SUPPLEMENTARY REPORT TO THE PRELIMINARY HAZARD AND RISK ASSESSMENT FOR THE ARROW ENERGY SURAT GAS PROJECT

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Supplementary Report to the Preliminary Hazard and Risk Assessment for the Arrow Energy Surat Gas Project

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EXECUTIVE SUMMARY

An update has been prepared to the Preliminary Hazard and Risk Assessment (PHA) which was undertaken for the Arrow Energy Pty Ltd (Arrow) Surat Gas Project environmental impact statement (EIS) to reflect project description changes since the EIS was finalised.

The supplementary PHA has been carried out in order to thoroughly review the updates made to the project description to determine whether the design has altered sufficiently to warrant a comprehensive re-evaluation of the risks assessed, or whether the design basis has remained basically intact and the conclusions made in the PHA remain valid.

The approach taken in this update has been to systematically assess all major changes that have been made to the installations, material, safeguards or systems, which were proposed at the time of the PHA that could potentially influence the results of the preliminary assessment of the hazards and risk to surrounding land uses or to individuals present on site.

The review has taken the following steps:

1. Identify changes made to the installations, material, operational parameters, safeguards or systems that may influence the assumptions or conclusions made in the PHA.
2. Undertake a systematic assessment of the project description changes to determine whether they will result in an increase (worsening) or a decrease (amelioration) of hazards and risks identified in the PHA.
3. Review the qualitative assessment of the hazards and risks of the project and update based on the project description changes, using the Arrow risk matrix.
4. Update of the risk contour and transect figures for inclusion in this update to the PHA.
5. Identify any changes or additions to the design, safety controls and management measures, as detailed in the PHA, which are required to manage the potential hazards and risks.
6. Identify any changes to (or additional) recommendations of the PHA.
7. Summarise and document the findings in an addendum report to be attached to the SREIS.

The review carried out has determined that there have been no substantial changes in the proposed design, construction, operation and decommissioning of the facilities since the EIS was finalised and as assumed in the PHA.

The large majority of changes relate to changes to equipment configuration and updating of layouts.

There has been no substantial change made to the single gas wells, gathering line, field or compression facility. Some changes have been made to the central gas processing facility

(CGPF), water treatment facilities and the high pressure pipeline. Further a multi well pad design has been introduced.

The assessment confirms that there has been no substantial change to the qualitative hazard and risk assessment provided in the PHA for the design and construction phase, operational phase or decommissioning phase which would warrant a reassessment. Hence, the qualitative hazard and risk assessment remains valid for all facilities that formed part of the project at the EIS stage.

The only notable difference that has an impact on the qualitative hazard and risk assessment is the addition of the multi-well pad design, which has necessitated the expansion of a number of potential hazardous incident scenarios associated with the single well design to account for the close proximity of the wells and the risk management measures in place to ensure the wells do not influence one another in any manner that could be hazardous to health and safety.

The multi-well pad design also alters the quantitative risk associated with the production wells, as assessed using quantitative risk assessment (QRA) techniques, compared with that of the single well design. The result is that larger buffers to industrial, active open space and residential development are required between the multi-well pad design and different land uses surrounding the well site compared with the single well. The buffers to business and sensitive development remain the same as for the single well design.

Project description changes associated with the CGPF are accounted for in the updated QRA. The result is a slight reduction in the level of risk and buffer zones associated with the CGPF compared to that assessed in the PHA, as shown in Figure 4 in the body of the report.

The design and safety controls and management measures identified in the PHA remain largely unchanged, and overall, the conclusions drawn in the PHA completed for the Arrow Surat Gas Project EIS remain valid.

The additional safety controls required relate to the multi-well pads which will require some additional control measures aimed at minimising the risk of damage to adjacent infrastructure during installation and operation of a neighbouring well.

GLOSSARY

AS	Australian Standard.
ALARP	'As Low As Reasonably Practical' is a term used to describe the principle of reducing a risk to a level where the cost of reducing the risk further, would be disproportionate to the benefit gained.
APIA	Australian Pipeline Industry Association.
CGPF	Central Gas Processing Facility
CSG	Coal seam gas. A natural gas created over millions of years as a by-product while organic matter is turned into coal; mainly comprising methane; trapped on the surface of the coal.
EIS	Environmental Impact Statement. A process used to assess and document the potential and actual environmental impact of a proposed development.
Hazard	A hazard is a potentially harmful or dangerous situation, although not necessarily the harmful event itself. Once the event has started it is classified as an emergency or incident.
HDPE	High Density Polyethylene
Propagation	Potential for an event to trigger secondary events due to layout, spacing, and failure of safety systems.
Loss of containment (LOC)	Describes unexpected/unwanted loss of substances from the equipment/piping and associated valves, instruments, etc. holding them.
PHA	Preliminary Hazard and Risk Analysis, generally required at an early stage of a project as part of the development application and the Environmental Impact Statement. A PHA may be based on limited information since complete data on the design and precise safeguards may not be available at the initial stage
QRA	Quantitative Risk Assessment. A detailed and systematic study of the potential hazards, associated with (often complex) industrial activities, their consequences and likelihoods.
Risk	A measurable quantity associated with each hazard, determined by combining the likelihood of an event occurring, and the consequence, if it were to occur.
SREIS	Supplementary report to the EIS
TJ	Terajoules. A metric (SI) unit of work and energy, frequently used in the oil and gas industry.

SUPPLEMENTARY REPORT TO THE PRELIMINARY HAZARD AND RISK ASSESSMENT

1 INTRODUCTION

1.1 BACKGROUND

Arrow Energy Pty Ltd (Arrow) proposes expansion of its coal seam gas operations in the Surat Basin through the Surat Gas Project (the project). The need for the project arises from the growing demand for gas in the domestic and global markets and the associated expansion of liquefied natural gas (LNG) export markets.

An Environmental Impact Statement (EIS) was prepared to assess potential environmental, social, economic and health and safety impacts of the project and ensure that appropriate measures are in place to manage the identified impacts. The EIS went on public exhibition on 16 March 2012, with submissions closing on 14 June 2012.

As part of the EIS, a preliminary hazard and risk assessment (PHA, Ref 1) was prepared in order to assess the hazards and risks to people, neighbouring facilities and property associated with the project which could occur during all stages of the project.

A supplementary PHA has been prepared to reflect project description changes since the EIS was finalised.

1.2 SCOPE AND OBJECTIVE

The supplementary PHA (this report) has been prepared as an addendum, to be attached to the supplementary report to the EIS (SREIS).

As such, this supplementary report complements the PHA which was conducted at the early design stage. It focuses on potential impacts of the changes made to the project description, on the hazard and risks identified in the PHA.

By conducting a thorough review of the changes made to the project description it is possible to determine whether the design has altered sufficiently to warrant a comprehensive re-evaluation of the risks assessed, or whether the design basis has remained basically intact and the conclusions made in the PHA remain valid.

The supplementary PHA determines whether any of the project description changes will result in an increase (worsening) or a decrease (amelioration) of hazards and risks identified in the PHA.

The update further identifies any changes or additions to the design, safety controls and management measures, as detailed in the PHA, which are required to manage the potential hazards and risks, and any changes to (or additional) recommendations of the PHA.

2 PROJECT DESCRIPTION CHANGES

Since preparation of the Surat Gas Project EIS, further knowledge of the gas reserves has been gained resulting in further refinement of the field development plan. The main changes to the project description presented in the EIS, which have the potential to affect the PHA, include changes to the size of the project development area, layout of the CGPFs, number and production capacity of production facilities, certain equipment and process conditions associated with production facilities and the addition of multi-well pads. Details of these changes to the project description are provided below.

Due to the relinquishment of parcels of land within Arrow's exploration tenements, there has been a reduction in the overall size of the project development area from 8,600 km^2 to 6,100 km^2. With a smaller project development area, there has been a reduction in the number of production wells anticipated to be drilled, reducing from 7,500 to approximately 6,500 wells. In addition to single wells described in the EIS, multi-well pad arrangements will also be drilled, comprising up to 12 wells per pad, approximately 8 m apart.

Advancement in the field development planning since preparation of the EIS has also seen the overall project development area being separated into eleven drainage areas, identified simply by sequential numbering, that correspond with the gas reserves that will be fed into each CGPF.

It is currently expected that eight of these drainage areas will be initially developed for the Surat Gas Project with each drainage basin incorporating wells, a water gathering network, a gas gathering network and a CGPF. A further three drainage areas may be developed with favourable reservoir outcomes and future market conditions.

Two of the eight drainage areas will include water treatment facilities. Irrespective of where the facilities are located, they are referred to by their function i.e., CGPF and water treatment facility. A water treatment facility will be located adjacent to one or two of the CGPFs (as opposed to six facilities, as reported in the EIS). In the EIS this arrangement was referred to as an integrated processing facility. This term will no longer be used and the facilities will be referred to by their function i.e., *CGPF* and *water treatment facility.*

Other material changes to the project description relevant to the supplementary PHA include:

- The layout of the CGPFs, which now incorporate four-stage centrifugal compressors, refer to Figure 4.
- Arrow's preference for electric power being sourced from the Queensland electricity grid. Note that for impact assessment purposes, power generation at the facilities has also been included to accommodate the scenario that this is temporarily required in the initial phase of operation, until production facilities, production wells and associated infrastructure including water treatment facilities are connected to the electricity grid. The EIS assumed that power would be self-generated.
- An increase in the maximum compression capacity of CGPFs; up to 225 TJ/d (with an n+1 sparing capacity, i.e. one additional compressor train), compared to the maximum of 150 TJ/d sized facilities considered in the EIS.

- Centrifugal compressors that require less maintenance and are quieter compared with other options such as screw and reciprocal compressors presented in the EIS are now Arrow's preferred option.
- The maximum pressure of the export high pressure pipelines (CGPFs discharge) has increased from 10,200 kPa to 13,500 kPa.

Further details on these project description changes and an evaluation against the assumptions made to prepare the supplementary preliminary hazard assessment, are provided in Table 1 in Section 5.

Details of the validation of the impacts of these project description changes on the assumptions and risks identified in the preliminary hazard and risk assessment are provided in Section 5.

3 LEGISLATIVE CONTEXT

Since finalising the PHA, the Queensland Work Health and Safety Act 1995 has been replaced by the Work Health and Safety Act 2011, which took effect on 1 January 2012.

The Australian Standard AS 2885 *Pipelines Gas and Liquid Petroleum* was updated in 2012.

Neither of these changes, nor the changes discussed in Section 2, alters the legislative context referred to in the PHA.

Shortly before issuing the PHA, a *Code of Practice for Constructing and Abandoning Coal Seam Gas Wells in Queensland* (Ref 2) was released by the former Department of Employment, Economic Development and Innovation (DEEDI) with input from the coal seam gas industry, the Australian Petroleum Production and Exploration Association (APPEA) and the former Department of Environment and Resource Management (DERM). The Code of Practice was developed to ensure that all CSG wells in QLD are constructed and abandoned to a minimum acceptable standard resulting in long term well integrity, containment of gas and the protection of groundwater resources. Arrow will be adhering to the stringent requirements in the Code of Practice. This will be done both for single wells and for the multi-well pads.

4 METHOD AND APPROACH

A review of the project description changes was undertaken as part of this supplementary PHA.

The approach taken was to systematically assess all major changes that have been made to the installations, material, operational parameters, safeguards or systems, which were proposed at the time of the PHA that could potentially influence the results of the assessment of the hazards and risks associated with the project, whether it be to people and property within surrounding land uses or to individuals present on site.

The review took the following steps:

1. Identify changes made to the installations, material, operational parameters, safeguards or systems that may influence the assumptions or conclusions made in the PHA.
2. Undertake a systematic assessment of the project description changes to determine whether they will result in an increase (worsening) or a decrease (amelioration) of hazards and risks identified in the PHA.
3. Review the qualitative assessment of the hazards and risks of the project and update based on the project description changes, using the Arrow risk matrix (Appendix 4 of the PHA).
4. Update of the risk contour and transect figures for inclusion in this update to the PHA.
5. Identify any changes or additions to the design, safety controls and management measures, as detailed in the PHA, which are required to manage the potential hazards and risks.
6. Identify any changes to (or additional) recommendations of the PHA.
7. Summarise and document the findings in an addendum report to be attached to the SREIS.

5 ASSESSMENT OF IMPACTS AND RISKS

5.1 EVALUATION AGAINST PHA ASSUMPTIONS

Details of the project description changes relevant to the PHA, together with the impacts of the changes on the assumptions and conclusions drawn in the PHA, are provided in Table 1 below.

Table 1 - Design Assumptions, Status at Updated Design

Aspect of project description	Basis of PHA	Status at Updated Design	Impact on Hazard and Risk Assessment / Re-Assessment Required
1. Total throughput from project	Total: 80 TJ/d supply for domestic gas with the addition of 970 TJ/d (including 10% feed gas) for export gas.	Total: 80TJ/d supply for domestic gas with the addition of 1,135 TJ/d (including 10% feed gas) for export gas.	NO
2. Number of facilities	Wells: 7,500 CGPF: 6 IPFs (incorporating CGPF and water treatment facility): 6	Wells: 6,500 CGPF: 8 (1 or 2 with associated water treatment facilities) IPFs: 0 (now referred to as CGPFs and water treatment facilities)	NO
3. Size of the project development area	Surface area occupied: 8,600 km^2	Surface area occupied: 6,010 km^2	NO
4. Central gas processing facility layout	CGPF layout was used as input to the QRA.	The layout of the CGPF facility has been updated.	The changes do not impact on the qualitative hazard and risk assessment. The changes have the potential to impact the quantitative assessment and will therefore require re-evaluation of the QRA.
5. Multi-well pads	Only a single well layout was used as input to the QRA.	A multi-well pad design (with up to 12 wellheads) has been included.	YES The addition of the multi-well pad to the project will impact the qualitative hazard and risk assessment as well as the QRA results.

Aspect of project description	Basis of PHA	Status at Updated Design	Impact on Hazard and Risk Assessment / Re-Assessment Required
6. Equipment and operating conditions associated with the facilities	A number of assumptions were made in the early design risk assessment. These assumptions had bearing on the results from the hazard and risk assessment reported in the PHA. These include: • Gas wells: Conservative assumption with regard to sizing of equipment, piping and plant response to upset operating conditions. • Gathering system: Assumed to be constructed in HDPE, GRE or steel (depending on the operating pressure). • CGPF: Throughput 150 TJ/d. • CGPF and high pressure pipeline: Maximum operating pressure 9,800 kPa(g). • CGPF: 2-15 screw and 1-6 reciprocal compressors. • Water treatment facilities: Capacity 60 ML/d.	Changes in equipment and operating conditions have been made to reflect the project description changes. These include: • Gas wells: Reduction in sizing of equipment and pipes and introduction of protective device with automatic response to upset operating conditions. • Gathering system: Constructed in HDPE for gas and water. • CGPF: Throughput increased to 225 TJ/d (with an n+1 sparing capacity, i.e. one additional compressor train). • CGPF and high export pressure pipeline: Maximum operating pressure increased to 13,500 kPa(g). • CGPF: Allowance has been made for a fourth train, although not contemplated at this time. Assessment has considered all four potential sources of failure. • Water treatment facilities: Capacity changed to 35 - 90 ML/d.	The changes do not impact on the qualitative hazard and risk assessment or the QRA for any of the facilities assessed, including for the water treatment facilities with the exception of the multi-well pad and the CGPF. The changes outlined will require re-evaluation of the QRA for the following facilities: - Multi-well pads - CGPF. The reduction in the pipe diameters for the gas wells and the application of the remote-controlled isolation valves on low-pressure gas will reduce the risk associated with the individual well. However, the risk reduction is very small and the results of the QRA associated with the single gas wells, remain unchanged. The risk associated with the high pressure pipeline was assessed in accordance with the relevant section of the pipeline Code AS 2885. Adherence with this standard will ensure that the pipeline risk is assessed at given intervals during the design, construction, operation and decommissioning phases. There is no need to re-evaluate the risk as part of the SREIS process.

Aspect of project description	Basis of PHA	Status at Updated Design	Impact on Hazard and Risk Assessment / Re-Assessment Required
7. Power generation	Self-generation of power was the primary mode of operation	Power to be primarily sourced from the Queensland electricity grid operated by external companies. In addition, Arrow plans to install underground or overhead (high voltage) distribution lines to transfer power between facility substations, production wells and other associated facilities such as water treatment facilities. Underground cables will be installed in the same corridor with the gathering lines whilst the above ground power lines will be subject to individual consultation with landholders. The option of self-generation of power will be retained and may be temporarily required in the initial phase of operation until infrastructure is connected to the electricity grid.	NO
8. Gas and Water nodes	Gas and water nodes, being common manifolds for gas headers or, in the case of water lines. In the gas lines a low point drain with underground separation and a collection boot, were included as part of the hazard and risk assessment of the gathering system in the PHA.	In the gas lines an inline separator with underground separation and a collection boot (low point drain) was kept but now using only one per pad, instead of one per well. In the water lines an inline underground degaser (first high point vent) was included at each wellhead. These changes do not significantly impact the hazard and risk assessment.	NO

Aspect of project description	Basis of PHA	Status at Updated Design	Impact on Hazard and Risk Assessment / Re-Assessment Required
9. Water Storage Facilities	Dam maximum capacity: • 840 ML untreated coal seam gas water dam • 960 ML treated water dam • 2x 1,440 ML brine dams The water and storage dams associated with these facilities spanned an area of 1 to 2 km^2 at each site.	Dam maximum capacity: • 450 ML to 1,050 ML untreated (RAW) water dam • 900 ML to 4,200 ML treated water dam • 90 ML to 2,880 ML brine dam The total footprint at each water treatment facility could be up to 2 km^2 (200 hectares), as originally stated in the EIS.	NO
10. Water Treatment Facility	Up to six water treatment facilities (integrated with the CGPFs) with 60 ML/d capacity.	Up to two water treatment facilities (co-located with CGPFs) with capabilities between 35 ML/d and 90 ML/d.	NO

5.2 QUALITATIVE EVALUATION AGAINST HAZARDS AND RISKS IDENTIFIED

The PHA provided a qualitative assessment of the cumulative hazards and risks of the project, using the Arrow risk matrix provided in the PHA. The status of the qualitative hazard identification and risk assessment reported on in the PHA is provided in light of the project description changes for each of the three phases of the project: design and installation; operation; and decommissioning. For further context on the following scenarios, refer to the PHA, Section 1.4 in the EIS

5.2.1 Design and Installation Phase

The design and installation phase, as defined in the EIS, incorporates the construction and commissioning activities of the project.

The qualitative hazard and risk scenarios remain largely unchanged. However, the addition of the multi-well design requires the hazard and risk assessment for the single well to be expanded to account for the multi-well design, as detailed in Table 2 below.

Only those scenarios that are changed are listed. All other scenarios for the design and installation phase remain unchanged.

Table 2 – Status of Hazards and Risk Identification for the Design and Installation Phase

Reference in PHA	Hazards and Risks Identified in the PHA	Status at Updated Design	Re-assessment Required
Table 13 (single gas well), 1st scenario	<u>As identified for the single gas well:</u> Ignition of flammable or combustible material, including incident involving gas released during blowdown or blowout catches fire and causes injury or destruction of property.	<u>As expanded for the multi-well pad:</u> Introduction of a multi-well pad design will affect the potential for fire at one well impacting neighbouring wells. This is because domino incidents may occur if a jet fire at one well impinges on the piping structure of a neighbouring well leading to damage and subsequent release and ignition. The consequence analysis conducted in the PHA shows that only large ignited leaks have the potential to impact a neighbouring gas well on the same well-pad, and that such leaks are highly unlikely. No change to the qualitative hazard and risk assessment for any of the installations assessed as part of the PHA, including for the single well pads.	• YES – scenario expanded to account for multi-well pads. • NO for all other installations
Table 13 (single gas well), 2nd scenario	<u>As identified for the single gas well:</u> Operator injury due to pressure burst (i.e. from a non-ignited release which may cause injury to a person standing nearby)	<u>As expanded for the multi-well pad:</u> Introduction of a multi-well pad design will introduce the potential for injury of operators working on one well due to a pressure burst on a neighbouring well. No change to the qualitative hazard and risk assessment for any of the installations assessed as part of the PHA, including for the single well pads.	• YES – scenario expanded to account for multi-well pads. • NO for all other installations

Reference in PHA	Hazards and Risks Identified in the PHA	Status at Updated Design	Re-assessment Required
Table 13 (single gas well), 10th scenario	As identified for the single gas well: Flammable gas co-mingles with (ground) water source	As expanded for the multi-well pad: Introduction of a multi-well pad design will impact the potential for interaction between wells below ground. This is being assessed separately by Arrow through detailed Hazard Identification Studies (HAZIDs) including a subsurface HAZID and a drilling HAZID. All controls listed for the single well pad remain relevant for the multi-well pad, as defined in PHA Table 13, 10th scenario. Additional controls to be adopted include: • Aquifer isolation in vertical and directional wells through the use of steel casing to line the well and cement to form a physical barrier between the well, coal seam producing zones and any aquifers. Multiple steel casings and cement may be utilised depending on individual well requirements ensuring a physical barrier is in place from the producing zones through to surface. Correct cement design and positioning of multiple casing centralisers ensures a homogeneous distribution of cement around the casing. In a deviated well, increased support to the casing may be required to maintain the position or “stand-off” of the casing in the middle of the bore hole during cementation. To achieve this, a more dense distribution of centralisers may be used on some well sections than in comparison to a straight / vertical hole. • Centraliser placement can be accurately calculated through computer modelling. • Adherence to strict design and management procedures with well design at a minimum compliance with Queensland regulations including the Code of Practise for Constructing and Abandoning Coal Seam Gas Wells in Queensland (Ref 2).	• NO

This assessment confirms that there has been no change to the qualitative hazard and risk assessment provided in the PHA for the design and installation of single wells, gathering lines, field compression facilities (FCFs), CGPF, water treatment facilities or high pressure pipeline.

The introduction of the multi-well pad design necessitates the single gas wells assessment to be expanded to also include the multi-well design.

Hence, the qualitative hazard and risk assessment remains valid for all facilities that form part of the project but requires updating for the multi-well pad. The expanded hazardous incident scenarios from the single well design in the PHA, to account for the multi-well design, are presented in Table 4.

5.2.2 Operational Phase

The operational phase, as defined in the EIS, incorporates the operation and maintenance phases (including workovers of wells) of the project.

The hazards and risks assessed in the PHA remain essentially unchanged, with the exception of the expansion of a number of hazardous incident scenarios associated with the single wells to account for the addition of the multi-well pad design, as detailed in Table 3 below.

Only those scenarios that are changed are listed. All other scenarios for the operations phase remain unchanged.

Table 3 - Status of Hazards and Risk Identification for the Operations Phase

Reference in PHA	Hazards and Risks Identified in the PHA	Status at Updated Design	Re-assessment Required
Table 19 (single gas well), 1st scenario	As identified for the single gas well: Loss of containment of flammable gas causes equipment damage or injury (from high pressure event) or, if ignition source is present, a fire.	As expanded for the multi-well pad: Introduction of a multi-well pad design will affect the potential for fire at one well impacting neighbouring wells due to the potential for domino incidents if a jet fire at one well impinges on a neighbouring well causing damage and subsequent release and ignition. As discussed in Table 2, the PHA shows that only large ignited leaks have the potential to impact a neighbouring gas well on the same well-pad and that such leaks are highly unlikely.	• YES – scenario expanded to account for multi-well pads • NO for all other installations
Table 19 (single gas well), 2nd scenario	Fire at the electrical generator involving lubrication oils used in pumps.	Power generation, assumed to be primarily self-generated in the PHA is now to be primarily via already established power grids operated by external companies. The option for self-generation remains however and may be temporarily required in the initial phase of operation until infrastructure is connected to the electricity grid. The risk of this scenario, while somewhat decreased compared with at the PHA stage, remains essentially the same.	• NO for all installations

Reference in PHA	Hazards and Risks Identified in the PHA	Status at Updated Design	Re-assessment Required
Table 19 (single gas well), 3rd scenario	External event such as bush fire threatens people, plant and equipment at the well compound or on their way to or from the compound.	The multi-well pad includes up to 12 wells and there are therefore more valves, meters, instrumentation, and piping on such a pad compared with what would be included at a single well. The threat to the multi-well pad from a bush fire warrants updating and comparison with that of a single well.	• YES – scenario expanded to account for multi-well pads • NO for all other installations
Table 19 (single gas well), 10th scenario	Operator injury and equipment damage due to pressure burst.	Introduction of a multi-well pad design will impact the potential for injury of operators working on one well due to a pressure burst on a neighbouring well. No change to the qualitative hazard and risk assessment for any of the installations assessed as part of the PHA, including for the single well pads.	• YES – scenario expanded to account for multi-well pads • NO for all other installations

This assessment confirms that there has been no change to the qualitative hazard and risk assessment provided in the PHA for the operational phase of single gas wells, gathering lines, FCFs, CGPFs and water treatment facilities.

Hazards and risks associated with the high pressure gas pipeline are not likely to increase beyond those reported in the PHA, which was conservative. The hazards and risks associated with the high pressure gas pipeline require a formal safety assessment which will be conducted in accordance with the Safety Management Study methodology defined in the Australian Standard AS 2885 Pipelines Gas and Liquid Petroleum, 2012. As such, the hazards and risks associated with the high pressure pipeline do not require further review as a part of this report.

The introduction of the multi-well pad design necessitates that the qualitative hazard and risk assessment for the single gas wells be expanded to also include the multi-well design.

Hence, the qualitative hazard and risk assessment remains valid for all facilities that form part of the project but requires updating for the multi-well pad.

The expanded hazardous incident scenarios from the single well design in the PHA, to account for the multi-well design, are presented in Table 4.

5.2.3 Decommissioning and Rehabilitation Phase

This assessment confirms that there has been no change to the qualitative hazard and risk assessment provided in the PHA for the decommissioning and rehabilitation phase of single wells, gathering lines, FCFs, CGPFs, water treatment facilities or high pressure pipeline.

Decommissioning of wells on the multi-well pad will be conducted using the same methods and the same precautions as for single wells and will be undertaken in line with the requirements of the CSG Code of Practice (Ref 2). The risk and controls associated with the decommissioning phase remain unaltered.

Table 4 – Expanded Hazardous Incident Scenarios at Updated Design

Hazard or Risk	Causes and Consequences	Required Controls	Qualitative Risk Assessment at PHA Stage	Qualitative Risk Assessment Status at Updated Design Stage
Design and Installation – Expansion to Hazardous Incident Scenarios for Single Well to Account for Multi-well pad				
PHA Table 13, 1st scenario: Fire risk causes injury or destruction of property.	Causes and consequences remain as per the single well pad assessed in the PHA. For multi-well pads, there is potential for the incident to spread to more than one well. Consequences have been assessed as the same as a single well pad.	All controls listed for the single well pad remain relevant for the multi-well pad, as defined in PHA Table 13, 1st scenario. Additional controls, as applicable for the drilling phase, include: • The wells are to be isolated at surface with pressure rated / tested wellhead (API 6A certified) before the drill rig is moved to the next well on the pad. • Wellheads are to be spaced such that the risk of collision of wellheads and any surface equipment by drill rig is minimised.	Consequence: Moderate Likelihood: Likely Risk: Medium Risk	Consequence: Moderate Likelihood: Likely Risk: Medium Risk
PHA Table 13, 2nd scenario: Operator injury due to pressure burst at multi-well pad.	Causes and consequences remain as per the single well pad assessed in the PHA. However, the presence of multiple wells on the same pad would introduce further causes of exposure of personnel working on a neighbouring well.	All controls listed for the single well pad remain relevant also for the multi-well pad, as defined in PHA Table 13, 1st scenario. For multi-well pads, formalised site handover and detailed Simultaneous Operation plans will be in place as well as a Manual of Permitted Operations to detail operations that occur between production and drilling and completion activities.	Consequence: Minor Likelihood: Possible Risk: Low Risk	Consequence: Minor Likelihood: Possible Risk: Low Risk

Hazard or Risk	Causes and Consequences	Required Controls	Qualitative Risk Assessment at PHA Stage	Qualitative Risk Assessment Status at Updated Design Stage
Operation and Maintenance – Expansion to Hazardous Incident Scenarios for Single Well to Account for Multi-well pad				
PHA Table 19, 1st scenario: Loss of containment of flammable gas at multi-well pad causes equipment damage or injury (from high pressure event) or, if ignition source present, a fire.	Causes and consequences remain as per the single well pad assessed in the PHA. For multi-well pads, there is potential for the incident to spread to more than one well. Consequences have been assessed as the same as a single well pad.	All controls listed for the single well pad remain relevant for the multi-well pad, as defined in PHA Table 19, 1st scenario. Additional controls include: • Wellhead spacing such that the risk of domino-effect from one well to a neighbouring well is minimised (as confirmed through QRA). • A full concurrent operations plan will be in place together with Arrow Energy's Emergency Response and Blowout Contingency Response Plans	Consequences: Major Likelihood: Unlikely Risk: Medium Risk	Consequences: Major Likelihood: Unlikely Risk: Medium Risk
PHA Table 19, 3rd scenario: External event such as bush fire threatens people, plant and equipment at the multi-well pad.	Causes and consequences remain as per the single well pad assessed in the PHA. However, the presence of multiple wells on the same pad would increase risk of exposure of personnel working on a neighbouring well.	All controls listed for the single well pad remain relevant for the multi-well pad, as defined in PHA Table 19, 3rd scenario. Fire breaks through vegetation management around facilities will be designed based on the infrastructure of the multi-well pad.	Consequences: Severe Likelihood: Rare Risk: Medium Risk	Consequences: Severe Likelihood: Rare Risk: Medium Risk

Hazard or Risk	Causes and Consequences	Required Controls	Qualitative Risk Assessment at PHA Stage	Qualitative Risk Assessment Status at Updated Design Stage
PHA Table 19, 10th scenario: Operator injury and equipment damage due to pressure burst at multi-well pad.	Causes and consequences remain as per the single well pad assessed in the PHA. For multi-well pads, there is potential for the incident to spread to more than one well. Consequences have been assessed as the same as a single well pad	All controls listed for the single well pad remain relevant also for the multi-well pad, as defined in PHA Table 19, 10th scenario. For multi-well pads, formalised site handover and detailed Simultaneous Operation plans will be in place as well as a Manual of Permitted Operations to detail operations that occur between production and drilling and completion activities.	Consequences: Moderate Likelihood: Possible Risk: Medium Risk	Consequences: Moderate Likelihood: Possible Risk: Medium Risk

5.2.4 Comparison with Qualitative Hazards and Risks Identified in the PHA

The assessment has confirmed that there is minimal change to the basis of the PHA, with regards to project design, construction, installation, operation, maintenance and decommissioning.

The main notable difference, which has an effect on the qualitative hazard and risk assessment, is the introduction of multi-well pad design which has introduced the need to expand the potential incident scenarios for the single well pad design to account for this design.

With the additional controls identified, the qualitative risk associated with the multi-well design, as determined using the Arrow risk matrix provided in the PHA (Ref 1), is identical to that of the single well pad design.

The increase in maximum dam size and volume, while not insubstantial, do not introduce any change in the qualitative assessment of water treatment facilities.

The small changes in equipment and operating conditions are not sufficient to impact the qualitative hazard and risk assessment in the PHA.

The use of power from the grid operated by external companies as the primary power source for the established operation of the facilities reduces the risk associated with power generation. However, the option of using self-generated power remains for the project, particularly in the initial phase of operation, until the infrastructure is connected to the electricity grid. The risk associated with this scenario, while somewhat decreased compared with the PHA stage, remains largely the same and hence there is no impact on the qualitative hazard and risk assessment in the PHA.

The decrease in the number of wells to be installed would reduce the overall risk from the project but is not sufficient to impact the qualitative hazard and risk assessment in the PHA.

The decrease in the area occupied by the project would again reduce the overall risk from the project but is not sufficient to impact the qualitative hazard and risk assessment in the PHA.

There has been no change in the cumulative risk from that assessed in the PHA.

5.3 QUANTITATIVE EVALUATION AGAINST HAZARDS AND RISKS IDENTIFIED

The PHA provided a QRA of the project during operation to determine appropriate buffer zones between the proposed facilities and neighbouring land uses.

Risk associated with the facilities which form part of the project was represented in the form of individual risk of fatality, injury and propagation, i.e. the likelihood (or frequency) of an undesired consequence (fatality, injury or propagation) affecting individuals or plant at locations around the site, as a result of any of the postulated incidents. The units for individual risk are probability (of fatality) per million per year.

The risk associated with the facilities was then compared with the relevant risk criteria, an explanation of which is provided in the PHA (Ref 1).

As defined in Table 1 (Section 5.1), the following elements of the QRA reported in the PHA have been updated in light of the project description changes for the operational stage of the project:

- Coal seam gas wells, multi-well pad: fatality, injury and propagation risk
- Central gas processing facility: fatality, injury and propagation risk

These reflect the risks associated with the credible incident scenarios outlined in Section 4 of the PHA. The results of the updated elements of the QRA are reported in Sections 5.3.1 and 5.3.2 below.

5.3.1 Coal Seam Gas Wells, Multi-well Pad

The risk associated with single gas wells is also relevant for the wells installed on a multi-well pad. Potential hazardous events include jet fires, flash fires and vapour cloud explosions.

In addition, there is a potential for domino incidents at the multi well pad, as a jet fire at one well has a potential to impinge on the piping structure of a neighbouring well for a sufficiently long time and with sufficient radiant heat that it causes thermal stress and failure of the steel, and subsequent release and ignition of flammable gas.

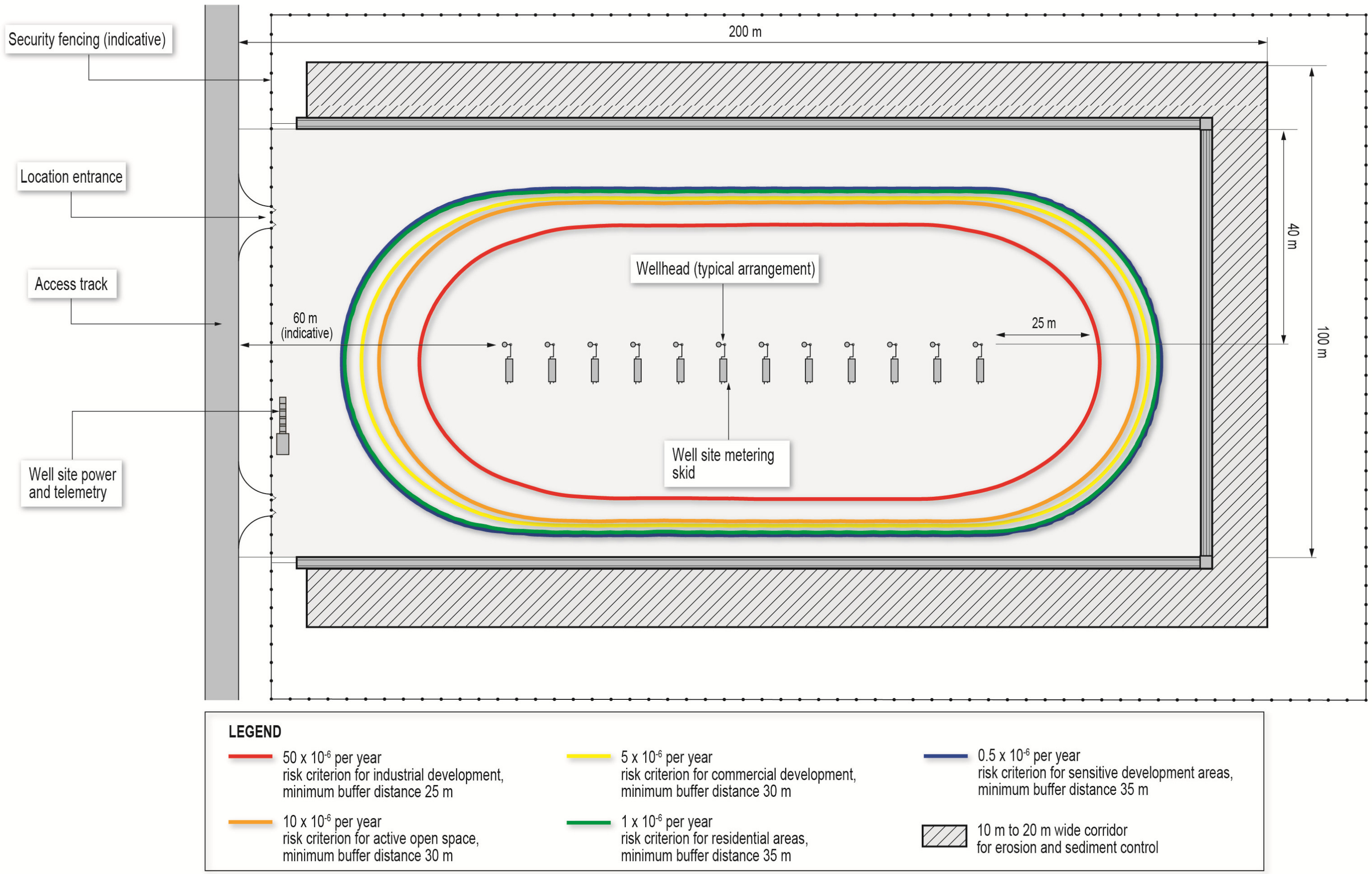
All (100%) of the jet fire scenarios from the PHA, where the heat radiation exceeds 23 kW/m^2 at a neighbouring well (Ref 3), were assumed to cause domino effects at the neighbouring well. This is a conservative assumption given that some of the jet fires would be directed away from plant and equipment and that the source of release would most likely be isolated, and hence the jet fire stopped, prior to potential damage to the plant occurring.

Due to the short duration of a flash fire, domino incidents from a flash fire are not a credible event. As such, flash fires from one well were not included as potential source of damage to a neighbouring well on the multi-well pad.

A. Individual Risk of Fatality

The individual risk of fatality associated with a multi-well pad is represented in Figure 1 below as risk contours, showing a graphical representation of the risk level as a function of the distance from the facility.

Figure 1 - Individual Fatality Risk Contours for Coal Seam Gas Multi-Well Pad (12 Wells)



Separation distances for the various types of land uses that may be found in the Surat Gas Project development area have been revised in light of the updates to the fatality risk contours, taking into account sensitivity issues. These are shown in the Table 5 below.

To provide a comparison with the single well results from the PHA, Table 5 also shows separation distances for the single well. The distances quoted are those:

- away from the axis along the wellheads (for multi-well pad)
- away from the wellhead of the single well (for single wells).

Table 5 – Multi-Well Pad, Minimum Distance to Satisfy Land use Risk Criteria[1]

Type facility	Minimum Buffer Distance (metres)				
	Industrial Buffer ($50x10^{-6}$/yr)	Active open space ($10x10^{-6}$/yr)	Business ($5x10^{-6}$/yr)	Residential development ($1x10^{-6}$/yr)	Sensitive development ($0.1x10^{-6}$/yr)
Multi-Well Pad - Wells with flexible connections	25 m	30 m	30 m	35 m	35 m
Single wells - Wells with flexible connections (refer Table 29 of the PHA)	10 m	25 m	30 m	30 m	35 m

The risk associated with the multi-well pad compared with that of the single well has increased such that larger buffers to industrial, active open space and residential development are required. However, the buffers to business and sensitive development remain the same.

The buffer distances in Table 5 represent minimum buffer distances. However, Arrow will apply more stringent buffer distances and production wells and associated wellhead infrastructure will be no closer than 200 metres or more from a sensitive receptor.

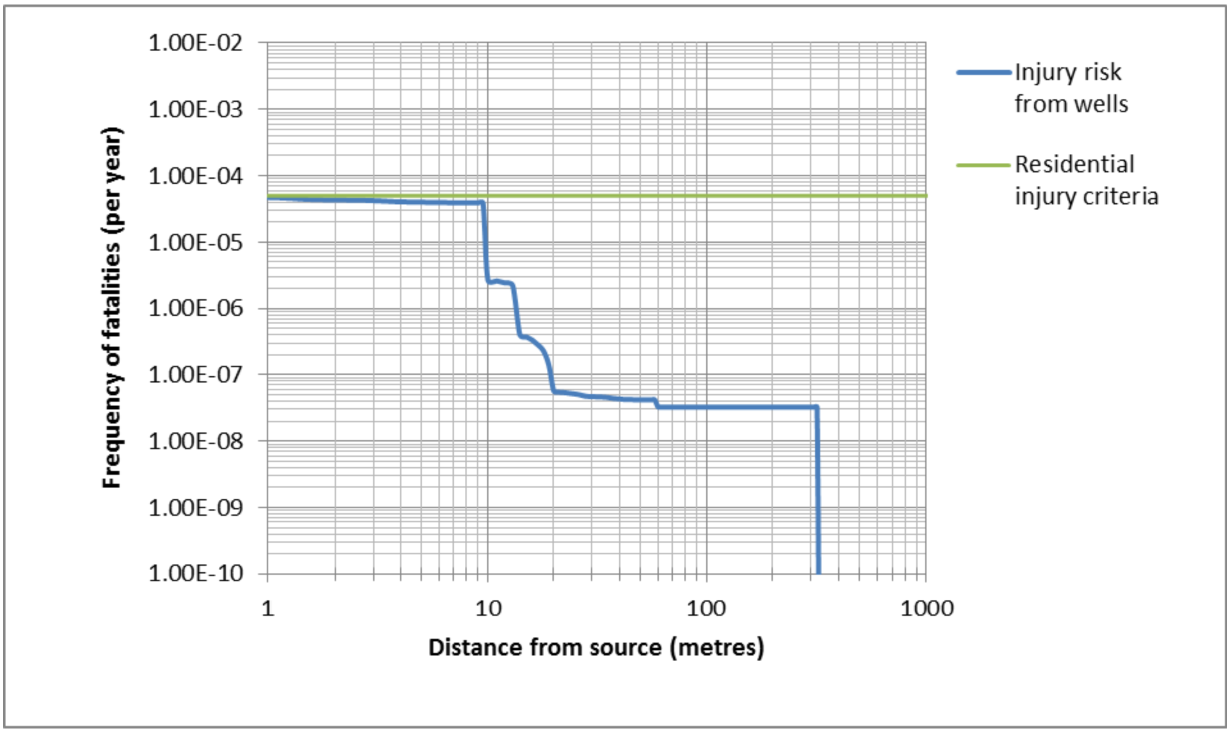
Please note that the Industrial Criteria applies to neighbouring industrial facilities and not risk to (Arrow or subcontracting) workers at the well.

[1] The minimum distances have conservatively been rounded up to the nearest 5, i.e. a calculated distance of 11, 12, 13, 14 or 15 metres would all be listed as of minimum distance to safety criteria of 15 m.

B. Injury Risk

The injury risk for a multi-well pad, corresponding to the *injury risk buffer* shown in Figure 2, is consistently below the risk criteria for injury risk to neighbouring residential areas. This is consistent with the results for the single wells.

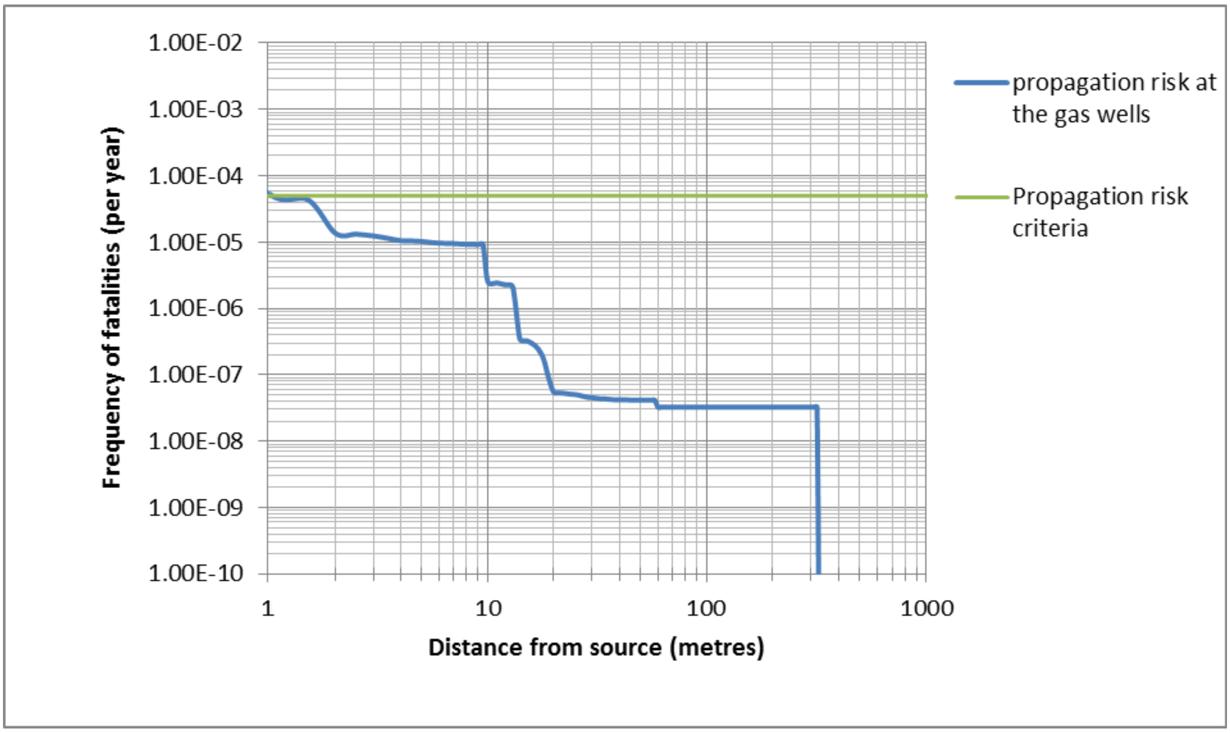
Figure 2 – Injury Risk for Coal Seam Gas Multi-Well Pad (12 Wells)



C. Propagation Risk

The propagation risk for a multi-well pad, corresponding to the *propagation risk buffer*, is consistently below the risk criteria for propagation risk to neighbouring industrial facilities (Figure 3). This is consistent with the results for the single wells.

Figure 3 – Propagation Risk for Coal Seam Gas Multi-Well Pad (12 Wells)



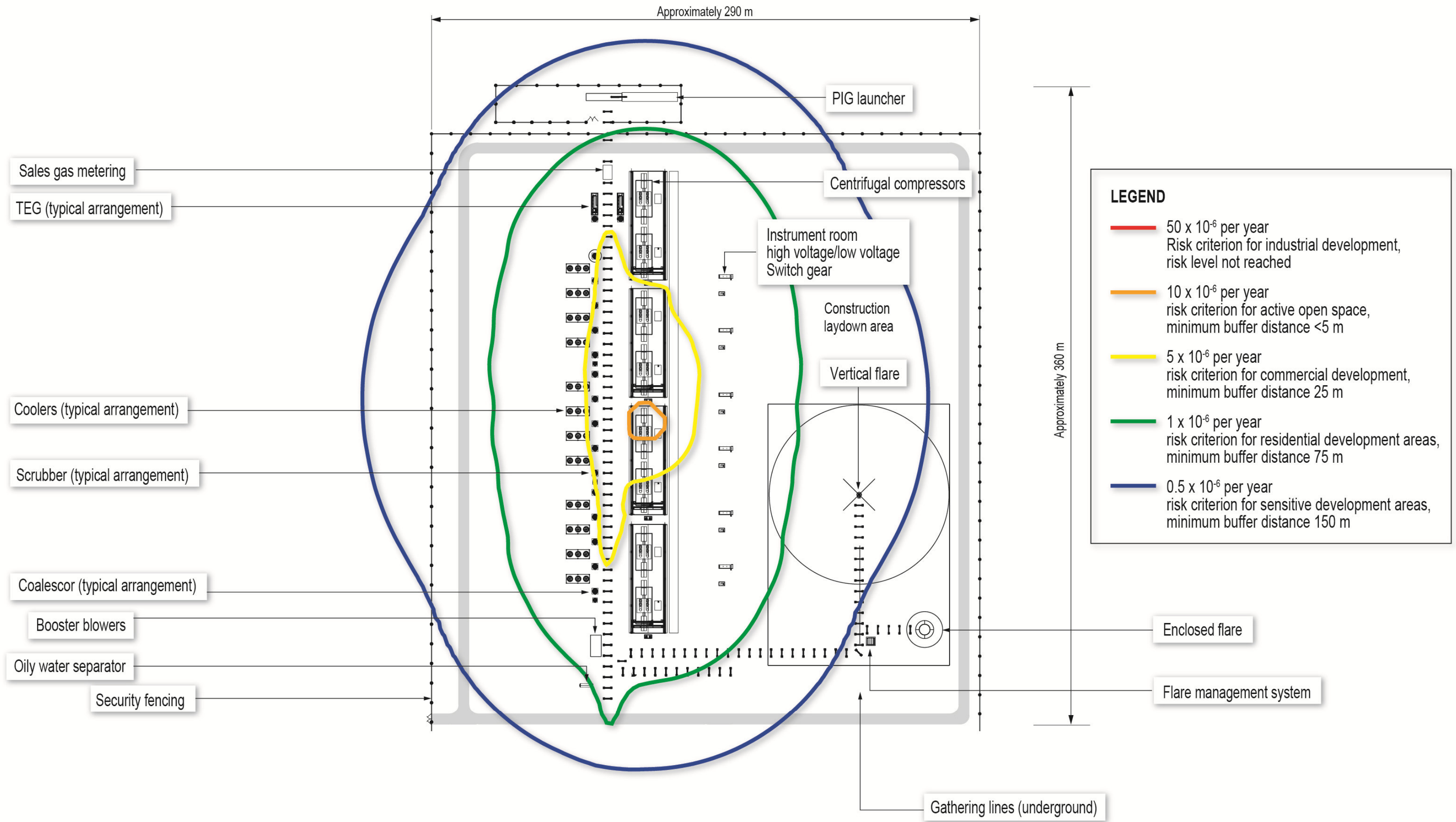
5.3.2 Central Gas Processing Facility

As defined in Table 1 (Section 5.1), the QRA for the CGPF, reported on in the PHA, has been updated in light of the project description changes for the operational stage of the project.

A. Individual Risk of Fatality

The risk associated with the CGPF, represented as *risk contours* overlaid on a site layout diagram, is shown in Figure 4 below. This site layout accounts for a maximum of four (4), four-stage centrifugal compressors. The largest capacity facility will nominally include three (3), four-stage centrifugal compressors, however, a sparing allowance for a fourth compression train, although not contemplated at this time, has been included in the assessment which considers all four potential sources of failure.

Figure 4 – Individual Fatality Risk Contours for CGPF



The minimum separation distances between the CGPF and neighbouring land uses are presented in Table 6 below. The distances quoted are those away from the outer edge of compressors.

This table updates Table 40 from the PHA and shows a reduction in risk associated with the CGPF compared with the values calculated in the PHA and presented in the EIS.

To provide a comparison with the CGPF results from the PHA, the distances to the various buffer zones for the CGPF as reported in Table 40 of the PHA are also provided in Table 6.

Table 6 – Central Gas Processing Facility, Minimum Distance to Satisfy Land use Criteria

CGPF	**Minimum Buffer Distance (metres)**				
	Industrial development (50×10^{-6} /yr)	**Active open space (10×10^{-6} /yr)**	**Business (5×10^{-6} /yr)**	**Residential development (1×10^{-6} /yr)**	**Sensitive development (0.5×10^{-6} /yr)[2]**
Outer edge of compressors at the Central Gas Processing Facility	Site boundary	<5 m from outer edge of compressors (contained on site)	25 m from outer edge of compressors (contained on site)	75 m from outer edge of compressors (contained on site except for in the axis of compressor train)	150 m from outer edge of compressors
Comparison with what was reported in the PHA	Site boundary	55 m from 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 contours associated with industrial, active open space and business development are contained inside the site boundary – this is consistent with the results from the PHA.

The risk contour to residential development has been reduced to 75 meters from the outer edge of the compressors, from 210 metres in the PHA. It is contained within the site boundary at all locations except for in the axis of the compressor train where it protrudes into the area outside of the site boundary.

The risk contour to sensitive development has been reduced to 150 meters from the centre line of the compressors, from 290 metres in the PHA. It extends outside of the site boundary at all points.

The risk reduction is due to the reduction in the number of compressors and the use of centrifugal compressors in lieu of the combination of screw and reciprocal compressors assumed in the PHA, with centrifugal compressors having a lower leak frequency (Ref 4).

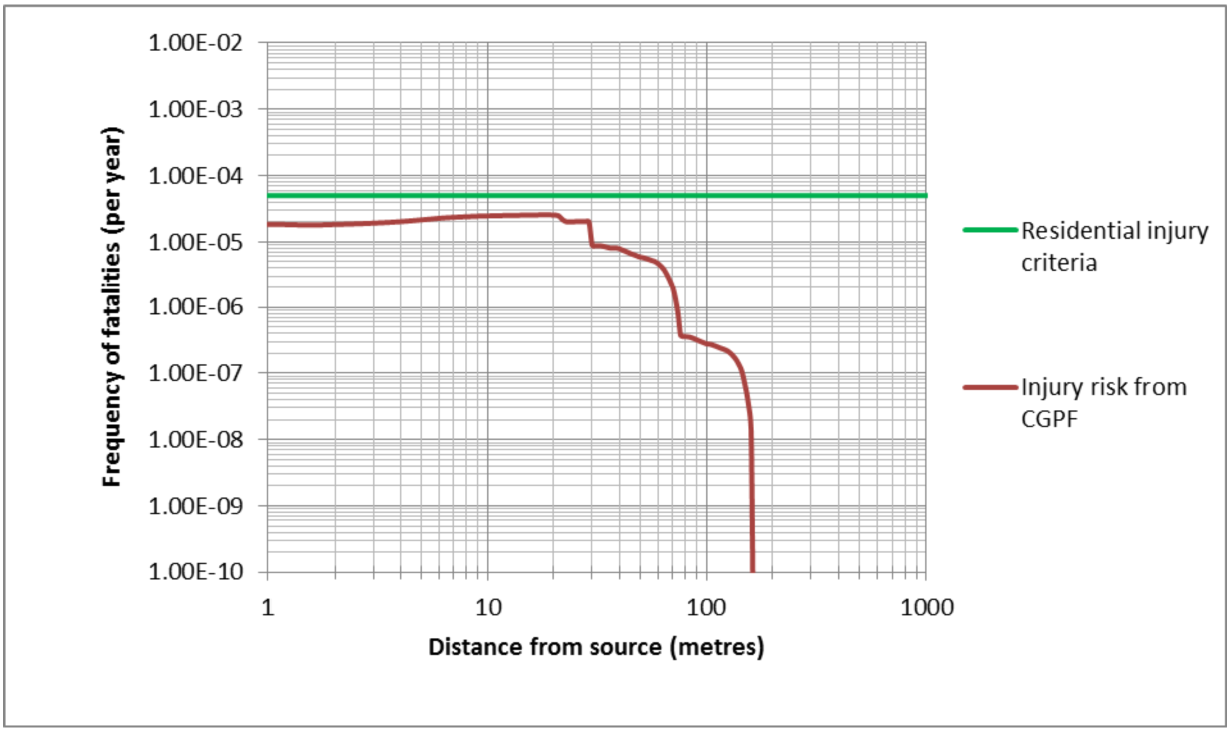
[2] The risk criterion for sensitive development of 0.5×10^{-7} per year relates to the criterion in force in the state of Queensland, as published in the Hazardous Industry Planning Advisory Paper No 4, 2011, as discussed in the PHA in Ref 1. The PHA used a more stringent criteria of 0.1×10^{-7} per year and the buffer zones quoted in the PHA were hence marginally larger than what would be required had the 0.5×10^{-7} per year criterion been applied.

B. Injury Risk

The injury risk for the CGPF, corresponding to the *injury risk buffer*, remains consistently below the risk criteria for injury risk to neighbouring residential areas (Figure 5). The injury risk therefore remains contained within the site boundary.

It shows a reduction in risk compared with the injury risk reported in the PHA, where the injury risk contour extended 30 metres beyond the outer edge of the compressors.

Figure 5 – CGPF Injury Risk

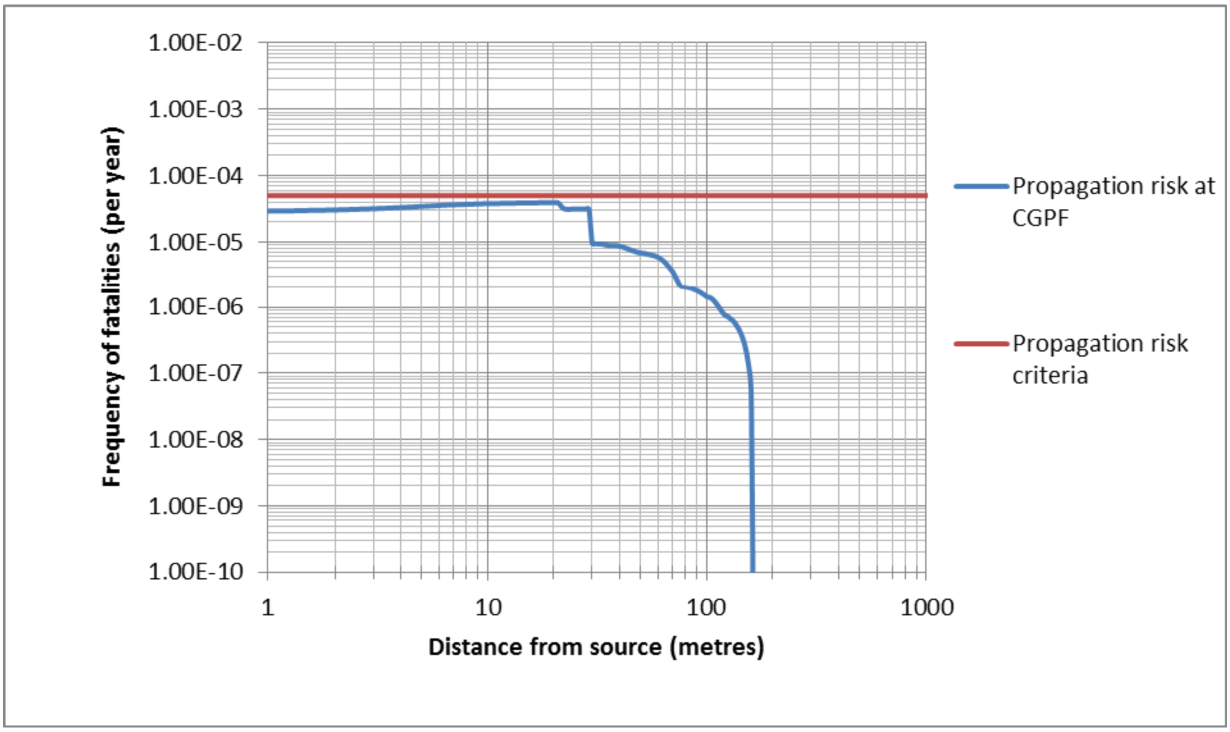


C. Propagation Risk

The propagation risk for the CGPF, corresponding to the *propagation risk buffer*, remains consistently below the risk criteria for propagation risk to neighbouring industrial areas (Figure 6). The propagation risk therefore remains contained within the site boundary.

It shows a reduction in risk compared with the propagation risk reported in the PHA, where the propagation risk contour extended 30 metres beyond the outer edge of the compressors.

Figure 6 – CGPF Propagation Risk



6 MANAGEMENT MEASURES

The majority of changes to the layout and design of the facilities that form part of this project, following design optimisation, do not warrant changes or additions to the design and safety controls and management measures identified and discussed in the PHA which are required to manage the potential hazards and risks.

The additional safety controls required relate to the multi-well pads which are aimed at minimising the risk of damage to adjacent infrastructure during installation, operation and decommissioning of a neighbouring well. These additional measures are discussed in Section 5.2 and are summarised below:

- Wells on multi-well pads are to be isolated at surface with pressure rated/tested wellhead (API 6A certified) before the drill rig is moved to the next well on the pad.
- A full concurrent operations plan will be in place together with Arrow Energy's Emergency Response and Blowout Contingency Response Plans. Wellhead spacing on multi-well pads are to be such that the risk of domino-effect from one well to a neighbouring well is minimised, as confirmed by the consequence assessment and QRA which formed part of this supplementary PHA.

7 CONCLUSIONS

A review of changes to the project description following design optimisation, and the implications of these changes on the assessment and conclusions drawn in the PHA was conducted.

The hazard and risk assessment reported in the PHA remains essentially unchanged with some improvements resulting from project description changes since the EIS was finalised. This is evident in the risk reduction achieved at the CGPF, which is due to the reduction in the number of compressors and the choice of compressor design.

The required buffer between the CGPF and various land uses has been reduced as follows:

- **Near Sensitive development**, including schools, hospitals, prisons, day cares, aged care facilities: No CGPF within 150 metres of sensitive development (from 290 metres in the PHA). Distance measured from the outer edge of the compressors the boundary of the sensitive development.

- **Near residential development**: No CGPF within 75 metres of residential development or zoning (from 210 metres in the PHA) from the outer edge of the compressors to the boundary of a residential development.

- **Near business development:** No CGPF within 25 metres from the outer edge of the compressors to the boundary of a business development (from 75 metres in the PHA).

- **Near active open space:** No CGPF in areas within 5 metres from the outer edge of the compressors to the boundary of an active open space (from 55 metres in the PHA).

- **Near industrial development**: Neighbouring industrial facilities can continue to be established at the site boundary of the CGPF (the buffer zone to an industrial facility was also contained within the site boundary in the PHA).

The multi-well pad design, proposed as part of the project description changes, does not introduce any new risk scenarios, as all risk scenarios associated with the single wells are also relevant for the multi-well pads. While the potential for domino effects for a single well is possible and heightened with the co-location of several wells closer together , the QRA showed that the risk associated with a loss of integrity of one well due to an incident at a neighbouring well is very low.

Apart from a small increase in quantitative risk results, the risk associated with the multi-well pad is similar to that of the single wells, with the exception of increased buffers to active open space and industrial development. The required buffer between the multi-well pad and various land uses is as follows:

- **Near Sensitive development**, including schools, hospitals, prisons, day cares, aged care facilities: No multi-well pads within 35 metres of sensitive development (as per the buffer zone determined in the PHA for a single well). Distance measured from the axis along the wellheads to the boundary of the development.

- **Near residential development**: No multi-well pads within 35 metres from the axis along the wellheads to the boundary of the residential development or zoning (compared with 30 metres for a single well). Note that this buffer indicates the necessary safety distance, however Arrow's infrastructure and facilities will be no closer than 200 metres to a sensitive receptor.

- **Near business development:** No multi-well pads within 30 metres from the axis along the wellheads to the boundary of the business development (as per the buffer zone determined in the PHA for a single well).

- **Near active open space:** No multi-well pads within 30 metres from the axis along the wellheads to the boundary of the active open space development (compared with 25 metres for a single well).

- **Near industrial development:** No multi-well pads within 25 metres from the axis along the wellheads to the boundary of the industrial development (compared with 10 metres for a single well).

It should be noted that the above buffers indicate the necessary safety distances only, and Arrow's production wells and associated wellhead infrastructure will be no closer than 200 metres to a sensitive receptor. The risk associated with the extraction, production and handling of the gas at the proposed development remains as low as reasonably practicable (ALARP) provided the hazard and risk framework approach for the proposed development is maintained, as discussed above.

8 REFERENCES

1 *Preliminary Hazard and Risk Assessment of Arrow Energy's Surat Gas Project, QLD*, Planager Pty Ltd, 12 December 2011

2 Department of Employment, Economic Development and Innovation (DEEDI), *Code of Practice for Constructing and Abandoning Coal Seam Gas Wells in Queensland*, Version 1.0, November 2011

3 Department of Planning, *Hazardous Industry Planning Advisory Paper Nº 4: Risk Criteria for Land Use Planning*; NSW Government, Sydney, January 2011

4 *Risk Assessment Data Directory*, Report No. 434 – 1, March 2010, International Association of Oil & Gas Producers (OGP)