
Gas release and/or fire and explosion due to loss of containment of flammable gas from a wellhead or associated piping resulting in injury and equipment damage	Physical damage to wellhead or piping caused by impact with vehicle or machinery. Failure of flexible coupling. Leak from piping flange. Overpressure event due to control system failure or well shut-in/blocked outlet.	Operations	Production wells		Major	Unlikely	Medium

Table 25.10 Summary of impact assessment – gas or pressure releases (cont'd)

Hazard Scenario	Potential Causes	Project Phase	Project Component	Summary of Mitigation Measures	Consequence	Likelihood	Residual Risk
Hazard scenarios and potential impacts involving gas or pressure release or fire and explosion							
Lubricating oil fire in electrical generator, pumps or compressors resulting in equipment damage and potential escalation.	Mechanical failure of equipment resulting in excess friction within lubricated components, resulting in heat and ignition.	Operations	Production wells Production Facilities	• Design all pipes and vessels to cope with maximum expected pressure. • Install pressure transmitters that remotely monitor high- and low-pressure alarms. • Design equipment to withstand considerable heat load. • Conduct regular patrols and inspections of pipeline easements. • Consider remote control isolation on gas and water lines. • Fit pumps with automatic pump shutdown or other safety devices. • Register pipelines and below-ground electrical services. • Minimise enclosed spaces where flammable gas may accumulate. • Where necessary, automate emergency shutdown systems at production facilities. • Consider installing flow and pressure instrumentation to transmit upset conditions and plant shutdown valves status. • Install fire and gas detection systems. • Implement security controls. • Design radiation exclusion zones around flares. • Install lightning mast and earthing grid at production facilities. • Install emergency shutdown buttons on each production facility.	Minor	Rare	Very low
Fire and explosion internal to pipelines, or production equipment due to ingress of air into process piping (creating a flammable atmosphere within the process) resulting in injury and equipment damage	Process equipment inadequately purged after installation or maintenance. Air present inside process piping during commissioning or start-up mixes with flammable gas with ignition through static.	Construction Operations Decommissioning	Gathering systems Medium- and high-pressure pipelines Production facilities		Moderate	Rare	Low
Gas release or fire and explosion due to loss of containment of flammable gas from gathering system or medium- and high-pressure pipelines resulting in injury or property damage (if ignition source present gas release may result in fire, if gas is allowed to build up or enter confined space and is then ignited may result in explosion)	Breach of integrity of gathering system through third-party activity (impact with machinery or vehicle (above ground components) or impact during excavation (underground component). Defect in construction of pipeline.	Operations	Gathering systems Medium- and high-pressure pipelines		Major	Unlikely	Medium

Table 25.10 Summary of impact assessment – gas or pressure releases (cont'd)

Hazard Scenario	Potential Causes	Project Phase	Project Component	Summary of Mitigation Measures	Consequence	Likelihood	Residual Risk
Hazard scenarios and potential impacts involving gas or pressure release or fire and explosion							
Gas release and subsequent fire and explosion due to loss of containment of flammable gas from production facility process resulting in injury or fatality and/or property damage (if ignition source present gas release may result in fire, if gas is allowed to build up or enter confined space and is then ignited may result in explosion)	Breach of integrity of process piping through corrosion or stress fracture or physical damage due to incident on site (e.g., impact with plant and equipment used during maintenance)	Operations	Production facilities	• Use suitably trained and supervised staff or contractors to carry out depressurising and purging activities. • Enforce a no hydraulic fracturing policy in the project development area. • Production wells will be designed and constructed so that the well is cased or concreted through aquifers other than the coal seam.	Severe	Rare	Medium
Bushfire as a result of ignition source on production facility (e.g., flaring or hot works) resulting in injury to third party, equipment and property damage.	Flare becomes an ignition source resulting in bushfire or brushfire	Operations	Production facility		Moderate	Rare	Low
Fire or explosion risk due to ignition of triethylene-glycol (used in the gas dehydration process) resulting in injury or property damage.	Loss of integrity of the triethylene-glycol process equipment and ignition through exposure to hot components or other ignition source.	Operations	Production facility		Moderate	Unlikely	Medium

Table 25.11 Summary of impact assessment – external events

Hazard Scenario	Potential Causes	Project Phase	Project Component	Summary of Mitigation Measures	Consequence	Likelihood	Residual Risk
Hazard scenarios and potential impacts involving external events such as bushfire and flooding.							
External events such as bushfires or floods encroach upon project infrastructure resulting in harm to workers, damage or loss of integrity of the equipment and potential escalation of incident.	Lightning strikes or anthropogenic sources causing bushfire. Excessive rainfall in the same catchment as project infrastructure.	All project phases	Production wells Gathering systems Medium- and high-pressure pipelines Production facilities	• Take into regard the State Planning Policy 1/03 for mitigating the adverse impact of flood, bushfire and landslide. • Design facilities to shut down and be isolated in preparation for impending bushfire. • Clear vegetation in proximity to wellheads and production facilities. • Keep access tracks to well sites clear of dry grass and combustible material. • Manage daily operations with consideration of the fire danger. • Install, inspect and service fire-fighting equipment. • Develop protocols for the control of construction activities during extreme fire danger periods. • Develop emergency response plans. • Develop fire plans for production facilities. • Design equipment to withstand considerable heat load. • Conduct patrols and inspections of pipeline easements. • Manage flood risk through site selection. • Design and size dams to account for predicted flood conditions.	Moderate to Major	Unlikely	Medium
External events such as bushfires or floods prevent access to project facilities preventing necessary maintenance or intervention resulting in propagation of additional incident.	Lightning strikes or anthropogenic sources causing bushfire. Excessive rainfall in the same catchment as project infrastructure.	Operations	Production wells Gathering systems Medium- and high-pressure pipelines Production facilities		Moderate	Rare	Low
External event such as bush fire, lightning or flooding prevents effective operation and maintenance of water treatment facility resulting in release of low quality water and harm to people.	Lightning strikes or anthropogenic sources causing bushfire. Excessive rainfall in the same catchment as project infrastructure.	Operations	Production facilities		Minor	Rare	Very Low

Table 25.11 Summary of impact assessment – external events (cont'd)

Hazard Scenario	Potential Causes	Project Phase	Project Component	Summary of Mitigation Measures	Consequence	Likelihood	Residual Risk
Hazard scenarios and potential impacts involving external events such as bushfire and flooding.							
External events such as flooding or extreme rainfall events cause failure of dam level management and integrity management resulting in catastrophic failure of dams and subsequent injury, property damage equipment damage.	Extreme or prolonged rainfall in the same catchment as project infrastructure. Earthquake or land subsidence.	Operations	Integrated processing Facilities	• Develop the construction, design and monitoring requirements for new dams and determine the hazard category of the dam in accordance with government manuals. • Construct dams under the supervision of a suitably qualified and experienced person. • Apply dam safety guidelines. • Subject each dam to separate approvals by the regulating authority. • Implement the dam operating plan. • Line banks of dam with an impervious lining. • Use a third party to certify that dams meet the dam design plan. • Inspect and maintain dam integrity. • Implement a decommissioning and rehabilitation plan in accordance with the dam design plan.	Major	Unlikely	Medium

Table 25.12 Summary of impact assessment – hazardous materials

Hazard Scenario	Potential Causes	Project Phase	Project Component	Summary of Mitigation Measures	Consequence	Likelihood	Residual Risk
Hazard scenarios and potential impacts involving the storage and handling of hazardous materials.							
Exposure due to loss of containment of potentially hazardous materials (diesel, hydraulic oil, chemicals including corrosives, toxics, biocides, oxidants and concentrated brine) from storage or during handling, e.g., during unloading or transfer or as a result of the by-products of mixing in drains or bunds results in injury or health impacts to member(s) of the project workforce.	Damage to containment due to physical impact with vehicle or machinery. Failure of integrity of piping or containment vessels due to corrosion. Failure of containment due external event such as lightning strike, bushfire, flooding, or earthquake.	All project phases.	Production wells Production facilities	• Implement internal and external hazard audit programs. • Design appropriate drainages for waste spills. • Automate the chemical dosage system for water treatment. • Consider the use of non-toxic gases for water treatment. • Ensure operator supervision for unloading of hazardous materials. • Establish overflow and operational controls for tanks and dams. • Apply appropriate standards and codes for the storage and handling of hazardous materials.	Minor	Unlikely	Low
Loss of containment of bulk volumes of liquid pollutant materials (concentrated brine, diesel, drilling muds, chemicals) resulting in injury and environmental harm.	Failure of structural integrity of a brine dam resulting in uncontrollable release of concentrated brine. Failure of integrity of bulk storage facility for diesel or chemicals. Failure to identify or respond rapidly to material release.	All project phases.	Production wells Production facilities		Moderate	Rare to Possible	Low to Medium

Table 25.13 Summary of impact assessment – personal safety

Hazard Scenario	Potential Causes	Project Phase	Project Component	Summary of Mitigation Measures	Consequence	Likelihood	Residual Risk
Hazard scenarios and potential impacts associated with the personal safety of the project workforce.							
Injury to workers associated with manual handling, working at heights, dropped objects, slips trips and falls and wildlife.	Falling equipment/dropped objects, fall from heights. Slips, trips and falls, Exposure to moving and rotating equipment. Breeding of mosquitoes in dams. Wildlife danger at work site.	All project phases.	Production wells Gathering system Medium- and high-pressure pipelines Production facilities	• Ensure all personnel are familiar with Arrow's 12 Life Saving Rules. • Implement a permit to work system. • Develop and implement safety training programs. • Conduct pre-job safety meetings. • Barricade fall points and use personal fall-arrest equipment and secure tools when working at heights. • Use whip check or safety chain and tie downs on high-pressure lines and pressurised air hoses. • Manage both personnel and public risks of injury during transport through safety programs. • Wear appropriate personal protective equipment. • Implement internal and external hazard audit programs. • Ensure equipment and vehicle operators are licensed. • Implement an in-vehicle monitoring system. • Establish lone-worker protocols. • Provide escape ropes and ladders within dams. • Machine guards all rotating equipment. • Develop rig move plans. • Dams and inner banks will be maintained so that they are free of vegetation as practicable to reduce mosquito breeding.	Moderate	Rare to Likely	Low to Medium
Road accident involving project vehicles and resulting in injury or fatality of member(s) of the workforce or public.	Driver condition or behaviours (e.g., inexperience, driving while fatigued, driving at excessive speed for conditions). Vehicle condition (e.g., mechanical failure). Environmental conditions (dust, rain, sunlight) Wildlife/livestock on roads. Road surface condition (e.g., rocks, potholes, loose gravel.	All project phases.	Production wells Gathering system Medium- and high-pressure pipelines Production facilities		Severe	Possible	High

Table 25.13 Summary of impact assessment – personal safety (cont'd)

Hazard Scenario	Potential Causes	Project Phase	Project Component	Summary of Mitigation Measures	Consequence	Likelihood	Residual Risk
Hazard scenarios and potential impacts associated with the personal safety of the project workforce.							
Road accident involving project vehicles and resulting in injury or fatality of member(s) of the workforce or public. (cont'd)	Changed road conditions including road works and associated machinery.	All project phases.	Production wells Gathering system Medium- and high-pressure pipelines Production facilities	• Train relevant personnel in the identification and avoidance of potentially hazardous wildlife and use qualified handlers to move wildlife.	Severe	Possible	High
Electrocution while maintaining electrical equipment resulting in injury or fatality of member of the project workforce.	Faulty equipment or failed isolation of electrical sources during maintenance on electrical equipment. Intersection with live overhead electrical cables whilst using machinery/intersection with underground electrical cables during excavation.	All project phases.	Production wells Gathering systems Medium- and high-pressure pipelines Production facilities		Severe	Rare	Low to Medium

Table 25.13 Summary of impact assessment – personal safety (cont'd)

Hazard Scenario	Potential Causes	Project Phase	Project Component	Summary of Mitigation Measures	Consequence	Likelihood	Residual Risk
Hazard scenarios and potential impacts associated with the personal safety of the project workforce.							
Working in a confined space exposes member(s) of the work force to toxic or oxygen deficient environments resulting in harm of member(s) of the workforce.	Asphyxiation during access to well cellar, mud pits and tanks on well sites and trenches/pits in gathering systems. Asphyxiation during access to compressor enclosures or similar enclosed spaces on production facilities.	All project phases.	Production wells Gathering systems Medium- and high-pressure pipelines Production facilities		Moderate to Major	Rare	Low to Medium
Heavy vehicle/machinery incident resulting in operator injury.	Operation of machinery on uneven ground.	Construction	Production wells Gathering systems Medium- and high-pressure pipelines Production facilities		Minor to Moderate	Likely to Possible	Medium

25.8 Inspection and Monitoring

Under the P&G Act, operators of a plant are obligated to prepare a safety management plan that is appropriate to the level of the plant. The Queensland Department of Natural Resources and Mines (now the Department of Employment, Economic Development and Innovation) prepared a SafeOP document (DNRM, 2005), which provides guidance to operators on matters that they must include in their safety management plan to ensure that it is compliant with the P&G Act and regulations. These documents include requirements for monitoring and inspection that will inform Arrow's safety management plans.

Monitoring and inspection will be undertaken to ensure that the proposed risk management measures are implemented and that residual impacts of the project remain as low as reasonably practicable.

Schedule inspections and develop a monitoring program to ensure that the safety management systems are functioning properly and that it is appropriate to the hazards identified. [C326]

In regards to dams, monitor dam levels [C528] and have a suitably qualified person routinely monitor the integrity and available storage of dams [C532].