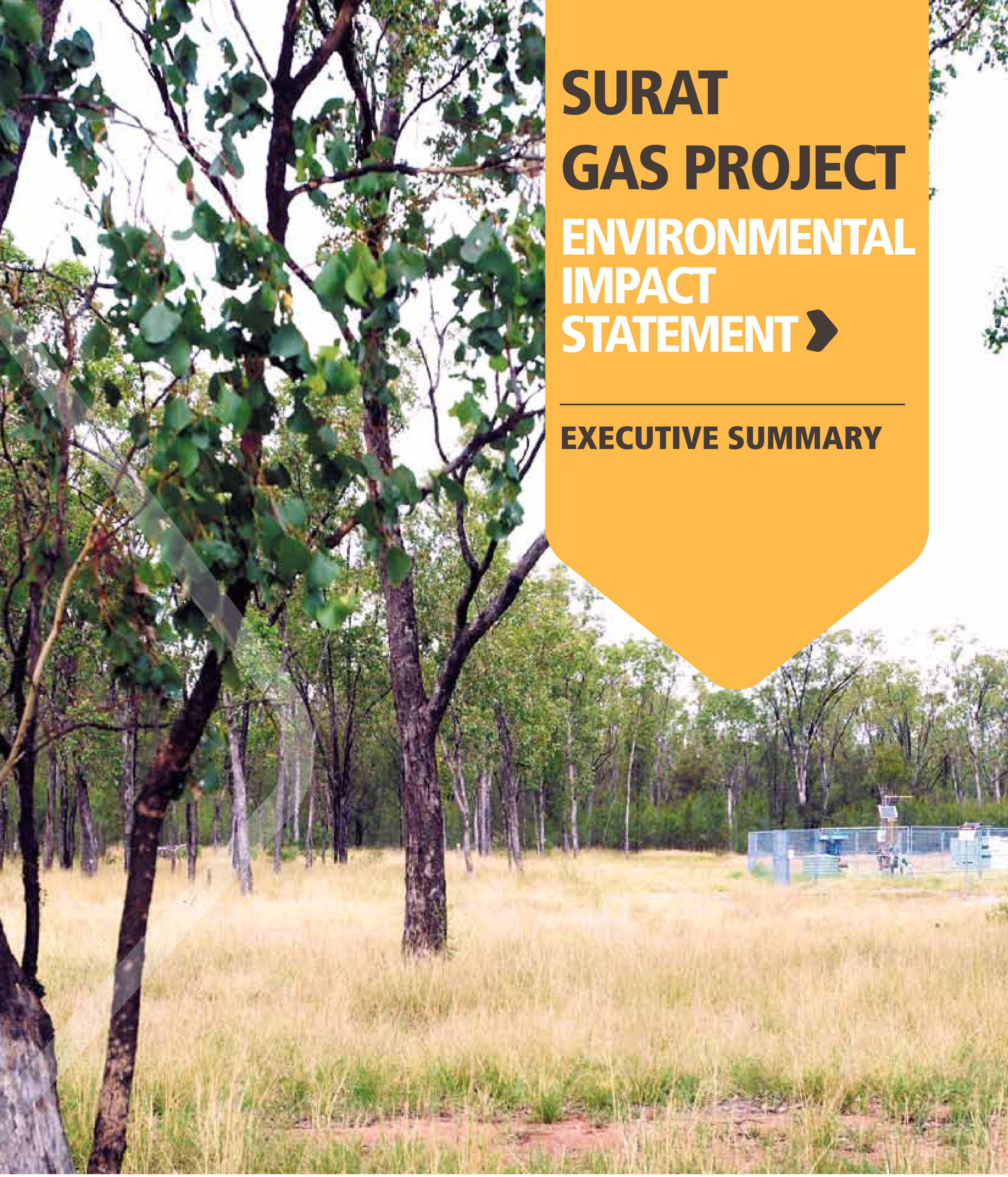
SURAT GAS PROJECT

ENVIRONMENTAL IMPACT STATEMENT

EXECUTIVE SUMMARY



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MARCH 2012

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Arrow Energy Pty Ltd

Surat Gas Project

Environmental Impact Statement

Executive Summary

March 2012

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1 INTRODUCTION

Arrow Energy Pty Ltd (Arrow) proposes expansion of its coal seam gas operations in the Surat Basin through the Surat Gas 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.

This executive summary provides an overview of the project, the contents of the environmental impact statement (EIS), how to view or obtain a copy, and how to make a submission.

1.1 Project Proponent

Arrow, the project proponent, is a Queensland-based wholly owned subsidiary of Arrow Energy Holdings Pty Ltd, a 50:50 joint venture between a subsidiary of Royal Dutch Shell plc and a subsidiary of PetroChina Company Limited (PetroChina). The joint venture took ownership of Arrow on 23 August 2010.

Royal Dutch Shell plc has had a presence in Australia since 1901. Current operations and equity interests include upstream exploration and production, petroleum refining, and wholesale and retail marketing of petroleum products. Royal Dutch Shell plc has been a pioneer and technology leader in liquefied natural gas (LNG) production and operates one of the largest LNG carrier fleets in the world.

PetroChina is a subsidiary of China's largest state-owned oil and gas producer and distributor, China National Petroleum Corporation, and is one of the world's largest oil companies.

1.2 Arrow Coal Seam Gas Operations

Arrow supplies gas from its Daandine and Tipton West gas fields near Dalby in the Surat Basin to the Daandine, Braemar 1 and 2 and Swanbank E power stations. Arrow and its joint venture partner AGL also supply coal seam gas from the Moranbah Gas Project in the Bowen Basin to Townsville Power Station. Arrow's current production is based on 500 wells (of which around 350 are in the Surat Basin) and amounts to 20% of Queensland's overall domestic gas production from all sources. Arrow holds a number of environmental authorities that cover its existing Surat Basin operations, including a project environmental authority for the Dalby Expansion Project. The Dalby Expansion Project covers the existing producing fields in the Surat Basin and includes approval for up to 200 new production wells and associated infrastructure that will ensure Arrow will continue to meet its current domestic gas supply obligations.

1.3 Surat Gas Project

1.3.1 Project Objective and Functions

The principal objective of the Surat Gas Project is to commercialise gas reserves in the company's petroleum tenures. Arrow's tenements straddle the common boundary of the Surat and Clarence-Moreton basins, with the majority of the tenements in the Surat Basin. Reference to the Surat Basin in the EIS includes proposed development in the Surat Basin and westernmost part of the Clarence-Moreton Basin. The project involves a major expansion of Arrow's coal seam gas production to supply gas to the domestic market and for the production and export of LNG.

The two principal project functions are to:

- Produce, dehydrate and deliver gas to existing pipelines and the proposed Arrow Surat Pipeline, which will supply domestic customers and the proposed LNG plant in Gladstone respectively.
- Treat coal seam gas water, supply for use by third parties and to safely dispose of water treatment residues (mainly brine).

1.3.2 Project Location

The project development area, approximately 160 km west of Brisbane in Queensland's Surat Basin, covers approximately 8,600 km^2 and extends in an arc from Wandoan in the north through Dalby in the east to near Goondiwindi in the south (Figure 1). Other major towns in the project development area are Miles, Chinchilla, Kogan, Cecil Plains and Millmerran. Project infrastructure, including coal seam gas production wells and compression and processing facilities, will be located throughout the project development area but not in towns. Facilities supporting the petroleum development activities, such as depots, stores and offices, may be located in or adjacent to towns.

For ease of management, the project development area has been divided into five development regions: Wandoan, Chinchilla, Dalby, Millmerran/Kogan and Goondiwindi (see Figure 1).

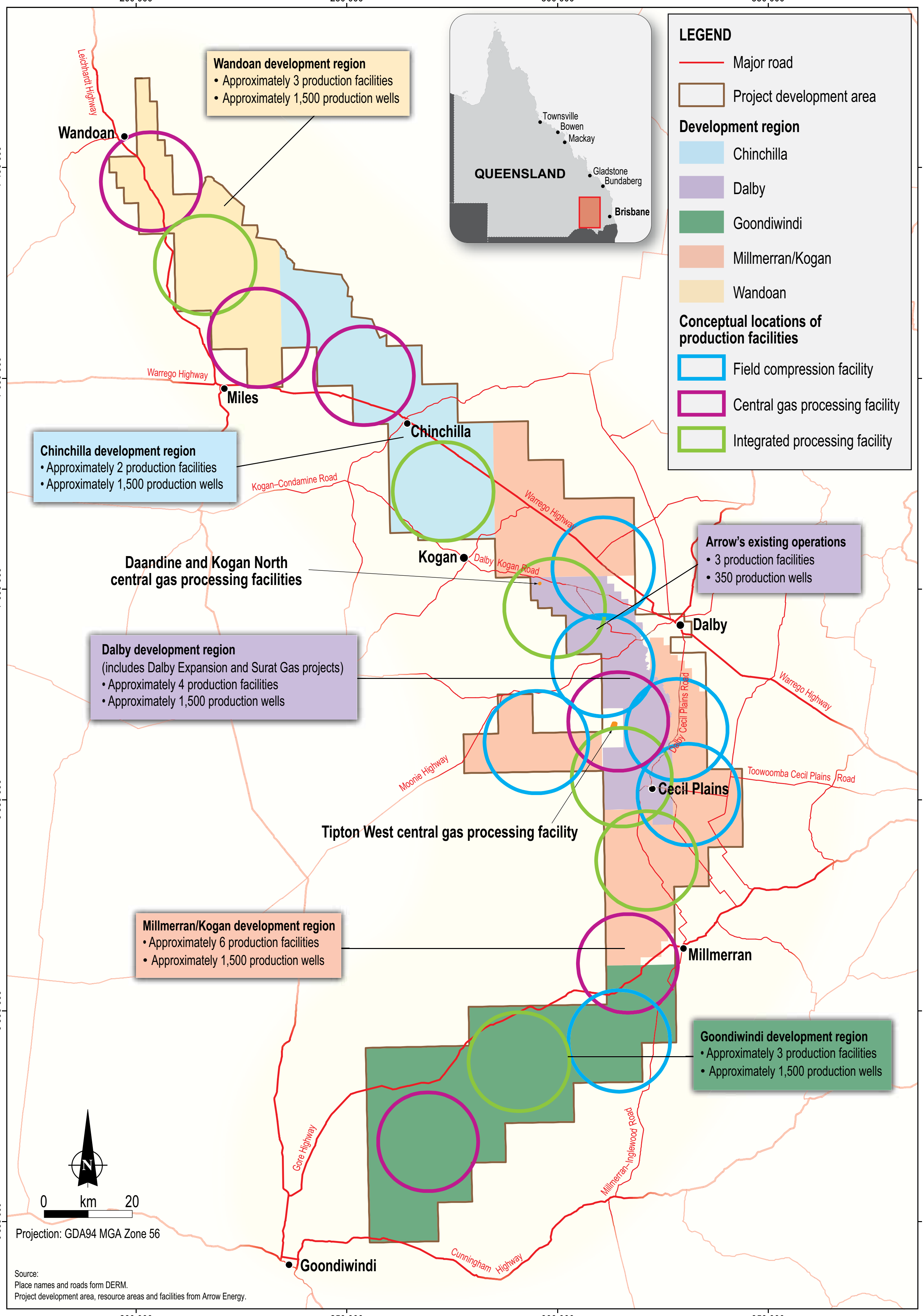


Figure 1 Surat Gas Project development regions

1.3.3 Project Overview

The conceptual Surat Gas Project design presented in the EIS is premised upon peak gas production from Arrow's Surat Basin gas fields of approximately 1,050 TJ/d. The peak gas production comprises 970 TJ/d for LNG production (including a 10% fuel gas requirement for facility operation) and a further 80 TJ/d for the domestic gas market.

A project life of 35 years has been adopted for EIS purposes. Ramp-up to peak production is estimated to take between 4 and 5 years and is planned to commence in 2014. Following ramp-up, gas production will be sustained at approximately 1,050 TJ/d for at least 20 years, after which production is expected to decline.

Conventional natural oil and gas reservoirs are geological formations in which hydrocarbons have become trapped after migrating from the host rocks in which they were formed. Not all hydrocarbons form reservoirs; many migrate to the surface as gas leaks or oil seeps or remain in their host rocks. Coal seam gas is an example of the latter.

In the Surat Basin, the main coal seam gas host rock is the Walloon Coal Measures, a formation in which gas has been kept in place under pressure by the overlying geological strata and the water that is also trapped in the coal formation within a confined aquifer. To allow gas to flow from the coal measures, the water pressure needs to be reduced, and this will be done by pumping the water from the same production wells that are drilled to access the gas.

The gas and water produced by production wells will be collected in a network of gathering pipelines and processed or treated in a series of production facilities that include compression, power generation and water treatment infrastructure. Processed gas will be dispatched to domestic gas customers and for LNG production and export, and treated water will be sent to various water users or injected into suitable aquifers (if proven to be technically feasible).

Infrastructure for the project is expected to comprise:

- Approximately 7,500 production wells drilled over the life of the project at a peak rate of approximately 400 wells drilled per year.
- Approximately 18 production facilities across the project development area expected to comprise six of each of the following:
  - Field compression facilities.
  - Central gas processing facilities.
  - Integrated processing facilities.
- Low-pressure gas gathering lines to transport gas from the production wells to the production facilities.
- Medium-pressure gas pipelines to transport gas between field compression facilities and central gas and integrated processing facilities.
- High-pressure gas pipelines to transport gas from central gas and integrated processing facilities to the sales gas pipeline.
- Water gathering lines (located in a common trench with the gas gathering lines) to transport coal seam gas water from production wells to transfer, treatment and storage facilities.
- Gas-powered generators co-located with project infrastructure to provide power for the project.

Further detail regarding the project infrastructure is provided in Section 4, Project Components.

Development of the coal seam gas resources will be staged to optimise production over the life of the project, with the rate of development influenced by energy market demand, gas sales contracts, and information gathered from Arrow's ongoing exploration program. The staging will involve concurrent development in several development regions as Arrow incrementally expands its current operations and develops new gas fields. This is described further in Section 3, Project Conceptual Design.

1.3.4 Related Projects

The Surat Gas Project is one of several projects that comprise Arrow's coal seam gas development, called the Arrow LNG Project (see Figure 2). The project will combine with five other separate but interdependent projects to produce gas for domestic and export LNG markets:

- **Arrow Surat Pipeline.** This 470-km-long pipeline, which has been approved, will carry gas from near Kogan in the Surat Basin to Gladstone.
- **Arrow Surat Header Pipeline.** This 106-km-long, high-pressure gas pipeline will deliver gas from the southern part of the project development area to the Arrow Surat Pipeline. This pipeline will be subject to a separate approvals process under the *Petroleum and Gas (Production and Safety) Act 2004* (Qld) (P&G Act) and the *Environmental Protection Act 1994* (Qld) (EP Act).

- **Arrow LNG Plant.** This proposed project, which comprises an LNG plant, marine, and ancillary infrastructure on Curtis Island near Gladstone, is the subject of a separate EIS process under the *State Development and Public Works Organisation Act 1971* (Qld). To be developed in two stages, the proposed LNG plant will have an ultimate capacity of up to 18 million tonnes per annum.
- **Bowen Gas Project.** This project proposes to expand Arrow's coal seam gas development in the Bowen Basin. Arrow will prepare a voluntary EIS under the EP Act for this project.
- **Arrow Bowen Pipeline.** This proposed 475-km-long, high-pressure gas pipeline and associated lateral pipelines will deliver coal seam gas from Arrow's tenements in the Bowen Basin to Gladstone. Arrow has prepared a voluntary EIS under the EP Act for this project.

The Dalby Expansion Project (see Figure 1) was approved in 2010 by amendment of Arrow's existing environmental authorities. To ensure the cumulative effects of this development are considered in the broader context, the Dalby Expansion Project area is included within the Surat Gas Project development area and its associated impacts have been considered in this EIS.

1.4 Environmental Impact Statement

1.4.1 Objectives of the EIS

Arrow has prepared a voluntary EIS under the EP Act. The Queensland process has been accredited by the Australian Government as the appropriate level of assessment under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC Act) for matters of national environmental significance. The EIS will inform the decision by the Queensland and Australian governments on whether the project should or should not proceed and, if so, under what conditions.

This EIS was prepared in accordance with those acts and provides:

- For affected and interested persons and organisations, a basis for understanding the proposed project, its impacts and how they will be managed.
- For government agencies and decision-makers, a framework for assessing the impacts of the project against legislative and policy provisions and for deciding whether or not the project should proceed and, if so, under what conditions.
- For Arrow, a mechanism to establish environmental protection objectives and measures.

1.4.2 Community Consultation

Community consultation is integral to the EIS process, as it allows community concerns and issues to be addressed in the EIS. Arrow's consultation has sought to maximise community input through various forums and in many sessions. Consultation has encompassed information sessions, workshops, call-in centres and meetings. Various committees have been formed to address community and agricultural issues and continue to provide forums for identifying and resolving issues. Arrow's commitment to community consultation is outlined in Box 1.

Box 1 Community consultation

Arrow is committed to building mutually beneficial relationships with the community throughout the life of the project, and aspires to understand community concerns, as well as form partnerships to resolve potential issues and explore opportunities for advancement of community interests in the Surat Basin.

1.4.3 EIS Documentation

The EIS documentation comprises this executive summary and seven volumes:

- Volumes 1 and 2 comprise the main report and its attachments, including the environmental management plan and the social impact management plan.
- Volumes 3 to 7 contain the supporting studies that describe the environmental, social, cultural and economic aspects of the project and present the findings of the impact assessments. The findings of the supporting studies are summarised in the main report.

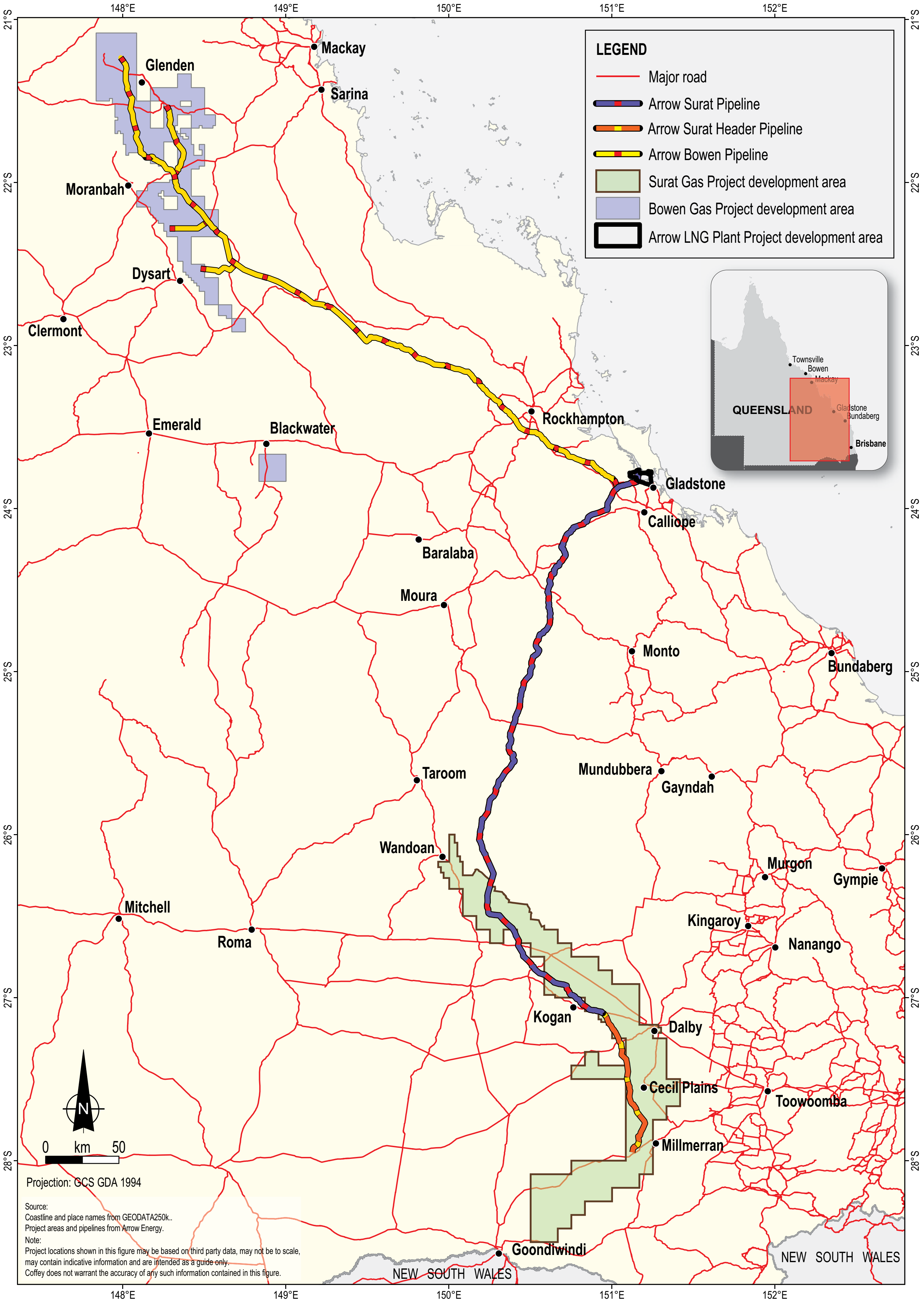


Figure 2 Arrow LNG Project

1.4.4 Viewing and Obtaining the EIS

The EIS may be viewed in the locations shown in Box 2.

Box 2 Viewing locations for the EIS

Department of Environment and Resource Management Customer Service Centre Level 3, 400 George Street Brisbane QLD 4000	Goondiwindi Regional Council Library 4-6 McLean Street Goondiwindi QLD 4390	Department of Environment and Resource Management Customer Service Centre 173 Hume Street Toowoomba QLD 4350
Cecil Plains Library Taylor St Cecil Plains QLD 4407	Toowoomba Regional Council Millmerran Service Centre 2-16 Campbell Street Millmerran QLD 4357	Western Downs Regional Council Customer Service Centre 80-86 Heeny Street Chinchilla QLD 4413
Dogwood Crossing @ Miles Murilla Street Warrego Highway Miles QLD 4415	Western Downs Regional Council 107 Drayton Street Dalby QLD 4405	Wandoan Visitor Information Centre 41 Royds Street Wandoan QLD 4419

Electronic copies of the EIS can be obtained, downloaded and viewed on line at www.arrowenergy.com.au or obtained on compact disc by contacting 1800 038 856 or emailing suratgas@arrowenergy.com.au.

Hard copies can be ordered by phone or email at a small cost (see Arrow's website, www.arrowenergy.com.au for details).

1.4.5 EIS Schedule

EIS milestone dates are provided in Table 1. The environmental approvals process began in early 2010, with a government decision on the project targeted for the third quarter of 2012.

Table 1 EIS milestones

Milestone	Milestone Date
Voluntary EIS application and Initial Advice Statement lodged with the Department of Environment and Resource Management (DERM).	27 January 2010
EPBC Act referral lodged with the Department of Sustainability, Environment, Water, Population and Communities	27 January 2010
DERM acceptance of voluntary EIS application	2 February 2010
EPBC Act referral decision (controlled action)	26 March 2010
Draft Terms of Reference advertised for public comment	29 March 2010 to 13 May 2010
Final Terms of Reference issued	7 September 2010
EIS public notification (public and government agency submissions)	Targeting Q1, 2012
EIS supplementary report	Targeting Q2, 2012
DERM Chief Executive's assessment report	Targeting Q3, 2012
Australian Government EPBC Act assessment report	Targeting Q4, 2012

2 PROJECT NEED

The technology that has facilitated the development of the coal seam gas resource, the demand and market that have developed in recent years, and the Australian and international gas resources that influence demand, as well as the project drivers, are described in this section.

2.1 Context

2.1.1 Technology

Gas supplies some 22% of the world's energy. In the nineteenth and early twentieth centuries, gas was mainly produced from coal, which was processed in municipal gas works, and used for lighting, heating and industrial applications. The subsequent discovery and development of large accumulations of natural gas progressively superseded these gas works.

Natural gas production was initially tied predominantly to markets located in the vicinity of the gas field. However, in the middle of the last century, the development of liquefaction processes overcame these limitations by enabling natural gas to be reduced to 1/600th of its original volume. This allowed LNG product to be transported by ship to distant markets.

More recently, the production of natural gas from coal seams has become technically and economically feasible. The reserves of unconventional gas far exceed the volumes of gas known to be contained in traditional gas reservoirs. This situation adds volume, competition and geopolitical diversity of supply to the global energy market.

2.1.2 Energy Policy

Australian and overseas governments' climate policies favour natural and coal seam gas over black and brown coal as a primary energy source. The greenhouse gas emissions of coal seam gas are about half those of brown coal. The development of coal seam gas will help Australia meet its commitments, made at the United Nations Climate Change Conference in Copenhagen in 2009 (UNFCCC, 2009), to limit greenhouse gas emissions.

2.1.3 LNG Demand and Markets

LNG comprises around 7% of global gas sales. Production is predicted to increase from 2007 levels of 165 million tonnes per annum to between 245 and 340 million tonnes per annum by 2015 (IEA, 2009).

Australian LNG exports are predicted to rise from 19 million tonnes per annum in 2010/11 to around 41 million tonnes per annum by 2015/16 (ABARES, 2011). Australia's main LNG markets currently include Japan, Korea and China. New markets are expected to develop in India, Thailand, Chinese Taipei and Singapore (ABARES, 2010). Australia's proximity to these existing and new markets provides a significant competitive advantage for local LNG producers. By 2015, Australian LNG exports from conventional gas fields in Western Australia will be joined by a substantial contribution from coal seam gas fields in Queensland.

The nature of LNG markets has also evolved to the advantage of both producers and customers. Over recent years, a growing global LNG customer base with newly constructed LNG receival and regasification infrastructure has seen the LNG business mature. Trading arrangements are accordingly becoming more flexible.

2.1.4 Australian Domestic Demand

The Australian Energy Market Operator (AEMO) recognises four groups of Australian gas consumers: the mass market (residential, commercial and small industrial), power generation, large industrial (minerals processing) and export LNG. AEMO forecasts an overall annual domestic demand growth of between 3% and 4.8%, with power generation the key driver of the growth.

2.1.5 Australian Gas Resources

Australia's gas reserves are shown in Figure 3. The contribution of natural gas (including conventional and coal seam gas) in New South Wales and Queensland is evident. Queensland's large and as-yet undeveloped resources of coal seam gas provide the basis for a long-term supply to both domestic and export markets. Geoscience Australia and the Australian Bureau of Agricultural and Resource Economics note that identified conventional and coal seam gas resources in 2008 were in the order of 393,000 petajoules (PJ), which is equivalent to 180 years of gas supply at 2010 production rates. (One petajoule equals one thousand gigajoules.)

Coal seam gas exploration undertaken to date has consistently resulted in the confirmation of existing resources, as well as the discovery of new resources. As exploration continues progressive and substantial increases in reserve estimates may be expected over time.

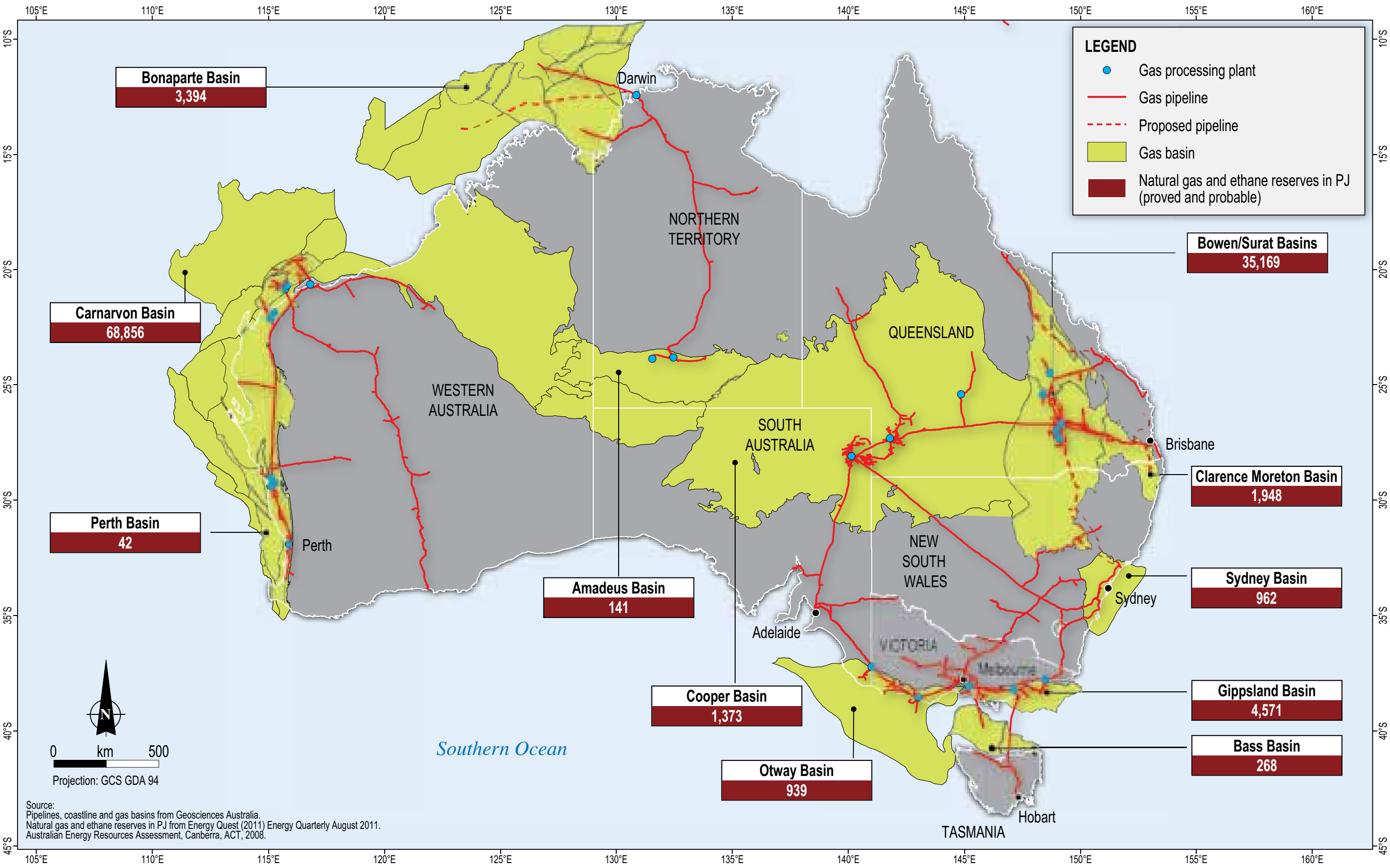


Figure 3 Australian gas resources by basin May 2011

2.1.6 Surat Basin Gas Reserves

The coal seam gas reserves to be developed by the Surat Gas Project are contained in the coal seams of the Walloon Coal Measures of the Surat Basin. The Surat Basin accounts for 61% of Australia's current proven (1P) and proven and probable (2P) coal seam gas reserves.

Arrow's gross proven, probable and possible reserves (1P, 2P and 3P) in the Surat Basin at 31 December 2009 were 472 PJ, 3,789 PJ and 4,587 PJ respectively.

2.1.7 Coal Seam Gas Industry Experience in the Surat Basin

Production of coal seam gas from the Surat Basin began in 1996 and has increased as exploration reveals the extent of the resource. Currently, Arrow operates the Daandine, Kogan North and Tipton gas fields; Origin Energy operates the Talinga and Spring Gully gas fields; Santos operates the Coxon Creek and Fairview gas fields; and the Queensland Gas Company operates the Argyle, Argyle East, Bellevue, Berwyndale, Berwyndale South, Codie/Lauren, Kenya, Kenya East and Woleebee gas fields.

These fields will be expanded and new gas fields will be developed to meet the domestic gas demand and the demand that will be created by LNG projects on Curtis Island. Development of the reserves will make the Surat Basin a major centre of the industry in Australia and provide the foundation for a new, substantial and globally competitive energy industry.

2.2 Project Drivers

Strong demand in international energy markets (especially for LNG) and the existence of a gas resource that will contribute to meeting that demand are the primary drivers for the Surat Gas Project. In addition, demand in domestic markets, new extraction technology, declining reserves in conventional gas fields in eastern Australia, government energy policies at home and abroad, and Australia's advantages over its international competitors in the country's gas resource base, human capital, coal seam gas operating experience and proximity to export LNG markets in East Asia all underpin the viability of the Surat Gas Project.

The project will also maintain momentum in eastern Australia's gas production industry at a time when conventional gas reserves from the Gippsland, Otway, Bass and Cooper basins are declining. The eastern Australian coal seam gas resource over and above what is currently proposed for development is potentially very large. Future exploration may be reasonably expected to confirm that this is indeed the case. The Surat Gas Project and other coal seam gas developments will have established both the production infrastructure and technical expertise by which to develop these resources, and so – irrespective of the vagaries of global energy markets several decades from now – this combination of gas resource and technical expertise will ensure that domestic gas demand can be met at least well into the next century.

3 PROJECT CONCEPTUAL DESIGN

The concept and sequence of development that is the basis for the project conceptual design are described in this section. The conceptual design will be refined over time by the factors discussed in Section 5, Field Development Planning.

3.1 Conceptual Design Basis

The nature of coal seam gas development and the associated land requirements, as well as the implications for environmental, social, cultural and economic aspects, are known from existing operations. Thus, the EIS has assessed a conceptual design that describes:

- The facilities, their function and typical components, land requirements, conceptual location, mode of operation, impacts and technical criteria for detailed planning and design.
- The environmental, social and cultural constraints that will need to be resolved in the detailed design.
- The process by which technical criteria and environmental constraints will be investigated and conflicts between them resolved.

3.2 Conceptual Development Sequence and Infrastructure Location

Development of the project in a manner that is staged and optimises production over time will require detailed investigation and planning. For reasons set out more fully in Section 5.1, Limitations and Opportunities, the precise locations of approximately 7,500 production wells and associated gas and water gathering systems, high pressure pipelines and 18 production facilities will be determined as field development planning processes are progressed. Field development planning will be informed by constraints maps and guidelines on permissible project activities and applicable environmental management controls that form the basis of the environmental framework described in Section 8.2, Environmental Framework. For the purposes of the EIS, a conceptual development sequence and indicative infrastructure locations have been developed, and these are discussed in this section.

3.2.1 Staged Field Development

The field will be developed in stages set out in concept in Table 2.

Approximately 1,655 wells will be required in the first five years of development to achieve the required production rate. As gas production from early wells decreases and the wells are decommissioned, additional wells will be drilled to maintain production.

The production wells and associated gathering systems will be developed in parcels in each development region. The parcels will be developed concurrently with the construction of the production facilities that are required to receive the produced gas and water. Parcels will be developed concurrently in several regions, as shown in Table 2. To minimise land requirements, production wells will, where possible, be located with common access or gathering systems.

Table 2 Conceptual field development sequence

Year	Development Region*				
	Dalby	Wandoan	Chinchilla	Millmerran/Kogan	Goondiwindi
2013					
2014	■	■			
2015	■	■			
2016	■	■			
2017	■	■			
2018	■	■		■	
2019	■			■	
2020			■	■	
2021				■	
2022			■	■	
2023			■		
2024		■	■		
2025				■	
2026				■	
2027				■	
2028				■	
2029		■	■	■	
2030			■	■	
2031					■
2032					■
2033					■
2034					■
2035					■

**Shaded areas denote the regions being developed. Development regions are shown in Figure 1.*

Approximately 18 production facilities will be constructed across the project development area. The numbers of facilities and their types are shown in Table 3 by development region.

Table 3 Summary of facilities expected by development region

Region	Integrated Processing	Central Gas Processing	Field Compression	Total
Dalby	2	1	1	4
Wandoan	1	2	0	3
Chinchilla	1	1	0	2
Millmerran/Kogan	1	1	4	6
Goondiwindi	1	1	1	3
Total	6	6	6	18

To enable an assessment of the potential impacts of the proposed development, particularly impacts that are determined through modelling, conceptual locations for the production facilities were identified. The conceptual locations were represented by 12-km-radius circles (see Figure 1) within which potential facility locations might be found. The actual location of production facilities will depend on the results of exploration, land access, field planning and conceptual design.

3.2.2 Ramp-up Period Conceptual Gas Management

The ramp-up period between first gas and sustained production of 1,050 TJ/d will require the produced gas to be managed. Accordingly, gas produced during the ramp-up period will, in order of preference, be:

- Directed to Arrow's existing gas-fired power stations.
- Sold on the gas spot market.
- Managed to avoid flaring by increasing well spacing and selectively bringing wells on line.
- Flared, as a last resort.

3.2.3 Factors Influencing the Actual Sequence and Rate of Development

Factors influencing the actual sequence and rate of development include:

- The supply requirements of long-term gas agreements.
- Confirmation of production rates through exploration and pilot well programs.
- Land access agreements.
- Execution capacity (drilling and construction resources).
- Capital cost of new infrastructure and access to existing infrastructure.
- Operating costs.
- The resolution of environmental and social issues.
- The development of the more productive parts of the field.
- Planning well depressurisation and developing infrastructure to manage the produced water.
- Completion of the Arrow Surat Pipeline and the Arrow LNG Plant.
- The availability of supporting services (such as accommodation), as these factors can encourage faster development, while others can constrain the speed of development.

3.2.4 Workforce Concept

A significant workforce will be required for the development of the Surat Gas Project, with peaks of approximately 1,000 personnel predicted in years 2021 and 2032. The peaks occur during heights of construction activity in the period when the operations workforce is reaching its peak and has plateaued.

Workforce predictions will be influenced by decisions about the design and operations of the coal seam gas fields, and contracted volumes of gas. Workforce requirements may increase or decrease with the rate of development.

Arrow's preference is to provide employment to people sourced locally (within the Darling Downs regional area); however, due to the high demand by other coal seam gas proponents and low unemployment rates, Arrow recognises that labour will likely need to be sourced from further afield. Arrow's aim, in this regard, is to implement a hierarchy of preferred employment and contractor candidates based on the employee's or contractor's home or source location. The order of preference is as follows:

1. Local (lives within the Darling Downs regional area).
2. Regional (lives within southern and central Queensland).
3. National (lives in Australia).
4. International (lives outside Australia).

A peak construction workforce of 710 personnel is predicted to occur in 2016 when two major production facilities will be constructed concurrently. The construction workforce will reduce to approximately 660 personnel in 2021, after which it will further reduce and fluctuate between 250 and 500 personnel with peaks coinciding with overlapping production facility construction programs. The construction workforce is likely to be predominately fly-in, fly-out due to the specialised nature of the work, and the short term duration of construction related roles.

The forecast operations workforce is expected to peak at about 460 personnel in 2025 and remain relatively constant thereafter. The operations workforce will be based at the central gas and integrated processing facilities, with support staff, depot personnel and administration located in towns. Arrow proposes to establish a local operations workforce by filling approximately 50% of the 300 new positions (in addition to the 100 existing personnel) from towns in or within a reasonable commute distance from the project development area. The remaining 50% of staff are expected to move into the area, where they will rent or purchase homes and become part of the local community. Some staff may elect to base themselves in Toowoomba and drive to places of work daily, particularly if they are engaged in activities in the southern development regions. Arrow does not plan to establish fly-in, fly-out or drive-in, drive-out operations.

Arrow expects most personnel involved in decommissioning to be sourced locally. Decommissioning activities are scheduled many years in the future, allowing time for adequate skills development in the local employment base.

4 PROJECT COMPONENTS

Following exploration and appraisal, which leads to resource definition, the gas production sequence involves the following steps:

- Constructing a series of production wells, each of which will be used to depressurise the confined aquifer and extract coal seam gas from the coal seams. The location of production wells will be informed by environmental constraints mapping and land access negotiations that culminate in landowner agreement on the location of the wells and gas and water gathering systems that transfer those products to production facilities.
- Processing gas and treating water at production facilities, including:
  - Compressing gas at field compression facilities.
  - Dehydrating and compressing gas, transferring coal seam gas water, and generating power at central gas processing facilities.
  - Dehydrating and compressing gas, treating coal seam gas water, and generating power at integrated processing facilities.
- Transporting gas in high-pressure gas pipelines from central gas and integrated processing facilities to domestic customers or for LNG production and export.

The main project components required to accomplish these activities are described in this section. A comprehensive list of the project components, including a description of the infrastructure, is presented in Table 4. Figure 4 presents the information as a simplified gas and water production flow chart. The sections that follow the table provide more detail on the project components.

4.1 Production Wells

A typical production well is shown in Figure 5. Examples of production wells are shown in Plates 1, 2 and 3. Production wells will generally be 300 to 750 m deep and located on an approximately 800-m-grid spacing, resulting in approximately one well per 65 ha, or 160 acres. A well spacing up to 1,500 m or greater is possible, depending on environmental, social and land use constraints; reservoir characteristics; and cost. Surface facilities at each wellhead (called wellhead facilities) will include a water pump, generator (Plate 4), and gas and water separation equipment. Wells will be operated and monitored remotely, with routine visits for weekly inspections, maintenance on an approximately monthly basis and a workover of the well (which involves the entire well site to be cleared and a rig to go to the site to replace the downhole equipment) every two or three years.

Table 4 Surat Gas Project main project components

Component	Description*	
Production wells	• Approximately 7,500 wells. • An average of approximately 400 wells drilled per year. • Well depth of between 150 to 750 m.	• Wells installed on an approximate 800-m-grid spacing, which equates to an indicative density of one well for each 65-ha (160-acre) spacing. Optimisation may increase well spacing to 130 ha (320 acres). • Nominal productive life of each well of 15 to 20 years.
Power generation	• Power for the extraction, transport and processing of gas and water. • Continuous operation.	• Coal-seam-gas-fuelled. • Up to 60 kW at production wells. • 8 to 56 MW at central gas and integrated processing facilities. • Noise barriers and other noise reducing techniques.
Gas and water gathering systems	• Buried low-pressure (100 kPa) and medium-pressure (1,000 kPa) gas pipelines and water pipelines. • Transport of gas from wells to production facilities.	• High-density polyethylene, plastic composite for low pressure pipelines, and glass-reinforced epoxy or steel pipelines for medium pressure pipelines. • 100- to 630-mm diameter (low pressure).
Field compression facilities	• Approximately six facilities planned. • Receipt of gas from production wells. • No water storage or treatment. Coal seam gas water bypasses field compression facilities to larger facilities for treatment.	• Compression of 30 to 60 TJ/d of gas to medium pressure (1,000 kPa) for transport to central gas or integrated processing facilities.
Central gas processing facilities	• Approximately six facilities planned. • Receipt of gas from field compression facilities and production wells. • Dehydration of gas.	• Water storage (temporary) and transfer facility. • Compression of 30 to 150 TJ/d of gas to sales gas pipeline pressure (10,200 kPa).
Integrated processing facilities	• Approximately six facilities expected. • Receipt of gas from field compression facilities and production wells. • Dehydration of gas.	• Water storage and treatment facility (see water treatment and storage below) and brine storage. • Compression of 30 to 150 TJ/d of gas to sales gas pipeline pressure (10,200 kPa).
Water treatment and storage	• Located at integrated processing facilities. • Coal seam gas water production: average 22 GL/a; peak 43 GL/a.	• Feedwater dams, treated water dams, filtration and reverse osmosis treatment plant, brine dams, distribution facilities for transfer of water to end users.
High-pressure gas pipelines	• Buried steel pipelines. • Operating pressure of 10,200 kPa.	• Transport gas from production facilities to sales gas pipelines.
Other	• Camps, depots and utilities. • Roads.	• Electricity substations and transmission facilities where power is drawn from the grid, an alternative power supply option.

* Quantities are nominal and to be confirmed by optimisation studies prior to final design.

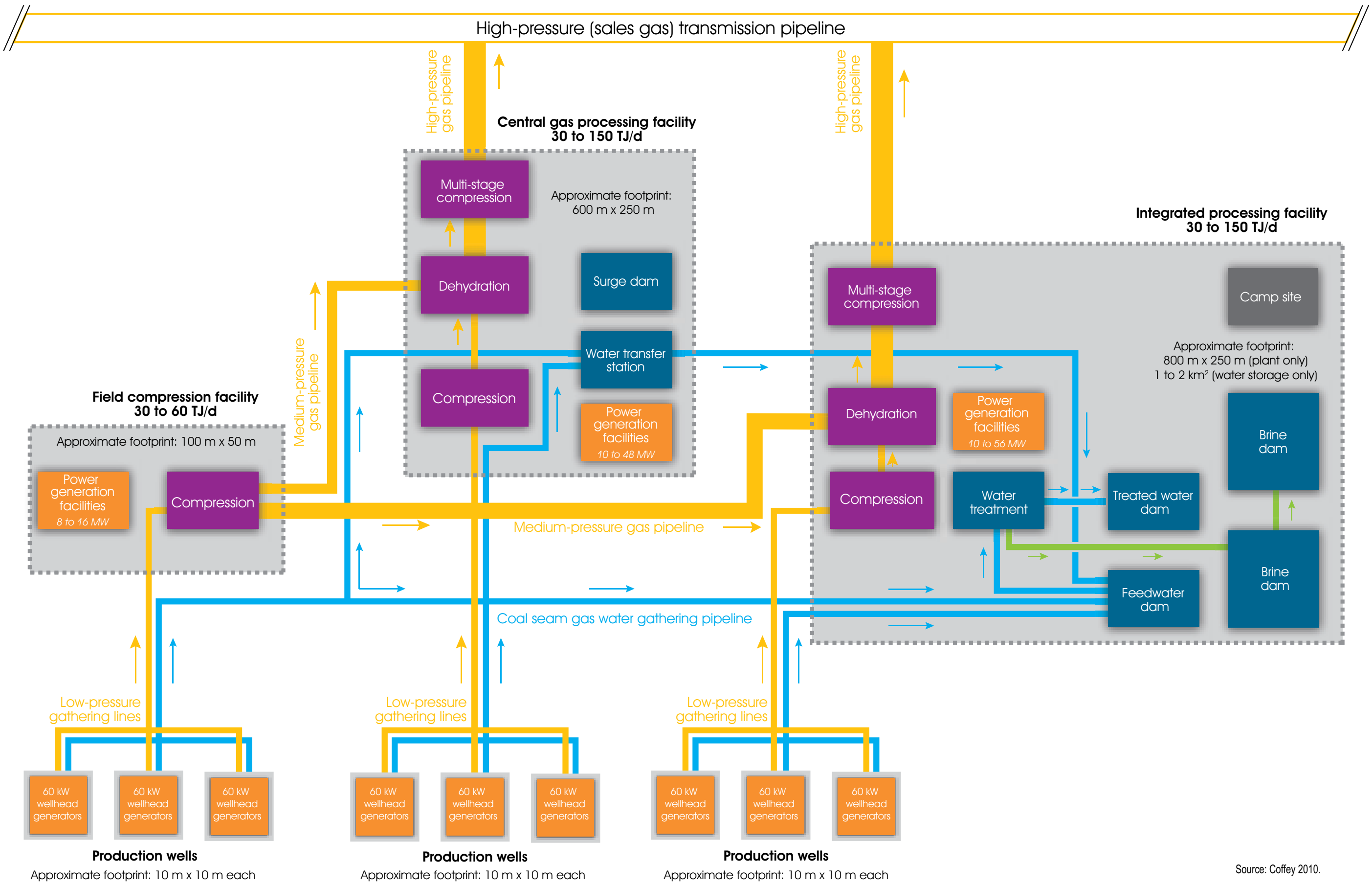


Figure 4 Gas and water production and treatment

4.2 Gas and Water Gathering System

Gas and water is separated down-hole, however some further separation of the gas and water streams may occur at the surface to remove residual gas from the water stream or vice versa. The gas and water leave the well through separate ports, are metered and controlled and then carried away in separate pipelines. The pipelines will be buried in a single trench. The pipelines will run from wellheads to a production facility. The water pipelines will run to either a central gas processing facility or an integrated processing facility. The field pipelines also include valve stations, vacuum break facilities and drains, which will require weekly inspections and annual routine maintenance.

4.3 Production Facilities

The three types of production facility are described in this section.

4.3.1 Field Compression Facilities

Field compression facilities will provide between 30 and 60 TJ/day of gas compression for production wells that are located at a distance from larger production facilities (i.e., where the wellhead pressure is not sufficient to efficiently transport the gas to a larger production facility). Field compression facilities provide intermediate compression generally of the order of 1,000 kPa, but may be higher where it is safe and efficient to do so. No water treatment or gas dehydration is carried out at field compression facilities. Coal seam gas water bypasses field compression facilities and is directed to either a central gas processing facility or an

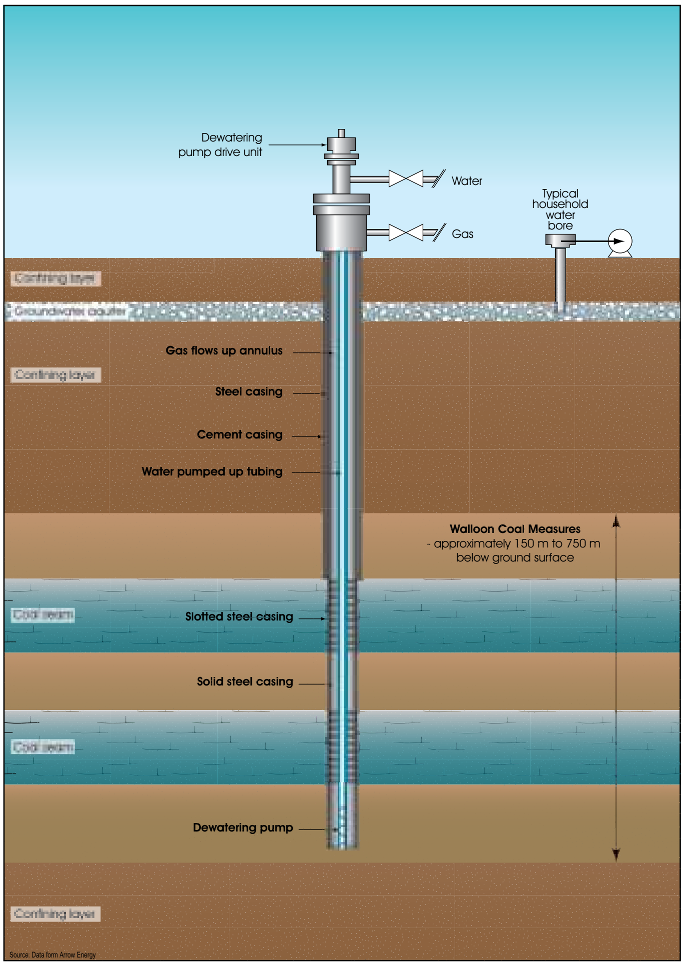


Figure 5 Typical production well

1 Production well surface facilities
2 Production well in cultivated land
3 Production well in grazing land
4 Well site generating set

integrated processing facility. Gas from field compression facilities is transported in medium-pressure pipelines to a central gas or integrated processing facility for dehydration and compression to transmission pipeline pressures. The conceptual design assumes coal seam gas will be used as a fuel to generate power on site to drive the compressors.

4.3.2 Central Gas and Integrated Processing Facilities

Central gas processing facilities will receive, dehydrate and compress between 30 and 150 TJ/d of gas to 10,200 kPa for transport to the sales gas pipeline. A water transfer station at each central gas processing facility will receive, temporarily store, and pump coal seam gas water to a treatment and storage facility at the nearest integrated processing facility. Each facility will have power generation capacity and may serve as a field base for operations personnel with offices, maintenance workshops and storage.

Integrated processing facilities perform the same function as central gas processing facilities with the exception that they will receive and treat coal seam gas water and store brine generated through the treatment process. Figure 6 shows a conceptual layout of an integrated processing facility. A typical gas compression facility is shown in Plate 5.

4.4 Water Treatment, Storage and Disposal Facilities

This section describes the infrastructure associated with coal seam gas water treatment, storage and transfer and with brine storage and disposal.

4.4.1 Water Treatment, Storage and Transfer

Coal seam gas water quality in the Walloon Coal Measures varies from fresh to saline or highly turbid. The water typically has the following characteristics:

- pH of approximately 7 to 11.
- Salinity in the range of 3,000 to 8,000 mg/L (i.e., brackish).
- Suspended solids that will usually settle out over time.
- Ions, including calcium, magnesium, potassium, fluoride, bromine, silicon and sulfate.
- Trace metals and low levels of nutrients.

Water treatment and storage facilities will be designed in accordance with Queensland's coal seam gas water management policy and the draft DERM guidelines on dams.

Water storage and transfer infrastructure at each central gas processing facility are expected to include a nominal 600-ML storage dam and a transfer pump.

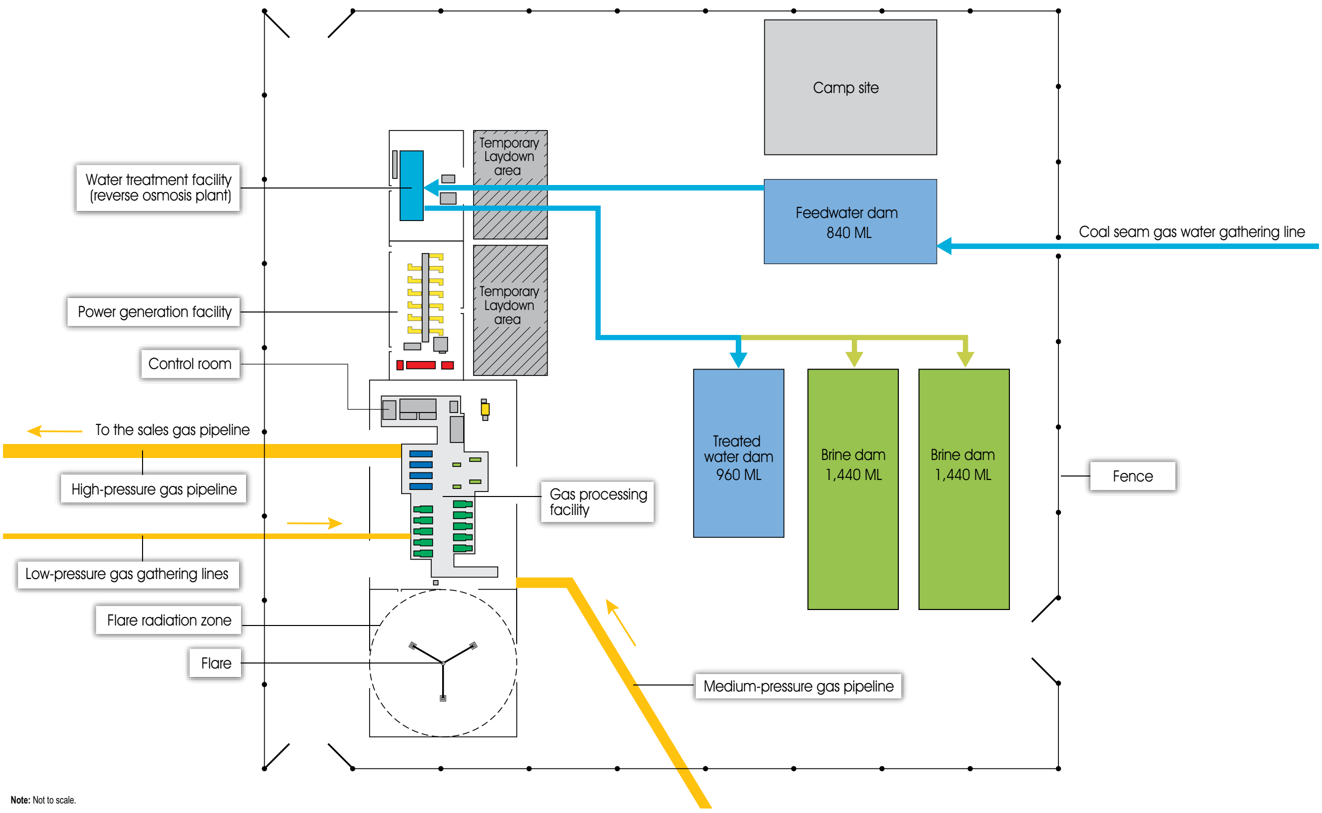


Figure 6 Typical integrated processing facility arrangement

Water treatment and storage infrastructure at integrated processing facilities are expected to include:

- 840-ML feedwater dam(s).
- 960-ML treated water dam(s).
- Reverse osmosis plant with 30 to 60 ML/d capacity (Plate 6).
- Two 1,440-ML brine storage dams.

Reverse osmosis is a desalination technology that is commonly used for water treatment around the world. Water passes under pressure through a selective membrane. Dissolved salts are retained as concentrated brine. Treated water may also be amended through the addition of trace elements so that it is suitable for a variety of beneficial end uses.

4.4.2 Management of Coal Seam Gas Water

Arrow has developed a strategy for the management of coal seam gas water (Attachment 9, Coal Seam Gas Water Management Strategy), elements of which will be reflected in its complementary groundwater management strategy. Figure 7 shows the project water management concept and a range of end uses for coal seam gas water.

The preferred management measure is substitution of existing groundwater and surface water allocations which involves licence holders accepting treated or untreated coal seam gas water that satisfies their end use in lieu of taking water under their current licences. Arrow has entered into discussions with the Queensland Government to facilitate the legislative changes required to enable substitution of allocations.

Arrow expects to identify and evaluate further uses of treated and untreated coal seam gas water, along with the agricultural (irrigation), industrial and urban uses already employed by Arrow. A high priority has been placed on the beneficial use of coal seam gas water through substitution of allocations and new uses where appropriate.

Injection of coal seam gas water into suitable aquifers (principally shallow and deep groundwater systems) is another preferred management measure and has the added benefit of mitigating the effects of groundwater depressurisation. Arrow has instigated injection trials that are investigating the geochemistry and storage potential of target groundwater systems.

Less preferred options are disposal to watercourses and to the sea via an ocean outfall. These options address the situation where there are no or insufficient beneficial uses or where aquifers targeted for injection do not have the capacity to accept the produced volumes of water. These options are still being evaluated with investigations aimed at defining appropriate monitoring of discharges.

The coal seam gas water management strategy includes options for the treatment and disposal of brine, a byproduct of water treatment using reverse osmosis.

The preferred management option for brine is selective salt precipitation. This option allows the beneficial use of the brine in the form of salt products, which can be used in a variety of industrial processes. The main products are salt (NaCl) and soda ash ($NaCO_3$). Arrow will commission studies to understand the chemical composition of the brine, methods for enhancing precipitation of the brine and the chemical processes required to transform the brine into commercial products.

If the injection investigations discussed above identify a suitable aquifer, Arrow will consider disposal of brine by injection. The target aquifer would have to be of poorer water quality for this option to be considered feasible. To date no such aquifers or formations have been identified.

Disposal of brine via an ocean outfall is a potential option for some of Arrow's areas of operation. The feasibility of an ocean outfall will be investigated in detailed design.

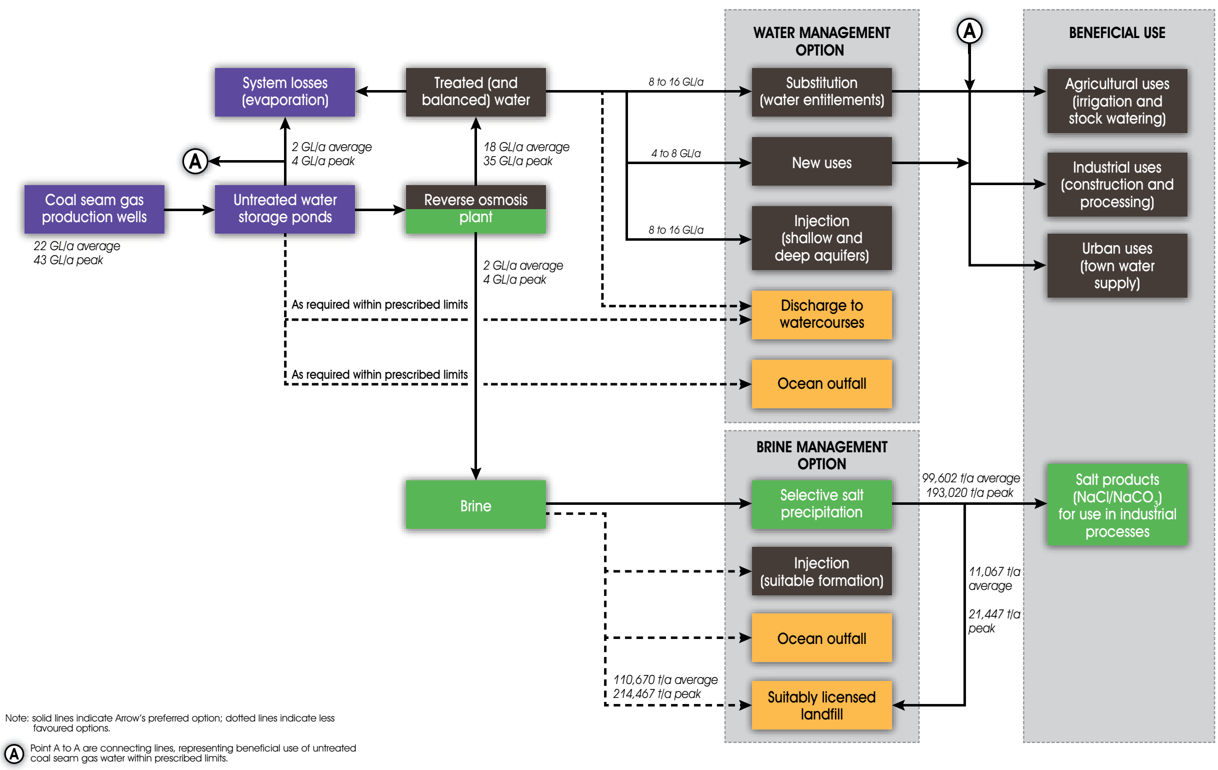


Figure 7 Conceptual coal seam gas water management overview

The least preferred option is disposal to a suitably licensed landfill. Investigations have confirmed that such facilities exist and it is Arrow's expectation that if commercial volumes of brine exist, including as a consequence of other developments, then new facilities might be developed to respond to demand.

Implementation of the above management options will, depending on the options selected, require the development of infrastructure including pipelines, water and/or brine pumping stations, injection facilities and selective salt precipitation plants. Selective salt precipitation infrastructure typically required to convert brine to a saleable product would include a facility comprising a concrete apron, process building, bunding and a roofed storage area. Each facility would be nominally 150 m by 150 m and require heavy articulated vehicle access and loading facilities.

4.5 High-pressure Gas Pipelines

Buried high-pressure steel gas pipelines will transport the gas at 10,200 kPa from the outlet of the central gas processing facilities and integrated processing facilities to the sales gas pipeline.

4.6 Power Supply

Power is required at the production wells and production facilities (see Figure 4). The facilities will consume electricity continuously 24 hours a day, 365 days a year, except for scheduled and unscheduled maintenance shutdowns.

Approximately 60 kW of peak power will be generated at each production well, using a coal seam gas–fired generator, to operate the water pumps and other electrical equipment. These generators will be located at or near the wells within the 10-m by 10-m footprint required for each production well.

Between 8 and 56 MW of power will be generated at each production facility, depending on type and anticipated production. Power generation at the production facilities will likely comprise a series of coal seam gas–fired engines that will use lean-burn technology to achieve high-efficiency generation with reduced emissions. These power generation facilities will be located within or in close proximity to the production facility. An estimated 80-m by 150-m footprint will be required to accommodate a power generation facility.

Generators will have acoustic treatments at the source to ensure noise emissions achieve the applicable criteria at the nearest sensitive receptor.

Arrow is also carrying out studies to assess the viability of an alternative power supply option that would draw power from the Queensland electricity grid where existing or proposed power transmission infrastructure can be easily accessed.

5 Gas compression facility

6 Water treatment facility (reverse osmosis plant)

5

6

5 FIELD DEVELOPMENT PLANNING

The limitations and opportunities for field development along with the planning process are described in this section, which also includes the environmental and social constraints considered in design.

5.1 Limitations and Opportunities

Coal seam gas field development typically proceeds on an incremental basis, with exploration and reservoir engineering respectively confirming the most productive areas and well density required to maximise recovery of gas. The actual locations of wells and production facilities are consequently, progressively identified and refined over the life of the project.

The location of wells and gathering systems will be driven by the best compromise of environmental, social, technical and economic outcomes, and will be set out in land access agreements negotiated with landowners. The time required to recover economic volumes of gas is influenced by the density of wells. Denser patterns can enhance recovery. Less dense patterns may require longer to achieve the same recovery. Progressive planning will benefit from experience gained throughout the life of the project including enhanced or new recovery techniques such as drilling multiple wells from a single pad.

Production facility locations and high pressure gas pipeline routes are less flexible due to their scale and nature. They will be chosen to reduce overall environmental and social impacts. Sympathetic siting will be used, where practicable, to reduce land use conflicts and amenity issues.

5.2 Development Planning

Detailed development planning over the life of the project will broadly address the following:

- The results of exploration and test drilling on which the detailed engineering design criteria for gas fields, production facilities, pipelines and ancillary facilities can be based.
- The economic and commercial risks that influence the extent and rate of field development (for example, proximity of new resources to existing infrastructure, market constraints and competition, land access and long-term gas supply contracts).
- The extended timeframe of field development, including ongoing refinement of the field development plan in response to new reservoir data from operating regions.
- New techniques, standards and practices.
- Social and environmental constraints on which the detailed, area-specific planning criteria for field facilities will be based.
- The results of operational and impact monitoring and consultation with landowners.

5.2.1 Exploration and Test Drilling

Arrow's exploration work has defined 2P and 3P reserves over much of the project development area. Ongoing exploration will focus on upgrading 3P reserves to 2P in the less appraised areas in the northwest and south. Exploration typically involves three phases of drilling:

- **Phase 1: stratigraphic holes** determine the presence, depth and lateral extent of the target coal seams.
- **Phase 2: core holes** retrieve intact samples of coal from which the permeability and gas composition of coal seams can be established.
- **Phase 3: pilot wells** (nominally 5 to 6 in number, 200 m apart and at approximately 10- to 20-km intervals) test water depressurisation and gas production rates over periods of 6 to 24 months. Test results also improve reserve calculations and are integral to field development planning.

5.2.2 Environmental and Social Constraints

Development planning within the project development area is also guided by environmental and social constraints, including landowner preferences. The conceptual design, including the design specifications (Table 5) of Arrow's health, safety and environmental management system (HSEMS), has taken account of these constraints as Arrow currently understands them.

5.2.3 Development Plans

Arrow will produce detailed development plans for each development region. Each plan will reconcile the design criteria for well fields, production facilities, pipelines and ancillary facilities with the planning criteria by which social and environmental constraints can be addressed.

The scope of each development plan will include:

- The exploration and appraisal history and status of the development region.
- Geological and reservoir modelling and subsurface development.
- Planning constraints and opportunities.
- The number, location, sequencing and spacing of wells.
- The location, quantity and size of production facilities.
- The quantity of coal seam gas water produced and subsequent treatment and storage requirements.
- The quantity and length of pipelines to transport gas and water.
- The high-level operations philosophy for the field layout.
- Capital and operating expenditures and schedules.
- Risk and opportunity register.
- Performance and compliance monitoring and reporting.

Table 5 Environmental and social design specifications of Arrow's HSEMS

Aspect	Design Specification
Air quality	• Reduce nitrogen dioxide emissions through selection of low NOx gas engines for power generation. • Minimise flaring by selling ramp-up gas to domestic markets.
Greenhouse gas	• Reduce greenhouse gas emissions through selection of high-efficiency drivers for compressors. • Minimise greenhouse gas emissions through the use of flares rather than venting.
Geology, landform and soils	• Avoid unstable slopes where possible, or design to address slope and soil stability issues.
Groundwater	• Avoid natural springs. • Construct dams using material capable of containing the water and brine and any contaminants.
Surface water	• Do not discharge coal seam gas water during normal operations. • Avoid wetlands.
Aquatic ecology	• Do not discharge coal seam gas water during normal operations.
Terrestrial ecology	• Avoid Category A* environmentally sensitive areas. • Avoid national parks. • Avoid wetlands (e.g., Lake Broadwater). • Minimise construction footprint through centralisation of water treatment facilities. • Minimise construction footprint through placement of gas and water gathering lines within the same trench.
Social	• Manage impacts on local communities through the construction phase by using fly-in, fly-out workforces and accommodating them in camps. Maximise employment of local people and minimise fly-in, fly-out arrangements for operations. • Avoid locating wells and infrastructure within 200 m of residences.
Cultural heritage	• Avoid significant heritage sites.
Hazard and risk	• Install and maintain fire and gas detection systems. • Install and maintain emergency shutdown systems. • Install and maintain emergency pressure release systems. • Install and maintain fire suppression systems in high-risk locations.

* *Category A environmentally sensitive areas are all areas designated as national park under the Nature Conservation Act 1992, as well as conservation parks, forest reserves, and the Wet Tropics World Heritage area.*

6 IMPACT ASSESSMENT

This section summarises the potential environmental impacts of the proposed construction, operation and maintenance, and decommissioning activities of the Surat Gas Project assessed in the EIS.

6.1 Air Quality

Emissions from infrastructure comprising the conceptual design were assessed to determine impacts on air quality. The assessment considered local impacts (within the vicinity of a facility) and regional impacts (across the study area).

Nitrogen dioxide (NO_2) and ozone (O_3), the two key indicators of photochemical smog, were the indicators used to determine regional impacts, and they were modelled under two scenarios:

- **Scenario 1:** emissions from all 18 production facilities operating at full capacity at once across the entire project development area, the theoretically possible worst case.
- **Scenario 2:** emissions in the year of maximum expected operations (2020), which would involve nine production facilities operating at full capacity all at once, the actual design worst case.

These scenarios included emissions from the 2,307 wellhead generators that are expected to be operating in 2020.

Maximum predicted concentrations of NO_2 and O_3 for each emission scenario are presented in Table 6 and show that emissions will not cause an exceedence of air quality objectives as set out in the Environmental Protection Policy (Air) (EPP (Air)).

The similar results for the two scenarios, as shown in the last two columns of Table 6, indicate that the facilities are sufficiently separated that their respective plumes do not combine to create a cumulative impact.

Coal seam gas contains only trace quantities of sulfur and carbon monoxide (CO) and are not expected to be generated at concentrations that may be harmful to human health, therefore emissions of sulfur dioxide (SO_2) and CO were excluded from modelling.

NO_2, volatile organic compounds (VOCs) and particulate matter are the key indicators of localised air quality impacts. These compounds were modelled assuming typical maximum emission rates and continuous power generation or flaring as a worst-case scenario. There were no significant impacts from VOCs or particulate matter, and the maximum predicted one-hour concentrations of NO_2 (inclusive of background concentrations) met the EPP (Air) objectives within close proximity of wellhead generators and production facilities. The EPP (Air) objectives were met between 175 m and 225 m of production facility emission sources, e.g., the exhaust stacks. Box 3 lists the key mitigation measures for protecting air quality.

Table 6 NO_2 and O_3 maximum concentrations and health-based objectives

	EPP (Air) Objective (µg/m³)	Averaging Time	Existing Value (µg/m³)	Scenario 1 – All Facilities (µg/m³)	Scenario 2 – Year 2020 (µg/m³)
NO_2	250[a]	1 hr	22[b]	85[b]	86[b]
	62	Annual	2.2	9	9
O_3	210[a]	1 hr	136[b]	160[b]	160[b]
	160[a]	4 hr	123[b]	154[b]	154[b]

a. *Value considers one-day exceedence allowable per annum as per EPP (Air).*
b. *Second highest day modelled value.*

Box 3 Protecting air quality

Arrow is committed to protecting the qualities of the air environment conducive to protecting the health and biodiversity of ecosystems; human health and wellbeing; and the aesthetics of the environment.

The following key mitigation measures ensure that the qualities of the air environment are maintained and relevant regulatory objectives are met:

- Design facilities to meet relevant EPP (Air) objectives at sensitive receptors and conduct site-specific air quality modelling once site locations are known to ensure objectives are met.
- Prevent venting and flaring of gas as far as practicable.
- Select equipment with consideration for low emissions to air, high energy efficiency and fuel efficiency and maintain equipment in accordance with manufacturer's recommendations.
- Implement dust suppression measures and manage odours so that they do not cause a nuisance or harm to sensitive receptors.

6.2 Greenhouse Gas

The project develops fossil fuel reserves (principally methane) for combustion, which in turn will emit the greenhouse gas carbon dioxide to the atmosphere. This section details the estimated emissions and Arrow's proposed abatement measures.

For greenhouse gas accounting purposes, 'project emissions' are those associated with the production of gas to the point where it enters the sales gas pipeline ('Scope 1' and 'Scope 2' emissions) but not emissions arising from its subsequent processing or use. Scope 3 emissions associated with shipping LNG product, managing waste products, and the embedded energy in construction materials were not considered in the EIS because those emissions occur as a consequence of the activities of an entity, but which arise from sources not owned or controlled by that entity.

Project emissions as a percentage of global, Australian and Queensland totals are shown in Table 7. The project's predicted carbon dioxide equivalent (CO_2-e) emissions are 0.012% of global emissions (based on a 2007 baseline) for the worst-case operational year (2030).

A greenhouse gas management plan will be prepared and will detail Arrow's commitment to reducing greenhouse gas emissions, as described in Box 4, through practical measures, energy efficiency programs, and research and development into new and emerging technologies. Practical measures include minimising vegetation clearing, fuel use, and flaring and optimising wellhead gas engine operation to reduce periods at low-efficiency levels.

Table 7 Project Contribution Estimates of greenhouse gas emissions

Source	Emissions per annum (Mt CO_2-e)	Surat Gas Project Contribution		
		Scope 1 (%)	Scope 2 (%)	Scope 1 and 2(%)
Global[a]	29,335.0	0.010	0.002	0.012
Australia (energy sector)[b]	408.2	0.688	0.166	0.854
Queensland[c]	181.6	1.546	0.373	1.92

a. *UNSD (2011), Millennium Development Goals indicators: Carbon dioxide emissions (CO_2), thousand metric tonnes of CO_2 (collected by Carbon Dioxide Information Analysis Centre).*
b. *Section 2, DCCEE (2009), Energy sector includes stationary energy, transport and fugitive emissions.*
c. *DCCEE (2009), Emissions including land use change.*

Box 4 Reducing greenhouse gas emissions

Arrow recognises the need to reduce greenhouse gas emissions. As such Arrow will:

- Select equipment that maximises energy efficiency and ensure that all equipment is operated and maintained to the highest standards.
- Minimise the project footprint and vegetation clearing.
- Support energy efficiency programs and actively participate in any government-approved emissions trading scheme.

6.3 Climatic Adaptation

Climatic variations are driven by seasonal, long term and, as yet not fully understood, processes acting on the earth. The frequency, duration and severity of natural events – droughts, floods, cyclones and bushfires – often vary from historic trends which are based on a relatively short period of records.

In response, government agencies periodically review the guidelines that propose appropriate design standards that account for climatic variation. The criteria are typically conservative to recognise the inherent uncertainty in predicting future events. The standards inform engineering design, contingency planning and development preparedness for emergencies.

Coal seam gas infrastructure, particularly production facilities, will need to be designed to account for the reasonably foreseeable extremes of heat, flood, drought and bushfire, as reflected in applicable guidelines and standards. As such, design of project facilities will take account of historic events, such as the flooding regime in recent years (Plate 7). Box 5 describes how Arrow will manage the impact of climatic variations on its operations.

Box 5 Climatic adaptation

Arrow will minimise the project's vulnerability to climate change by designing infrastructure to withstand forecast climatic variations, as reflected in relevant design guidelines and standards.

Arrow will also participate in government climate change programs and monitor emerging opportunities to manage potential impacts from climate change.

6.4 Land and Water

This section summarises the potential environmental impacts on land and water that were assessed as part of the EIS.

6.4.1 Geology, Landform and Soils

The geology of the project development area comprises basement rocks overlain by sediments with volcanic intrusions. A subdued topography of plains and uplands of low elevation and relief support a range of slopes and soils. These materials and locations have variable properties for which management requirements are broadly known. Understanding of the specific geology and soils at each specific facility location will be integral to project design, project management and the rehabilitation of completed works areas; and the residual impacts are expected to be low and localised. Key features of the project development area include extensive areas that, predominantly due to soil properties, are declared as good-quality agricultural land or are known to be areas of black soils that are sensitive to disturbance. The Chinchilla Sands Local Fossil Fauna Site is a sensitive land feature within the project development area and will be avoided altogether. Box 6 presents key geology, landform and soils mitigation measures.

Box 6 Geology, landform and soils management

Environmental protection objectives for geology, landform and soils are to maintain or restore soils; stabilise landforms; minimise alteration of drainage systems; and protect sensitive areas. Key mitigations to achieve these objectives include but are not limited to:

- Minimising the project footprint and vegetation clearing.
- Clearing areas progressively and implementing rehabilitation as soon as practicable.
- Designing and planning project activities to avoid steep slopes dissected by gully networks.
- Confining project traffic to designated roads and access tracks.
- Installing and maintaining sediment and erosion-control structures.

6.4.2 Land Contamination

Because the project development area comprises predominantly developed agricultural land and many notifiable activities (fuel storage, chemical storage) can be associated with agricultural activities, the EIS conservatively assumes that all land on which such activities may be conducted could have been contaminated by historical activities.

Disturbance of areas of contaminated land is likely to have impacts on the surrounding environment, as well as on the health and safety of workers and members of the public. Wherever practicable, Arrow will avoid development on contaminated land. To achieve that objective, Arrow will implement a process of checking government registers and conducting site inspections before commencing intrusive works.

Wherever Arrow cannot avoid development on contaminated land, procedures will be implemented to manage any contaminated soil or groundwater that is exposed in accordance with Queensland Government requirements.

Arrow will build facilities and operate coal seam gas infrastructure to minimise the possibility of contaminating land, as described in Box 7, and will appropriately assess and remediate any land that becomes contaminated during the course of its operations.

Box 7 Avoidance of contaminated land

Arrow's priority is to avoid the disturbance of contaminated soils and to minimise the potential for contamination of soil and groundwater as a result of project activities. Avoidance requires:

- The review of government registers and site inspections for evidence of existing contamination.
- Design, construction and operation of project infrastructure in accordance with industry standards.

Contaminated soil or groundwater that cannot be avoided will be managed by investigating the type, severity and extent of contamination and remediation as per the Queensland Government's Guidelines for the Assessment and Management of Contaminated Land 1998 (DE, 1998).

7 Overland flow
January 2011 flood event

6.4.3 Groundwater

The project will extract coal seam gas and water from the Walloon Coal Measures. There are numerous groundwater-bearing formations (aquifers) underlying the region, and these are interbedded with low-permeability, generally fine-grained formations (aquitards). Major aquifer formations present in the project development area can be grouped into groundwater systems with similar characteristics, as presented in Figure 8. The characteristics of the four principal groundwater systems are summarised in Table 8.

Table 8 Project development area groundwater systems and their characteristics

Shallow Groundwater System (Condamine Alluvium)		
• Unconfined aquifer. • Overlies the Walloon Coal Measures in places. • Several recharge mechanisms, including Condamine River. • Base flow to Condamine River in some reaches.	• Possible flow between the Condamine Alluvium and the Walloon Coal Measures. • Locally unique aquifer. • Dynamic and resilient. • Regular and rapid groundwater level recovery. • Fast recovery following extraction compared to recovery in confined aquifers.	• Water quality variable; fresh to very saline. • Generally suitable for agricultural uses. • Declining water levels from historical extraction.
Intermediate Groundwater System (Kumbarilla Beds)		
• Predominantly a confined aquifer system. • Part of a regional aquifer system common across the Great Artesian Basin. • No known physical connection with surface features in the project development area.	• Possible groundwater flows to and from other systems. • Resilient, with several recharge mechanisms. • Moderate recovery rates following extraction.	• Water quality ranges from fresh to moderately saline with slight alkalinity. • Generally suitable for agricultural uses.
Coal Seam Gas Groundwater System (Walloon Coal Measures)		
• A confined aquifer system. • Part of a regional aquifer system common across the Great Artesian Basin. • No known physical connection with surface features in the project development area.	• Possible groundwater flows to and from other systems. • Low resilience: recharge by rainfall on outcrops and inter-aquifer leakage. • Moderate recovery rates following extraction.	• Poorer water quality than other aquifers. • Brackish to saline supply generally suitable for industrial uses or stock watering.
Deep Groundwater System (Hutton Sandstone/Marburg Subgroup and Precipice Sandstone)		
• A confined aquifer system • Equivalent systems common across the Great Artesian Basin. • Connection between system and springs in regional Great Artesian Basin discharge areas (outside the project development area). • No known physical connection with surface features in the project development area.	• Possible groundwater flows to and from other systems. • Less dynamic and resilient than other, shallower systems. • Limited recharge by rainfall in distant outcrop zones and inter-aquifer leakage. • Slow recovery rates following extraction.	• Better water quality than other aquifers. • Generally suitable for agricultural uses. • Historic artesian flow and cultural significance as an artesian groundwater resource.

Irrigation is currently the principal use of groundwater, and the Condamine Alluvium aquifer is the most widely accessed groundwater resource in the project development area (see Figure 9) (DERM, 2009; DERM, 2010). The main beneficial environmental functions of groundwater systems in the project development area are base flows to the Condamine River from the unconfined Condamine Alluvium aquifer and the potential to support groundwater discharge springs and features of spiritual and cultural significance, including the springs and historic wells (Fensham et al., 2005; Hillier, 2010).

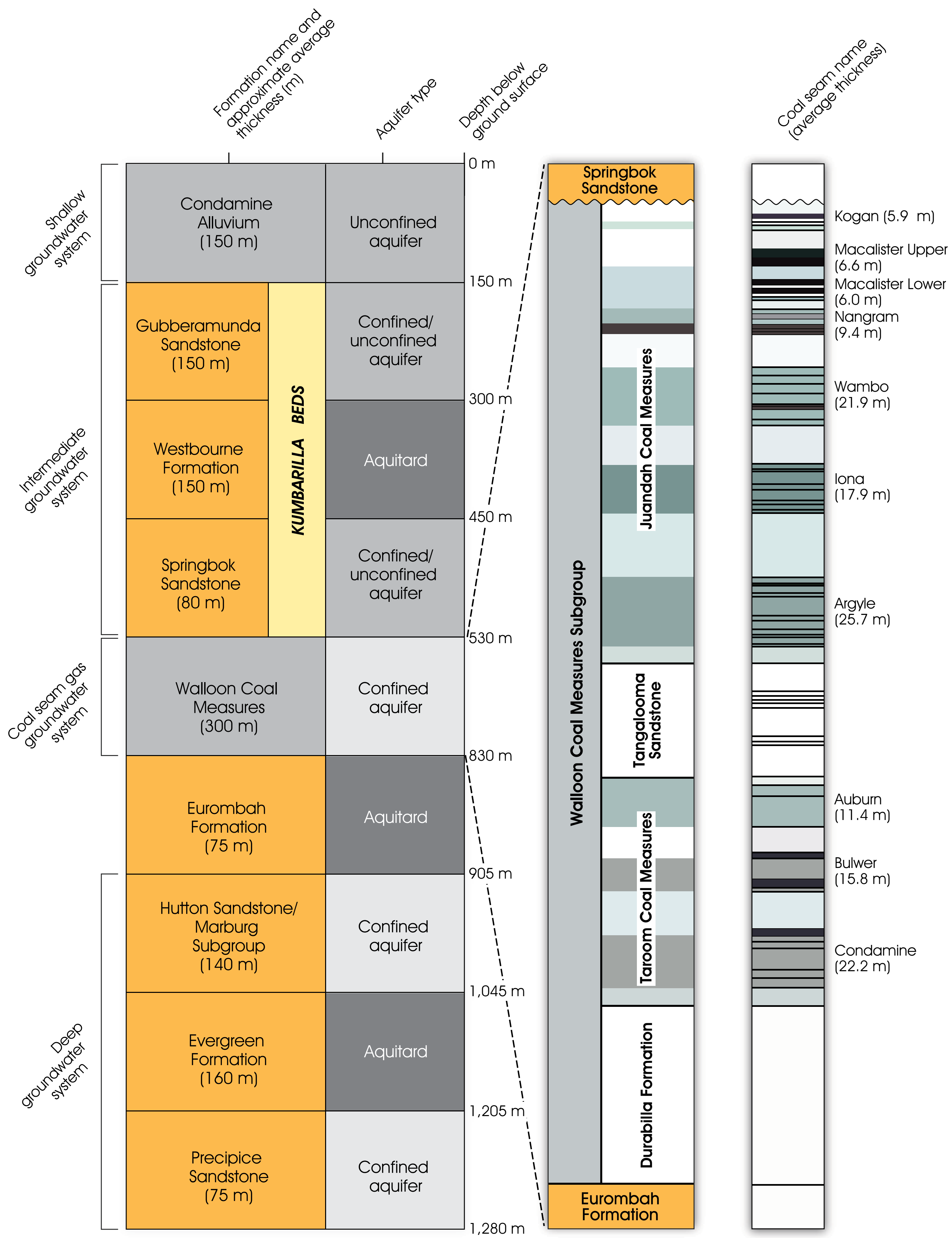
The main concern with depressurisation of the groundwater system associated with the Walloon Coal Measures is the direct impact on water resources within the coal measures and consequential indirect impacts on other water resources due to potential interconnectivity between the coal measures and the overlying and underlying aquifers. Predictive modelling was conducted to allow assessment of these potential impacts.

The unmitigated extraction of coal seam gas water from the Walloon Coal Measures was modelled for three different extraction scenarios, as listed below:

- **Scenario 1.** Simulates the potential unmitigated impacts on the groundwater system resulting from Arrow operations alone.
- **Scenario 2.** Simulates the potential unmitigated impacts on the groundwater system resulting from a combination of Arrow operations and other coal seam gas proponents that had made a final investment decision prior to 31 January 2011.
- **Scenario 3.** Simulates the potential unmitigated impacts on the groundwater system resulting from all coal seam gas operations in the Surat Basin, regardless of their final investment decision status.

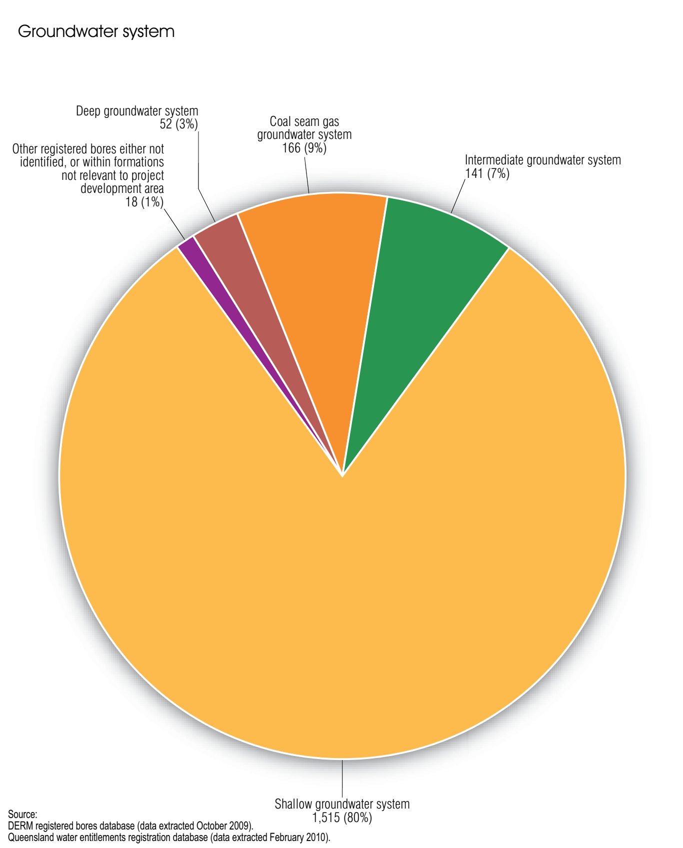
Modelling of the Arrow-only scenario (i.e., excluding other coal seam gas developments) resulted in prediction of the following unmitigated direct impacts on formations in the Walloon Coal Measures, which comprise the Juandah Coal Measures, Tangalooma Sandstone, Taroom Coal Measures and Durabilla Formation:

- Peak unmitigated drawdown in the Juandah Coal Measures is predicted to exceed 75 m in 2024 (see Figure 10).
- Most unmitigated drawdown in 2024 is within the project development area and is generally less than 5 m within 10 km.
- Peak unmitigated drawdown in the Taroom Coal Measures and the Tangalooma Sandstone is predicted to range from 50 to 75 m in 2024.
- Without any mitigation measures in place, significant groundwater recharge and level recovery is predicted by 2061 (20 years after coal seam gas production stops), with residual drawdown of less than 10 m across the Juandah Coal Measures, Taroom Coal Measures and Tangalooma Sandstone formations.
- Without any mitigation measures in place, variable drawdowns are predicted across the five development regions according to the thickness of the modelled geological units and predicted coal seam gas extraction rates in each region.



Source: Data form Arrow Energy
Scott et al (2004)

Figure 8 Stratigraphy and groundwater systems present within the project development area



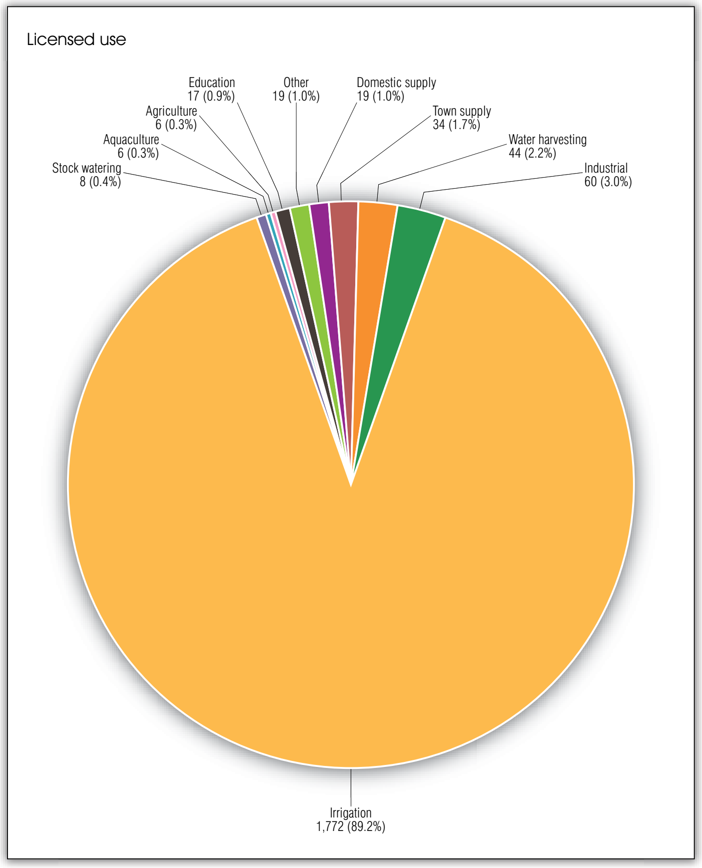


Figure 9 Distribution of licensed groundwater bores (left) and uses (right) within the project development area

Modelling of the Arrow-only scenario also resulted in prediction of indirect impacts on aquifers above and below the Walloon Coal Measures. These are summarised in Table 9.

Table 9 Predicted unmitigated indirect groundwater impacts

Groundwater System/Aquifer	Predicted Unmitigated Maximum Drawdown	Comments
Shallow groundwater system Condamine Alluvium	Greater than 0.1 m to less than 1 m along the western extent of the Condamine Alluvium (see Figure 11)	• Average drawdown less than 1 m across project development area. • Peak drawdown in 2059 indicates a lag between gas extraction and corresponding drawdown in the shallow Condamine Alluvium. • Recovery also lags with full recovery not occurring until after 2071.
Intermediate groundwater system Kumbarilla Beds	20 to 30 m in 2029 along the eastern boundary of the Kumbarilla Beds	• Average drawdown in surrounding areas predicted to range from 2.5 to 5 m. • Recovery of drawdown in the eastern extent of the Kumbarilla Beds to 5 m by 2061. • Drawdown extends south late in the project with gas production from the Goondiwindi development region.
Deep groundwater system Hutton Sandstone/ Marburg Formation	20 to 30 m in 2027 across the majority of the project development area	• Peak drawdown will occur in 2027 with the most pronounced impacts expected to occur in the Wandoan development region. • Average drawdown of 10 to 20 m. • Drawdown in 2027 up to 0.5 m predicted to extend approximately 25 km west and 5 km east of the project development area. • Recovery to an average of 5 m by 2061. • In 2061, up to 0.5 m drawdown will extend west approximately 60 km from the project development area.
Deep groundwater system Precipice Sandstone	10 to 15 m in 2042 within the Dalby development region	• Average drawdown outside of the Dalby development region generally 1 m to 5 m. • Recovery under way by 2061 around the Dalby development region. • Slower recovery beyond the Dalby development region.

* *Quantities are nominal and to be confirmed by optimisation studies prior to final design.*

Potential impacts on groundwater systems in the project development area will be managed through a hierarchy of groundwater management options that are linked to Arrow's coal seam gas water management strategy, specifically substitution of groundwater allocations and injection (see Box 8).

The actual direct and indirect impacts on groundwater users are predicted to be low because:

- Arrow intends to treat most of the coal seam gas water extracted from the Walloon Coal Measures so that it is useful for a range of agricultural, industrial and urban uses. By substituting existing allocations, this will respectively reduce third party drawdown of groundwater systems and depletion of surface water resources reducing overall impacts to those systems.
- Coal seam gas water will substitute for existing water allocations.
- Substitution of coal seam gas water for water that would otherwise be drawn from aquifers should facilitate natural recharge of those aquifers and offset depressurisation impacts in the aquifers.
- Injection of treated coal seam gas water into the shallow (Condamine Alluvium) and deep aquifers is expected to offset the impact of drawdown in those aquifers as a result of coal seam gas water extraction from the Walloon Coal Measures.

Other potential impacts include aquifer interflow, contamination by surface and subsurface coal seam gas activities, impact on the water balance of the Great Artesian Basin, impact on cultural features and reduced infiltration or recharge. These potential impacts are all considered to have a low likelihood of being realised if standard design, construction and operations practices are implemented.

The assessment that the residual impact will be ultimately a low impact on groundwater uses and functions can be made because of the following key points:

- The sensitivity of the groundwater resource is derived from its commercial and environmental importance. The resource is well protected through policy controls. Arrow's project planning and design will necessarily place a very high priority on protection of the resource through monitoring and adaptive management.
- The water treatment and delivery infrastructure required to manage and adapt to impacts identified through monitoring and to provide a water resource by substitution of existing allocations are integral to project design and operation.
- The monitoring regime that will be undertaken will facilitate updating of the groundwater predictive model with real data as it becomes available. Further monitoring will also ensure that any divergence from predictions will be discovered as they are happening, allowing the management of Arrow's operations to be adjusted with consideration of observed impacts.

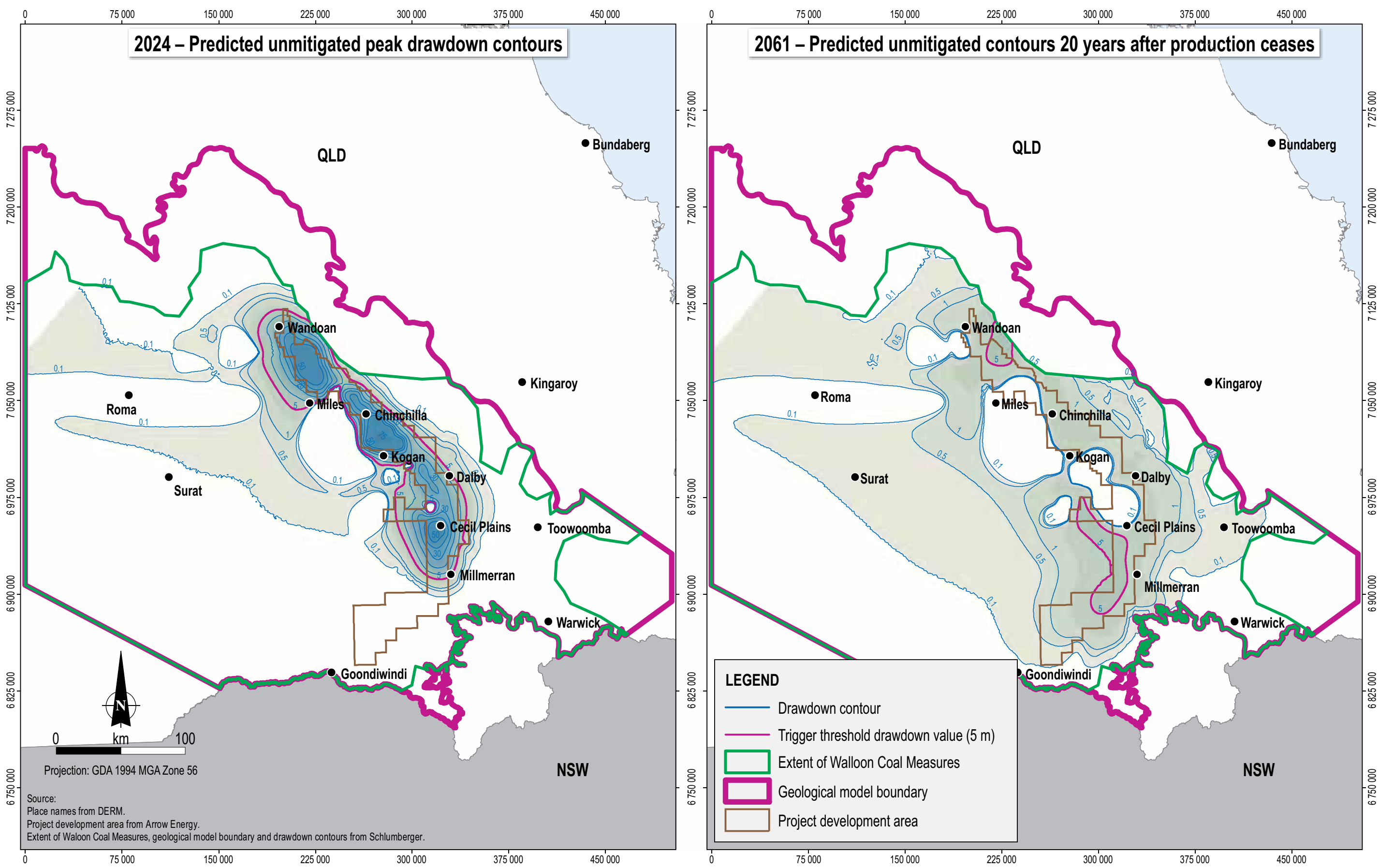


Figure 10 Predicted unmitigated groundwater drawdown contours in the Juandah Coal Measures (modelling scenario 1: Arrow-only)

Box 8 Groundwater management

Integral to Arrow's Coal Seam Gas Water Management Strategy is the beneficial use of coal seam gas water. Arrow will minimise the potential for reduction in groundwater supply to existing and future groundwater users across the project development area by considering substitution of water allocations to enhance shallow aquifer recovery, as well as investigating options for agricultural, industrial and urban uses.

Arrow will also minimise impacts to groundwater quality through:

- Enforcement of no hydraulic fracturing (fraccing) in the project development area.
- Installation of wells, surface storage and subsurface infrastructure in accordance with relevant industry standards, and perform routine inspections and monitoring programs to ensure integrity and compliance throughout the life of the project.

Arrow is committed to better understanding the uncertainties surrounding the potential impacts to groundwater systems through ongoing investigations that include:

- Investigative programs to improve confidence in aquifer properties, sensitivity and basin-specific issues.
- Installation of a regional groundwater monitoring network to enable routine monitoring of groundwater levels and quality indicators in key aquifer formations over time.

6.4.4 Surface Water

Surface water hydrology in and adjacent to the project development area is characterised by drainage basins with relatively flat terrain where rainfall runoff finds its way to the major rivers and streams via a maze of defined, poorly defined and indistinct channels. The flat terrain and labyrinth of waterways combine to produce extensive overland flows during seasonal and unseasonal flooding, a phenomenon that contributes to the agricultural productivity of the region, which derives from the black soils and their ability to retain soil water replenished by floods.

Obstruction or diversion of overland flows is a significant issue for the region because diverted or concentrated flows can result in erosion and waterlogging, which individually and collectively can result in reduced or lost productivity. Use of existing access tracks, considered access track design and effective management of topsoils and subsoils during ground-disturbing works and rehabilitation are expected to avoid these inherent risks and potential impacts.

Significant surface waterbodies within the project development area, such as Lake Broadwater, are not known to be groundwater dependent. Lake Broadwater is situated at the edge of the Condamine River floodplain and is connected to surface watercourses, specifically Wilkie Creek via the Broadwater Overflow and to the Condamine River when it is in flood.

Project impacts on the hydrology, morphology or functions of these waterbodies are not expected through the implementation of appropriate mitigation and management measures, including commitments presented in Box 9. The assessment of limited impacts is based on the broad assumption that water from Arrow's operations will not be discharged to watercourses under normal conditions.

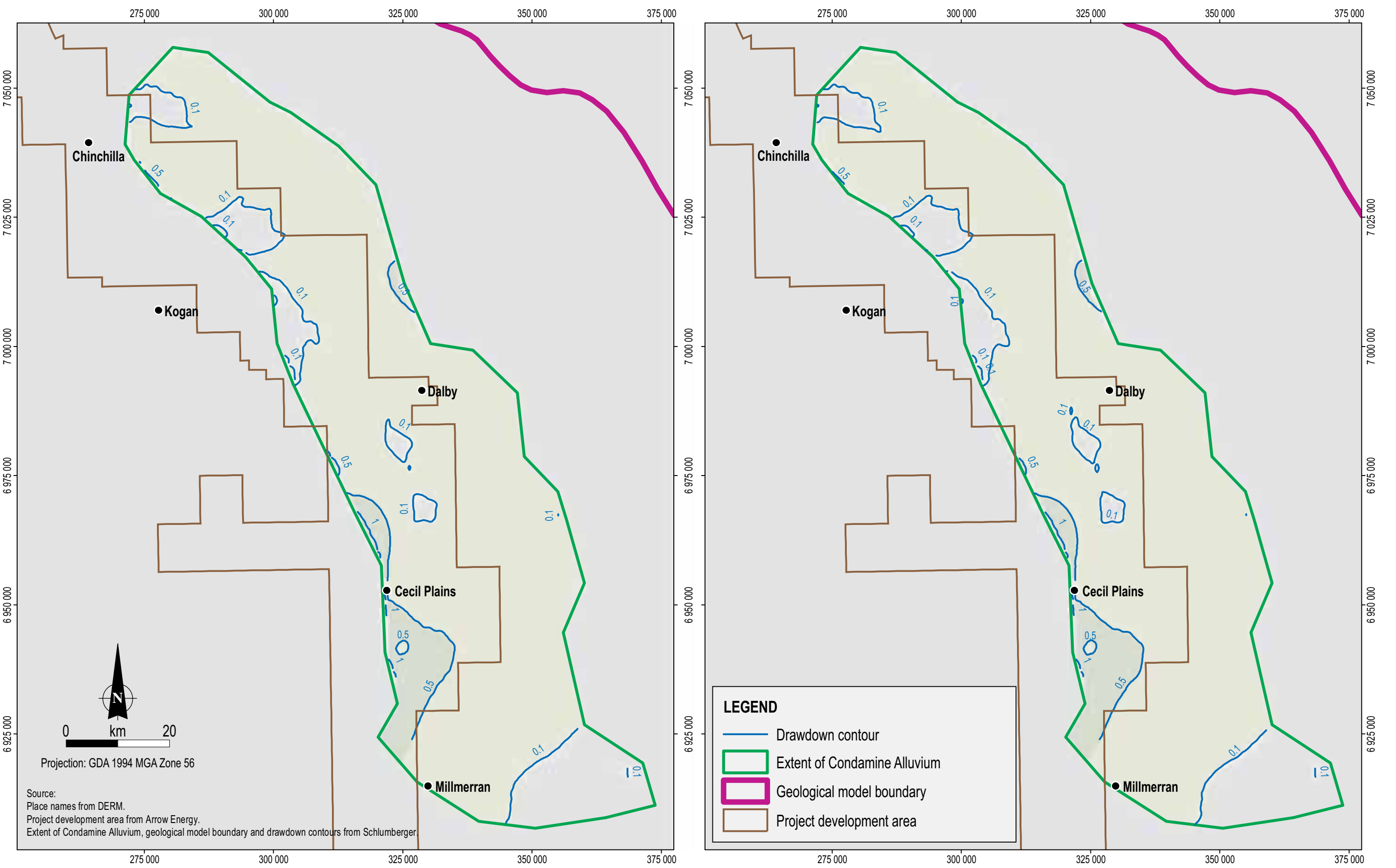


Figure 11 Predicted unmitigated groundwater drawdown contours in the Condamine Alluvium (modelling scenario 1: Arrow only)

Box 9 Surface water management

The extensive network of watercourses within the project development area will be protected by managing impacts to the physical form and hydrology of watercourses and surface water quality. Arrow will:

- Site facilities to avoid wetlands and watercourses that are highly susceptible to erosion.
- Avoid permanent pools, chains of ponds, and alluvial islands, where practicable.
- Minimise watercourse crossings, where practicable.
- Develop site-specific management plans for permanent and semi-permanent watercourse crossings.
- Implement buffers around environmentally sensitive areas and watercourses.
- Adhere to surface water quality discharge objectives.

6.5 Nature Conservation

Clearing native vegetation from the fertile soils of the region for agriculture has reduced remnant vegetation to patches and linear strips along watercourses, around waterbodies and in road reserves. Larger tracts of remnant vegetation exist on the less fertile soils along the western boundary and in the north and south of the project development area. Consequently, terrestrial and aquatic ecological assets are valuable resources. This section summarises the potential environmental impacts to aquatic and terrestrial ecology.

6.5.1 Aquatic Ecology

The aquatic habitats of the project development area comprise wetlands and permanent, semi-permanent and ephemeral watercourses. Important features include:

- Lake Broadwater.
- A section of Oakey Creek thought to support an extremely limited distribution of locally threatened fish.
- Watercourses (notably the Condamine River) and numerous small swamps and billabongs.

Water quality across the project development area shows the elevated salinity, turbidity, nutrients and low dissolved oxygen characteristic of agricultural land uses and supports modified aquatic ecosystems.

Project impacts on surface water quality and aquatic ecology, such as erosion and sedimentation, will generally be localised and temporary in nature. Implementation of proven construction control measures and rehabilitation of completed works areas should limit sedimentation and consequential effects in severity and duration. Plant and equipment hygiene is intended to prevent the spread of exotic plants, and project activities will avoid the Lake Broadwater Conservation Park and the important section of Oakey Creek. Box 10 presents the key aquatic ecology mitigation measures.

Box 10 Protecting aquatic ecology

The protection of aquatic ecology requires the avoidance of sensitive areas and minimisation of adverse impacts to permanent, semi-permanent and ephemeral watercourses. Protecting the aquatic environment will include, but not be limited to:

- The implementation of appropriate buffer zones to Lake Broadwater Conservation Park and watercourses.
- Minimising ground disturbance works, vegetation clearance and disturbance of riparian corridors.
- Appropriate design of pipeline and road watercourse crossings.
- Implementation of erosion and sediment control measures.
- Implementation of a weed and pest management plan.

6.5.2 Terrestrial Ecology

Approximately two-thirds of the project development area has been cleared. There are areas of remnant vegetation and native regrowth, some of which are quite large, on land that is not suited to cultivation or grazing. The most notable of the remnants are:

- Lake Broadwater Conservation Park.
- Bendidee and Wondul Range national parks.
- Barakula, Bendidee, Braemar, Western Creek and Whetstone state forests.

Extensive land clearing has significantly reduced some ecological communities in Queensland to the extent that they are now listed as endangered. Endangered communities present in the project development area include brigalow woodland, semi-evergreen vine thickets, weeping myall woodland and coolibah-black box woodland. Although weeping myall woodland species occur within the more widely distributed poplar box woodlands, viable remnants were not found during the ecological surveys. Coolibah-black box woodlands extend along the major rivers and creeks of the project development area. Brigalow is widely distributed throughout the project development area, whereas semi-evergreen vine thickets exist only as degraded isolated remnants.

Critically endangered vegetation communities identified were native grasslands on basalt and fine-textured alluvial plains, which are found in road reserves and stock routes, and white box-yellow box-Blakely's red gum grassy woodland and derived native grassland, which exists in and around Captains Mountain, south of Millmerran.

Numerous state- and national-listed flora and fauna species were identified in association with the vegetation communities. Habitat for the endangered bull oak jewel butterfly extends beyond the Bendidee National Park into the adjoining Bendidee State Forest. A recovery plan has been developed by the Queensland Parks and Wildlife Service (Lundie-Jenkins & Payne, 2000) for this species. Other endangered fauna include reptiles whose preferred habitat is native and derived grasslands and various bird species whose habitat encompasses all core habitats of the project development area. One endangered mammal, the spotted-tail quoll (Plate 8), may occur in forested habitats but is highly unlikely to occur in the project development area. Notable reptiles include the five-clawed worm-skink, grassland earless dragon (Plate 9) and grey snake. Endangered bird species include the regent honeyeater.

EIS field surveys, which targeted the areas adjacent to existing developments, have supplemented published studies and conservation databases to determine terrestrial ecosystems sensitive to impact. Ecologically sensitive areas are shown on Figure 12.

Habitat fragmentation, degradation or loss is the principal potential impact, as this can lead to consequential impacts on plant and animal populations with fauna mortality and changed ecosystem function key indicators of such impacts.

The primary mechanism for minimisation of impacts to ecologically sensitive areas is avoidance. The information developed for the EIS has been used to prepare constraints maps that will facilitate avoidance and the establishment of appropriate buffers and management requirements for areas in which project facilities might be located. Conditions attached to environmental authorities specify buffer distances to Category A, B and C environmentally sensitive areas and to watercourses and nominate the types of activities permitted within the buffers.

Implementation of the environmental management controls recommended in the EIS such as those presented in Box 11, along with diligent site supervision, will ensure protection of the terrestrial ecological values of the project development area. Induction and training programs will ensure workers' awareness of the location of significant remnant vegetation and buffers, as well as their awareness of the management measures to be implemented. The controls and awareness programs will reduce the severity of residual impacts on terrestrial ecology.

Box 11 Protecting terrestrial ecology

Arrow will actively protect the terrestrial ecological values of the areas in which it operates through:

- Avoidance of:
  - Category A environmentally sensitive areas.
  - 'Critically endangered' EPBC Act-listed communities, including three natural grasslands in road reserves.
  - Chinchilla Sands Local Fossil Fauna Site.
- Implementation of appropriate buffers to endangered communities, state forests and other listed sites of conservation value.
- Preconstruction clearance surveys that identify core habitats and listed species.
- Demarcation of sensitive areas prior to ground disturbance.

Photos by Mark Sanders (EcoSmart Ecology)

8 Spotted-tailed quoll (*Dasyurus maculatus maculates*)

9 Grassland earless dragon (*Tympanocryptis* cf. *tetraporophora*)

6.6 Agriculture

The project development area is located entirely within the Darling Downs (the Australian Bureau of Statistics statistical division relevant to the project development area), one of Australia's prime agricultural areas, with annual livestock and crop production worth some $1.7 billion. Some 105,700 ha are under irrigation from surface water and groundwater sources and much of the area enjoys policy protection as good-quality agricultural land and, more recently, as potential strategic cropping land.

Water is the main factor limiting agricultural production. The Darling Downs Statistical Division accounts for approximately 20% of irrigated land in Queensland and produces mainly cotton (61,859 ha) and cereal (17,859 ha) (plates 10 and 11). High-value fruit and vegetable production is also significant.

Agricultural practices in the region have evolved to overcome the constraints posed by gilgai, dissected landscapes, salinity, sodic and impermeable soils, and limited water sources. The latter has had a major influence on the layout and operation of farms. Collectively, the constraints have resulted in each enterprise being unique, with its own challenges and sensitivity to disruption. Some enterprises are more tolerant of disruption than others.

Project activities have the potential to affect productivity and increase costs through reduced crop yields and losses, disturbance of farm animals, degraded soil structure and fertility, and increased management overheads. Potential impacts to agriculture can be summarised, as follows:

- **Reduced Productivity and Increased Costs.** Caused by changes in farm configuration (e.g., creation of more headlands), disruption to farming practices (e.g., changes to irrigation infrastructure, interference with overland flow), unsuccessful rehabilitation and temporary loss of arable land.
- **Crop Losses or Disturbance to Stock.** Caused by drilling or construction occurring during inopportune times disrupting cropping or breeding (depending on the proximity to breeding animals and the nature and intensity of the disturbance), and unsuccessful rehabilitation.
- **Soil Disturbance.** Caused by compaction from traffic, mixing and inversion of soil horizons, settling of pipeline trenches or soil loss from erosion caused by construction activities.
- **Increased Costs of Farm Management.** Caused by increased operating overheads from management of coal seam gas activities and coordination of activities (e.g., spraying and withholding periods) and integration with farm plans. Increased costs may also result from limitations on development of farms to incorporate new technologies and farming techniques.
- **Loss of Amenity.** Caused by contractors and employees entering and working on properties, disruption to lifestyle, increased levels of noise and dust, and the visual impact of project infrastructure.

Other potential impacts include contamination of soil and water from project activities, and the introduction and spread of weeds and plant and animal pathogens.

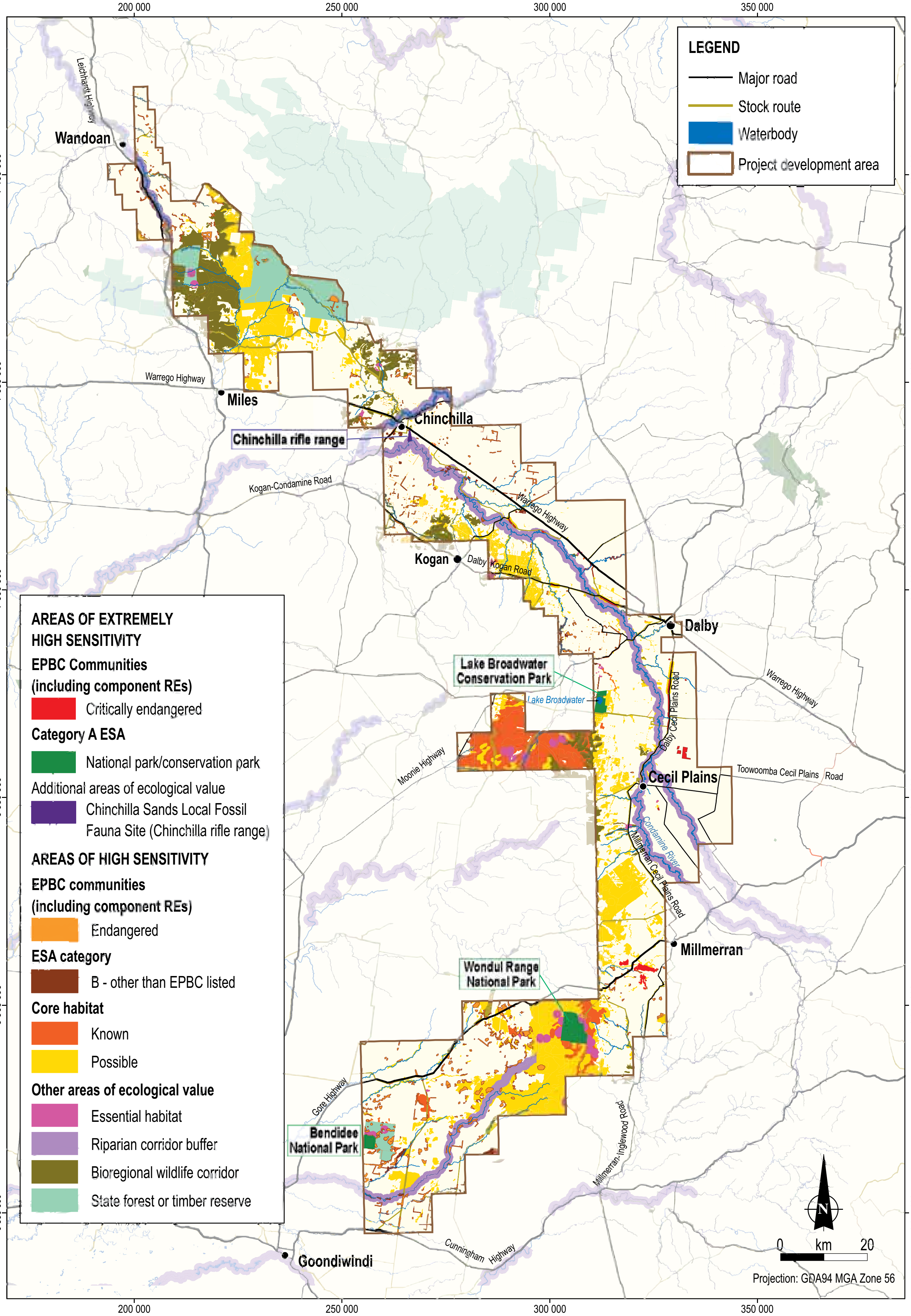


Figure 12 Ecologically sensitive areas

Experience to date indicates that up to 2 to 3% of land associated with a typical production well spacing of 800 m, which equates to 65 ha (160 acres), will be required and disturbed by activities associated with the construction and operation of a production well, the associated water and gas gathering lines, and the access track. Between 0.5 ha and 223 ha will be required for the development of production facilities, with easements up to 25 m wide required for medium-pressure gas pipelines and other ancillary services.

Rehabilitation of gathering system and pipeline rights of way will return land affected by these activities to productive use. Production well sites will be rehabilitated to former land uses, removing the obstacle from the property. The construction of production facilities involves major earthworks to establish pads for compressor and power generation units and the construction of water treatment and storage facilities (including feedwater, treated water and brine dams) at integrated processing facilities. Rehabilitation of production facility sites would seek to re-establish endemic native vegetation communities or pasture grasses that would support grazing land use, or the sites would be redeveloped for other suitable purposes. Field development planning will focus on siting production facilities in areas where reinstatement of the former land use is possible. Production facilities will, where possible, be sited to avoid intensively farmed land.

Seasonal floods produce expansive overland flows that are important for replenishing soil water, a key factor in the fertility of the black soils of the Condamine River floodplain. Diversion of the flows through construction of elevated access track formations or well pads can reduce infiltration and cause erosion leading to topsoil loss. Use of existing access tracks and consideration of existing drainage patterns when designing new access tracks and well pads will reduce the potential for diversion of overland flows.

Obstacles in cultivation paddocks can result in lost productivity and overheads. Additional headlands and cultivation islands can be introduced when production wells disrupt the planting pattern. The placement of production wells in cultivation paddocks can be very disruptive (Figure 13b), but they can be arranged to reduce the overall impact on machinery movement (Figure 13c).

Planning and design has been identified as the most effective way of mitigating the impacts of coal seam gas infrastructure and activities on agricultural enterprises and production. The location and layout of production wells and associated gathering systems will be designed in consultation with landowners to minimise impacts to their properties. Activities will be planned to integrate with farm plans and include consideration of cropping cycles, withholding periods, crop rotations and farm development.

10

11

10 Broadacre cropping on black soils

11 Irrigated cereal crop

Planning and design objectives supported by good-practice environmental management controls, are proposed to ensure coal seam gas development is integrated with agricultural activities. The categories are:

- Avoidance or separation from susceptible agricultural facilities or activities.
- Conservation of soil and maintenance of existing drainage patterns.
- Scheduling of project works, traffic and other activities to avoid critical periods in the farming cycle.
- Consideration of site specific constraints in production well and gathering system design.
- Rehabilitation of disturbed areas to agricultural production capability.

Potential impacts can be successfully managed through field development planning, modifying work practices and rehabilitation. The success of rehabilitation will determine whether there are any residual impacts and their severity.

The primary factors that will influence the success of rehabilitation include:

- The hydrologic regime and drainage patterns of the disturbed land and surrounding area i.e., can the pre-disturbance drainage patterns be reinstated or replicated to ensure a stable landform that does not alter overland flow behaviour or cause erosion.
- The type and properties of the disturbed soils i.e., can the soil profile, micro and macro pore connections, soil organic matter, soil chemistry and biological function be reinstated.
- The pre-disturbance land use and productivity i.e., can the former land use and productivity be reinstated.

The type of coal seam gas infrastructure – production wells, gathering systems, pipelines, production facilities – will determine the techniques, effort and investment required to achieve successful rehabilitation and reinstatement of former land use and productivity.

Residual impacts will be identified through inspection and monitoring. They will be remediated or addressed through appropriate compensation.

The potential impacts and residual impacts described above are recognised by Arrow who acknowledges that field development plans will need to consider the location of infrastructure, the timing and duration of site access, and how drilling and construction activities will be conducted. To ensure coal seam gas development is effectively integrated with agricultural activities Arrow is engaged with the farming community in a range of forums, which include:

- **Arrow Surat Community Reference Group.** A consultative forum that consists of spokespeople from the Basin Sustainability Alliance, Future Food Queensland, Cotton Australia, Central Downs Irrigators, Australian Petroleum Production and Exploration Association, DERM, DEEDI, regional councils, University of Southern Queensland and Arrow. The forum provides an opportunity for Arrow to provide project updates and to hear and work through community issues and concerns.
- **Arrow Intensively Farmed Land Committee.** Comprised of representatives from Arrow and various landholders representing different agricultural enterprises on intensively farmed land, the committee provides an opportunity for feedback from the farming representatives on Arrow's proposed approach to development on intensively farmed land, including the establishment and reporting of case studies and trials.
- **Community Consultation.** Since June 2010, Arrow has consulted with more that 1,200 landholders and community members in the Surat Basin via various forums including community information sessions, call-in centres, and meetings with representative bodies, state and local government agencies, and individual community members. Public consultation has included displays and coal seam gas water management workshops attended by independent experts.
- **Irrigator Groups.** Arrow is currently working with the Central Downs Irrigators Group, the Basin Sustainability Alliance and Future Foods to investigate the best means of implementing Arrow's coal seam gas water management strategy.
- **CSG Engagement Group.** This group provides a forum for state government Directors-General and local government Mayors, Queensland Water Commission, coal seam gas industry, Agforce, Cotton Australia, Basin Sustainability Alliance, landholders, Australian Petroleum Production and Exploration Association and the Queensland Resources Council to identify and resolve concerns relating to the coal seam gas industry. Arrow is also represented on two sub-committees, the water and land access working groups.

Arrow's approach to achieving environmental protection objectives for agriculture is set out in Box 12.

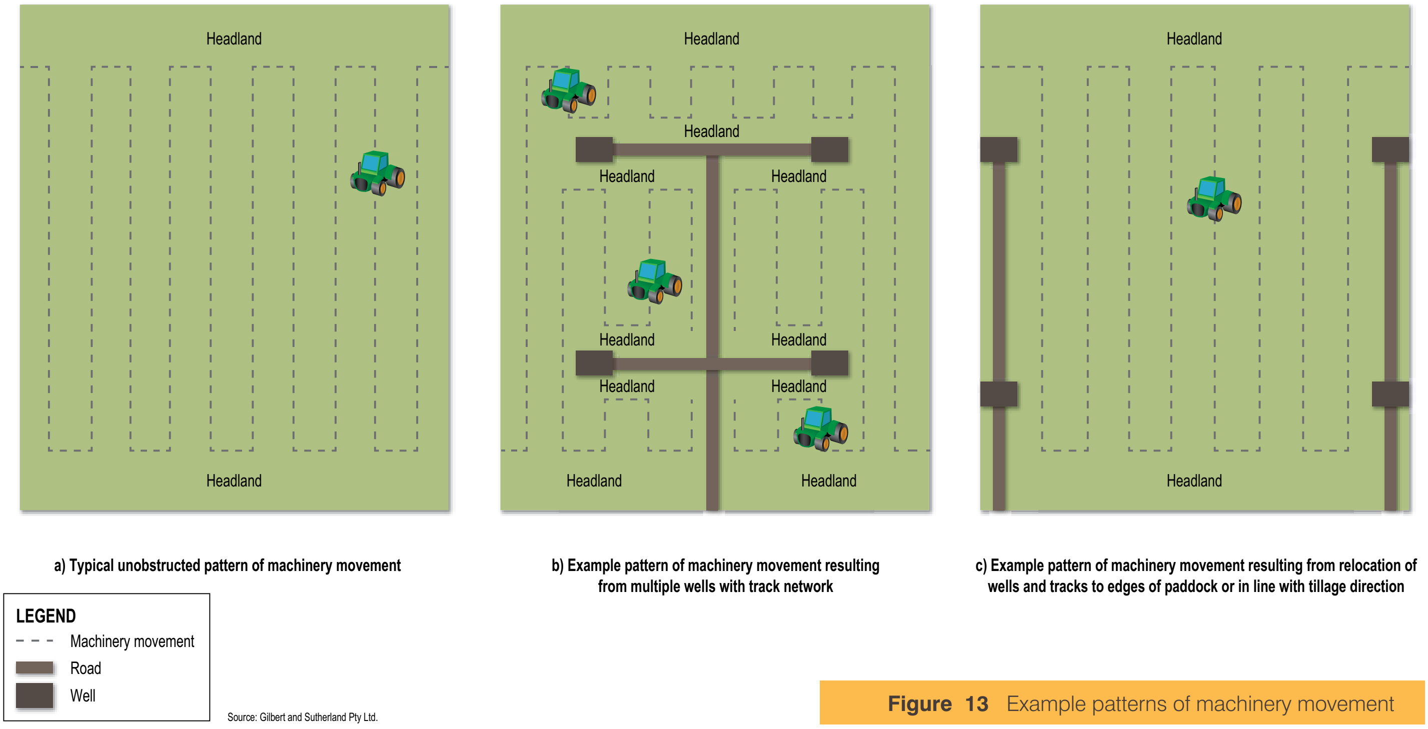
Box 12 Agriculture

The key environmental protection objectives for agriculture are to avoid or reduce adverse impacts to agricultural infrastructure, agricultural production (i.e., cropping and breeding) and farming practices (i.e., day-to-day agricultural activities) and to maintain and/or restore soils to support the intended land use.

These objectives will be achieved through implementation of the following:

- Siting of infrastructure to reduce potential impacts on agricultural land and agricultural enterprises.
- Designing, constructing and operating infrastructure in a manner that integrates with farm plans and activities.
- Rehabilitating land disturbed by project activities to its former use and productivity.

Arrow is committed to ongoing engagement with the community through a range of forums on issues associated with development on intensively farmed land.



Source: Gilbert and Sutherland Pty Ltd.

Figure 13 Example patterns of machinery movement

6.7 Landscape and Visual Amenity

The landscapes of the project development area are typified by arable plains between Chinchilla and Dalby and Cecil Plains and Millmerran. These plains are located on either side of the woodlands that extend along the Condamine River, which is bordered to the west by pastures. The terrain rises and undulates running southwest from Chinchilla towards Goondiwindi, with brigalow farmland, native forest on incised sandstone plateaux, and rough pasture interspersed with scrub. Project facilities will be most visible in the relatively flat, developed country between Kogan and Cecil Plains.

Arrow's planning and design objective is to render facilities visually unobtrusive. This will be achieved through a combination of separation from the most sensitive viewpoints, screening, and the application of design (facilities may look more like agricultural sheds and fences than industrial facilities) and surface treatments (matt paints drawn from a colour palette designed to blend into various Surat Basin landscapes).

It is also Arrow's intention to site the larger central gas processing and integrated processing facilities in the less productive land along the western edge of the project development area where screening provided by remnant vegetation will be augmented with plantings to conceal views to the facilities. The effective screening of an integrated processing facility by augmenting existing stands of remnant vegetation is shown in Plates 12 and 13 for the lowland native forest landscape unit that extends along much of the western boundary of the project development area. Screening of production wells in arable land with vegetation would result in a larger footprint and is not favoured. Other treatments described above would be more effective in reducing the visual presence of wellhead infrastructure in the arable plains landscape unit.

See box 13 for landscape and visual amenity mitigation measures.

Box 13 Management of the landscape and visual amenity

Arrow's objective is to avoid or minimise the impact on sensitive viewsheds and the landscape character of the project development area. Arrow will:

- Site infrastructure and facilities to avoid sensitive viewsheds.
- Integrate facilities into the landscape setting by consideration of building structure, colour and texture.
- Use landscape features to screen project infrastructure, where possible.

12

12 Lowland Native Forest: Integrated processing facility visualisation prior to mitigation

13 Lowland Native Forest: Integrated processing facility visualisation after mitigation

13

6.8 Roads and Transport

Project construction and operation will increase traffic volumes across the road network and raise issues of efficiency, safety and amenity. Staged development means that there will be times when the construction, operations and decommissioning phases will be occurring concurrently across the project development area.

Annual daily project traffic will average up to 104 vehicles per day and peak at up to 330 vehicles per day, with the highest volumes on roads that link depots to production facilities and accommodation camps. Peak additional project heavy-vehicle travel on the road network will be less than 2% of existing (2009) levels, and light-vehicle travel will be less than 1%.

Project traffic volume is not, therefore, a significant increment over existing levels; and provided specific measures are in place to cater for localised areas of heavy construction traffic, then the impacts should not unduly increase efficiency, safety and amenity.

See box 14 for roads and transport mitigation measures.

Box 14 Managing traffic and road impacts

The safety of the community and Arrow's workforce is paramount. Ensuring construction and operation activities do not adversely impact the road network is another priority. Potential impacts on road safety and road network efficiency will be minimised through:

- Management of increased traffic volumes and road safety issues by developing traffic management plans in consultation with councils and the Department of Traffic and Main Roads.
- Development of project logistics and journey management plans that promote safe movement of people and materials, and minimise traffic volumes.
- Implementation of traffic controls, including signage and restrictions of movements.
- Driver training and fatigue awareness for employees and contractors.
- In-vehicle monitoring systems.

6.9 Noise and Vibration

The predominantly rural environment of the project development area currently has very low background noise levels. Noise emissions from project construction activities and production facility operation have been modelled with consideration of that low background level plus worst-case meteorological conditions characterised by a temperature inversion and gentle breeze from the noise source to the sensitive receptor.

The modelled data provides an indication of the distance at which established noise criteria (designed to minimise sleep disturbance and nuisance) will be met. It is expected that the noise criteria will be met within 300 m of a production well and at 1 km from a production facility assuming the application of standard noise attenuation measures. With the application of further attenuation measures, these distances may be reduced in some circumstances.

The ultimate separation required to meet the noise criteria will be determined in detailed design when equipment selection is finalised. Following commissioning, noise monitoring will confirm whether or not the predicted noise levels have been achieved and, if not, the reduction required, which in turn will inform the type and extent of attenuation required to ensure compliance.

Vibration during construction and operation is expected to be below the threshold of human detection and to cause no damage to structures, as blasting is not anticipated.

See box 15 for noise and vibration mitigation measures.

Box 15 Managing noise and vibration

Arrow recognises that the project development area is typically a quiet rural environment dominated by natural sounds. The protection of amenity at nearby sensitive receptors will be achieved by:

- Selecting sites in sparsely populated areas.
- Noise modelling of production facilities to ensure relevant guidelines are met.
- Implementation of noise controls.
- Consultation with landowners prior to the commencement of noise-producing activities.

6.10 Economic

Economy underpins society, and economic issues will always be prominent in people's minds when changes are proposed. This section examines the economic changes and resulting impacts expected from the project. The assessment was completed on the basis of an economic model with consideration of a baseline economic environment that drew data from multiple project and external sources.

6.10.1 Darling Downs Regional Context

The economy of the Darling Downs is dominated by public administration (11.5%), mining and energy (10.7%), construction (9.6%), and agriculture, forestry and fishing (9.1%).The gross regional product in 2009/10 was $12.6 billion. The resident population has been growing more slowly than the state average, but unemployment is low, and there is a sizable and growing transient population to meet demand for labour. Growing mining and coal seam gas industries have helped the region through the recent drought and global economic difficulties, but skilled workers are in short supply, and there is competition for them. Wages are below the state average but catching up.

Property markets are tight in response to demand for accommodation from the mining and energy sectors.

Local business has evolved to service agriculture. It has the capacity and capability to diversify into mining and energy services, but smaller local businesses may have challenges meeting the supply and quality-control requirements of the industrial proponents. In addition, the region's transport and telecommunications infrastructure requires upgrading.

Agriculture is emerging from a long and serious drought with operating losses and higher debt and is facing wage competition from the growing mining and energy sectors.

Overall, however, the Darling Downs has a diverse and resilient economic base due to the quality of agricultural land and growth in mining and energy.

6.10.2 Gross Regional, State and National Product

The Surat Gas Project will generate economic benefits for the economies of Queensland, Australia and the Darling Downs, increasing the gross regional product by approximately $75 million in 2013/14 (or just under 6% of 2009/10 Darling Downs gross regional product) and rising to approximately $1.15 billion from 2018/19 and continuing at approximately $1.3 to $1.4 billion on average, once peak gas production is reached. The Darling Downs is anticipated to receive the vast majority of growth generated by the project.

6.10.3 Government Taxes and Revenues and the Australian Dollar

Significant positive impact in terms of government revenues will be generated by the project. Additional revenues are estimated to be approximately $120 million per annum to the Queensland Government and approximately $230 million per annum to the Australian Government.

The project will help to strengthen Australia's balance of trade, which will lower the cost of imports but will make Australian exports more expensive and adversely affect import-competing local industries, including manufacturing and some agricultural commodities.

6.10.4 Impacts on Employment, Workforce, Business, Population, and Wages

Project employment will peak in 2015/17 with a net increase of just under 500 full-time equivalent employees (0.375% of the Darling Downs total) and will fluctuate through the life of the project, with a generally downward trend experienced after the peak construction activity in 2016/17. The estimate of full-time equivalent employees comprises Arrow's operations workforce resident in the region, the operational staff moving to and taking up residence in the region, and the small percentage of the construction workforce sourced in the region, whether as existing residents or people moving to the region. It does not account for the majority of the construction workforce.

The most significant impact occurs in the demand for technicians and tradesmen, which will peak at 1.2% of the Darling Downs total in the lead-up to peak production in 2020, after which it will fall to 0.8% for the balance of the life of the project.

Around 38% of the Surat Gas Project's well development capital cost is expected to be expended on local labour and business in the Darling Downs.

Population is anticipated to increase, in part via the project workforce but more so via employment growth in local businesses and recreational and community services, all of which encourage business investment, relocation to and expansion in the region.

The Surat Gas Project could increase real wages in the Darling Downs by an average of 0.5% (2013/14 to 2027/28). While notable, the increase is not expected to destabilise the regional labour market. Household incomes are expected to increase by 0.5% to 0.7% over the project life.

6.10.5 Impacts on the Property Market

A number of factors will moderate the project's impacts on residential property prices and rents: camps will be used to accommodate the construction workforce, the number of operational employees migrating to the region will be small, the lead time to peak workforce is long, and project facilities are spread over a wide region. Even so, the project will inevitably place some upward pressure on accommodation costs, which have already risen considerably in the past five years, especially housing prices (by more than 75%) and vacant land (by more than 150%) in Dalby and Wandoan areas.

The project will add to existing demand for industrial and commercial land in the Darling Downs, where land ready for development is already insufficient and prices have doubled in some areas in the past two years.

6.10.6 Economic Impact Issues and Mitigation

The overall economic impact of the project is positive, with added investment and diversity in the region. However, a number of local and regional impacts will require mitigation. They include deepening the existing skills shortage and competition for labour; competitiveness of local business; availability and cost of commercial, industrial and residential land; and infrastructure. See Box 16 for economic mitigation measures.

Box 16 Economic growth

The nature of the potential impacts requires a collaborative approach to mitigation, with the coal seam gas industry engaging with state and local government in forecasting needs and monitoring trends to enable effective planning for the provision of labour, infrastructure and services. Initiatives proposed to address the issues include:

- Continue working with Construction Skills Queensland to increase the construction skills of local job seekers.
- Collaborate with other coal seam gas proponents and Energy Skills Queensland to access the Skills Queensland Strategic Investment Fund.
- Collaborate with state and local government, local industry, industry organisations, and coal seam gas proponents to back-fill vacancies left by people drawn to the project from other sectors.
- Continue support for the CSG/LNG Industry Training Program.
- Brief councils, economic development organisations, the Industry Capability Network and state government about locally available goods and services required by the project.
- Inform local businesses of the goods and services required by the project, of the service provision opportunities and of the requirements of businesses to secure contracts.
- Establish and implement a local business strategy that assists qualified local and regional businesses to tender for provision of goods and services that support the Surat Gas Project.

With an expected annual average contribution of $1.4 billion to Gross Regional Product in the Darling Downs, the Surat Gas Project will have a positive impact in the region through:

- Enhancing the stability and sustained growth of the Darling Downs economy.
- Increasing employment rates by up to 0.5%.
- Increasing household incomes by providing high paying jobs for those directly employed by the project.

6.11 Social

Economic factors influence a community's perceptions of change, but not exclusively. Perceptions of impacts on what people value also matter, often more so than the economic factors. Residents of the region strongly identify with being a part of a rural society characterised by stable, close-knit communities; hard-working, friendly people; and wide open spaces with unique and diverse recreational opportunities.

Throughout their histories, these communities have displayed a high level of resilience to both environmental challenges and fluctuations in agricultural commodity prices. They have experienced population growth and decline; however, the integrity of these communities has remained throughout. Recent industry diversification is affecting communities in terms of the uncertainty of the ultimate character of their community.

Darling Downs Regional Context

Agriculture and public administration have traditionally been the dominant employers of rural Australia and have been the main influences on the social setting at the regional scale.

The communities of the Darling Downs are dispersed in large and small towns, which have evolved to service the agricultural sector but now support a growing number of people working in the mining and energy sectors. Population growth has been less than the state average, with a decline in some smaller townships. Unemployment is generally very low.

Housing is relatively affordable, and home ownership is high. However, residential growth rates are strong in Toowoomba, Chinchilla and Dalby; and the market has been tightening in recent years. Hotel and motel accommodation is also limited.

Indigenous employment, health status and standard of living are generally all low.

Educational facilities are concentrated in Toowoomba and Dalby, with fewer in smaller communities.

The region enjoys generally good health and emergency services, a safe and healthy living environment and low crime rates; but services are inevitably better in the larger towns. Facilities for youth and children, specialist counselling and aged care are generally limited.

Residents appreciate the region's social cohesion and affordable lifestyle generally in a friendly rural environment.

Social Impact Issues and Mitigation

Arrow's characterisation of the social impact issues has relied not only on demographic statistics but also on the attitudes and opinions that people have expressed in a region-wide and lengthy (and continuing) process of community engagement, project briefings, focus groups, interviews, telephone surveys, discussions with government agencies and councils, and feedback in numerous forms.

During successive stages of consultation, stakeholders and communities were asked to contribute their knowledge about the management of potential impacts. Their responses are presented in Table 10.

Key potential negative impacts identified in the social impact assessment relate to the affordability and availability of housing and accommodation, increased demand for health services and on medical facilities, uncertainty for landowners and community members, heightened road safety risk due to increased traffic levels, and the impact that higher wages may have on the viability of local businesses. While the anticipated changes are, in isolation, not large, the relatively rapid establishment of a new economic driver along with the cumulative effect of simultaneous projects may exacerbate the impacts, at least in the short term.

Not all impacts are negative. The project will deliver a range of positive social effects, including direct and indirect employment, enhanced training and skill development prospects, additional local business opportunities and an injection of wealth and vitality into local communities. Industry diversification also may improve the economic and social resilience of both communities and agricultural enterprises, as the latter are exposed to seasonal variations and international trading conditions.

Table 10 Stakeholder contributions on managing project impacts

Management of Adverse Impacts	Opportunities
• Put things in place to manage water use, quality, use and discharge (38%). • Look after agricultural and farm lands (including weed management) (31%). • Provide greater communication and consultation before and during the project (29%). • Carry out traffic management and road infrastructure (20%). • Provide compensation for farmers' and landowners' rights and cooperation (15%). • Assist local employment and support local business (13%).	• Assist local economic growth and job creation and use local businesses (52%). • Communicate, get involved and interact with the local community (23%). • Provide more facilities and infrastructure (14%). • Provide additional sources of water and reduce water wastage (12%) • Upgrade or maintain roads and railway (8%).

Source: Appendix P, Social Impact Assessment.
The percentages in brackets indicate the portion of respondents who supported each view. The respondents were able to support more than one view resulting in total numbers not equalling 100%.

Social impacts will be managed through the social impact management plan prepared by Arrow and attached to the EIS. The social impact management plan details the commitments – incorporated in action plans – made by Arrow to address the identified issues and impacts. A living document, the social impact management plan will be updated to incorporate further information, particularly the outcomes of programs and initiatives implemented by other proponents. This will enable a more measured and targeted response to the prevailing issues at the time Arrow embarks on this major expansion of its operations. See Box 17 for social mitigation measures.

Box 17 Social responsibility

The project will deliver a range of opportunities that increase direct and indirect employment, enhance training and skills development, provide local business opportunities and inject wealth and vitality into local communities. To ensure these opportunities are realised and adverse impacts are minimised, Arrow will:

- Maximise the positive benefits of the project through investment in community programs.
- Participate in forums convened by the Queensland Government to reduce the impact of escalating housing and living costs on communities of the region.
- Minimise additional demands on existing services and social infrastructure.
- Expand the opportunities available for the region under the Brighter Futures program and the Social Investment Plan
- Make a positive contribution to community wellbeing and livability through supporting community values and lifestyles.

As part of Arrow's Brighter Futures program, Arrow has partnered with other companies working in the region to provide a medivac service to respond to project-related and community emergencies. A helicopter with a supporting doctor and medics is based at Toowoomba (and also at Roma).

Arrow will continue to actively engage the community throughout the ensuing phases of the project to inform the responsible design, construction, operation and decommissioning of the Surat Gas Project, as part of an ongoing stakeholder engagement program.

6.12 Heritage

The project development area contains known and unknown Indigenous cultural heritage of the three clans – Wakka Wakka, Kamilaroi and Turubul – that are known to have inhabited the region for some 22,000 years. This may consist of artefacts and places that are significant to those Indigenous people and that have intrinsic archaeological and historic value.

Cultural material predominantly consists of stone artefacts and scar trees. The artefacts are concentrated in the most prospective areas for Indigenous cultural heritage, which occur along and adjacent to defined waterways (including lagoons), ridges, escarpments and rocky uplands. The Condamine River and Dogwood, Wongongera, Kogan, Braemar, Wilkie and Commoron creeks are highly prospective sites.

Barakula State Forest, the Chinchilla Sands Local Fossil Fauna Site and Lake Broadwater Conservation Park are listed on the Register of the National Estate as having Indigenous cultural heritage value, and nearly 500 places are listed on Queensland Government heritage databases. Arrow recognises that in addition to sites listed in cultural heritage databases, places and artefacts of significance to Indigenous persons may be encountered virtually anywhere in the project development area, particularly those areas that have not yet been developed.

With this understanding, Arrow proposes to meet its 'duty of care' obligations under Queensland legislation either through a suitable native title agreement or agreements that do not expressly exclude cultural heritage or through an approved cultural heritage management plan. Arrow proposes to seek approval of process and site management cultural heritage management plans to address the difficulties with a staged development.

The specific processes for management of cultural heritage will be formalised in the cultural heritage management plan and will include protocols for clearance surveys, avoidance of known places, monitoring of works areas, and courses of action to be taken when artefacts are discovered. The protocols will be implemented through the site management cultural heritage management plans, which will serve to minimise the impact on Indigenous cultural heritage places and artefacts, as well as to improve the knowledge of Indigenous cultural heritage in the project development area.

The post-European settlement cultural heritage of the project development area comprises memorials, monuments, and the remains of historical events and activities that are typically associated with the early settlement. All but one of the sites listed on the Queensland Heritage Register are located within towns, which will not be subject to petroleum activities. Wyaga Homestead, located between Millmerran and Goondiwindi, will be avoided. Chance finds during project activities will be subject to a protocol for investigation, assessment and management agreed to in consultation with the Queensland Heritage Office. See Box 18 for heritage mitigation measures.

Box 18 Conservation of heritage

Arrow's objective is to avoid or minimise disturbance by project activities to cultural heritage sites and artefacts. Key measures to achieve this objective include:

- Development and implementation of cultural heritage management plans in consultation with relevant authorities and Aboriginal parties.
- Implementation of a 'chance finds' procedure for the discovery of unknown sites during construction.
- Documentation of cultural heritage finds to preserve the area's history for future generations.

6.13 Preliminary Hazard and Risk

Coal seam gas is predominantly comprised of methane, which is flammable and, when confined, potentially explosive. In addition, methane can displace air, creating an oxygen-deficient atmosphere. These characteristics have the potential to impact on public safety and the safety of the project workforce.

The separation required from hazardous facilities and infrastructure to ensure public and worker safety was assessed in a quantitative risk assessment that considered three credible scenarios:

- Jet fires, involving a continuous release of gas under pressure producing a long, stable flame.
- Flash fire, where a flame travels through a cloud of gas in the open.
- Vapour cloud explosion of gas in a confined space.

A complementary qualitative risk assessment, which considered credible incident scenarios, has addressed project activities and processes, such as driving, the storage and handling of chemicals and fuel, construction methods and operating procedures.

Petroleum facilities are designed and engineered in accordance with international, Australian and industry-accepted standards. Examples include the routine installation of automatic and manual isolation valves (that limit the volume of gas available to feed any release or subsequent fire), the routine installation of automated emergency shutdown valves, and the periodic internal inspection of high-pressure steel pipelines to detect any evidence of corrosion. Threats from wildlife and natural disasters, such as bushfires, cyclones, floods, and earthquakes, are an integral part of the risk assessment.

Arrow's objective is to reduce residual risk to 'as low as reasonably practicable', an internationally recognised concept that is embodied in relevant Australian standards. Where this cannot be achieved purely through design, Arrow will apply procedural controls and behavioural programs. See Box 19 for hazard and risk mitigation measures.

Box 19 Hazard identification and risk management

Hazard identification and risk management is integral to Arrow's integrated health, safety and environmental management system. Arrow is committed to minimising the potential risks to employees, the community, property and the environment from activities associated with the Surat Gas Project.

Arrow plans to achieve this commitment through their high standards of occupational health and safety, and environmental management, which include:

- Detailed engineering design, construction and operation of facilities in accordance with relevant Australian and international standards and industry codes of practice.
- Implementation of safety buffer zones around facilities to minimise risks to the community and the surrounding environment.
- Tiered management of hazards through site and technology selection, the application of engineering, and procedural and behavioural controls.

6.14 Waste

Project activities will generate solid, liquid and gaseous waste streams; the potential impacts of which can be managed responsibly with the implementation of the standard waste hierarchy of avoidance, reuse, recycling and disposal.

Brine management has been discussed in Section 4.4.2, Management of Coal Seam Gas Water. See Box 20 for waste mitigation measures.

Box 20 Waste management

Arrow aims to minimise the release of any harmful substances to the air, water or the land through the responsible management of its wastes. Arrow is committed to:

- A waste management hierarchy based on avoidance, reuse, recycling, treatment and disposal.
- Minimising resource utilisation by reuse and recycling of waste.
- Reducing impacts to the environment from the management of waste.
- Reducing the quantity of waste that is sent to landfills by recycling and reuse of waste.

7 CUMULATIVE IMPACTS

The potential environmental, economic, social and cultural impacts identified in the EIS, when combined with the impacts of other developments in the region (Figure 14), will, in some instances, have a cumulative impact. The severity and duration of the cumulative impact will depend principally on the timing and duration of construction activities, as operations activities will, over time, establish a new equilibrium in supply and demand.

The geographic separation of known and proposed developments in the region will reduce the severity of some impacts, particularly where the impacts are concentrated at or near the project site. However, in some instances, this also serves to increase the severity of cumulative impacts, as activities are concentrated in the larger towns that provide the necessary infrastructure and services.

Environmental aspects that will experience cumulative impacts, the severity of which will be largely determined through environmental management at the site of disturbance, include:

- Terrestrial ecology through habitat fragmentation.
- Aquatic ecology through diminished water quality.
- Agriculture through disruption to farming activities and temporary or permanent loss of productive land.
- Visual amenity of the affected community through industrialisation of a rural landscape.

An often overlooked cumulative impact in rural areas is the availability of landfill for domestic and construction waste. Implementation of waste management strategies and consultation with municipal authorities will be required to ensure project activities do not prematurely exhaust available landfill capacity.

Three aspects of the environment are subject to potential impacts that will potentially have a significant cumulative impact and will require an integrated approach involving all proponents to ensure the impacts are managed to reduce their severity and duration. The aspects are groundwater, social and economic, and roads and traffic.

7.1 Groundwater

The expansive nature of groundwater systems in the Surat Basin will result in the individual impacts of projects drawing water from the same or interconnected aquifers combining to exacerbate the predicted impacts. This is particularly relevant for proposed coal seam gas developments but less relevant for proposed mining developments.

The potential cumulative impacts will manifest themselves as groundwater drawdown, land subsidence and groundwater contamination. Causes for the cumulative impacts include the extraction of groundwater and surface and subsurface activities (e.g., drilling of production wells) that could potentially contaminate groundwater.

The residual impacts from depressurisation of groundwater systems in the Surat Basin were determined by modelling. Figure 15 shows the predicted coal seam gas water extraction between the years 2011 and 2051 that formed the basis of the cumulative impact assessment modelling. The modelling considered impacts 10 years after the cessation of coal seam gas extraction to understand the recovery potential of the affected groundwater systems.

The results of the groundwater modelling for the Surat Gas Project alone and for all coal seam gas developments cumulatively are summarised in Table 11.

Table 11 Summary of cumulative unmitigated groundwater drawdown impacts

Groundwater System and Aquifer	Predicted Maximum Groundwater Drawdown – Surat Gas Project Only	Predicted Maximum Groundwater Drawdown – Cumulative
Shallow groundwater system (Condamine Alluvium)	More than 0.1 m to less than 1 m	2.5 m
Intermediate groundwater system (Kumbarilla Beds)	30 m	60 m
Coal seam groundwater system (Walloon Coal Measures)	More than 75 m	150 m
Deep groundwater system (Hutton Sandstone/Marburg Formation and Precipice Sandstone)	10 to 30 m	75 m

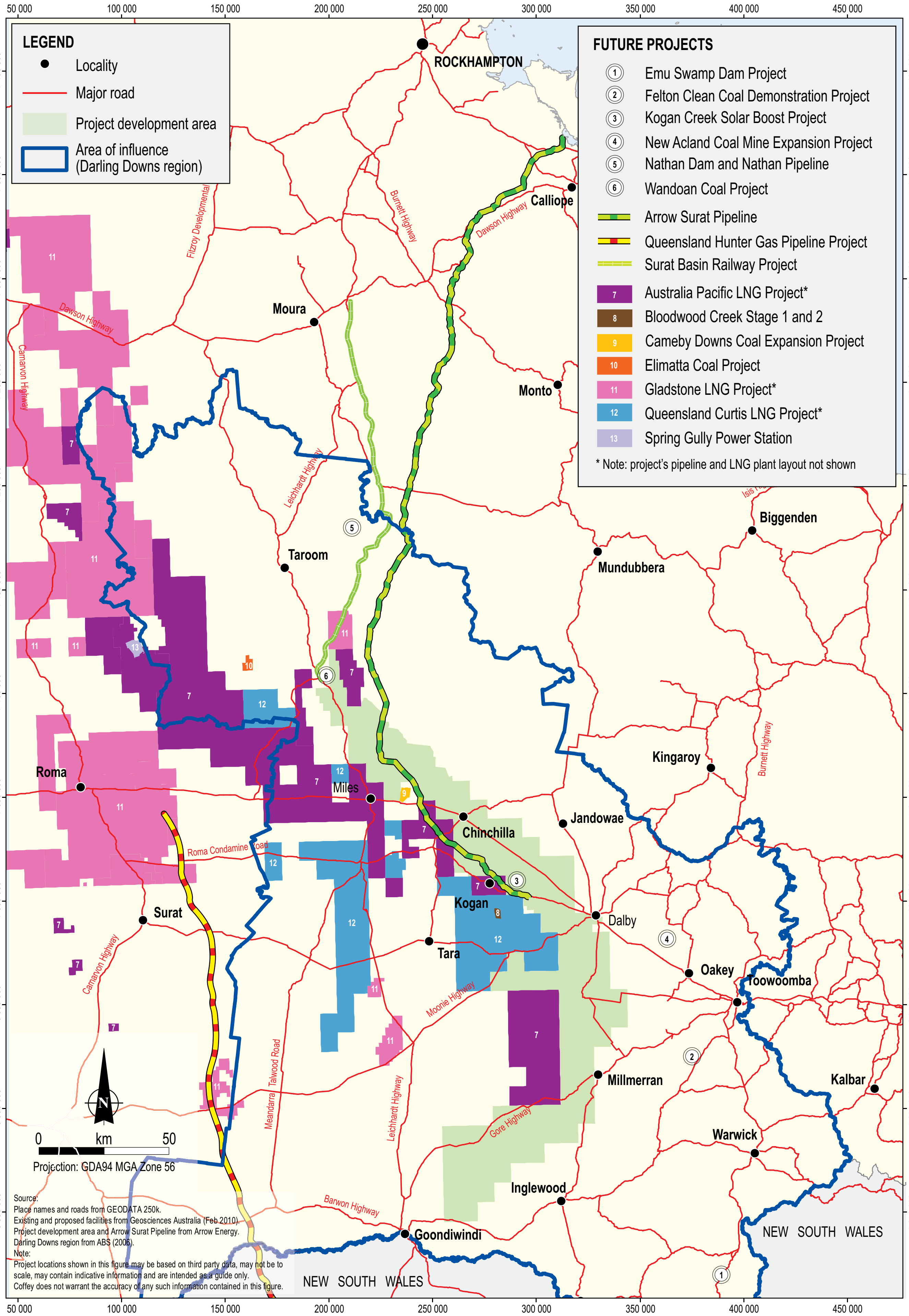
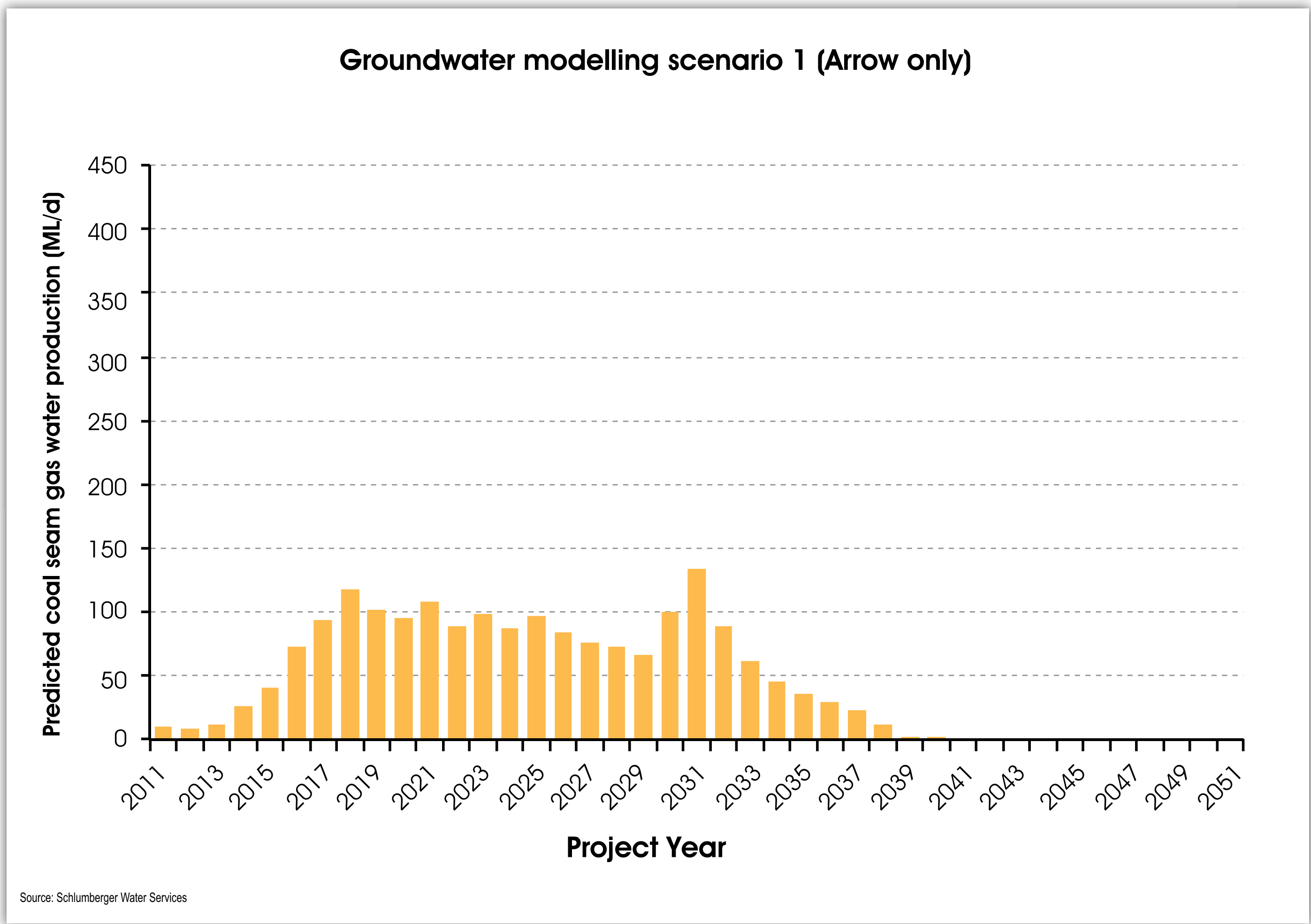


Figure 14 Projects considered relevant for regional cumulative impact assessment



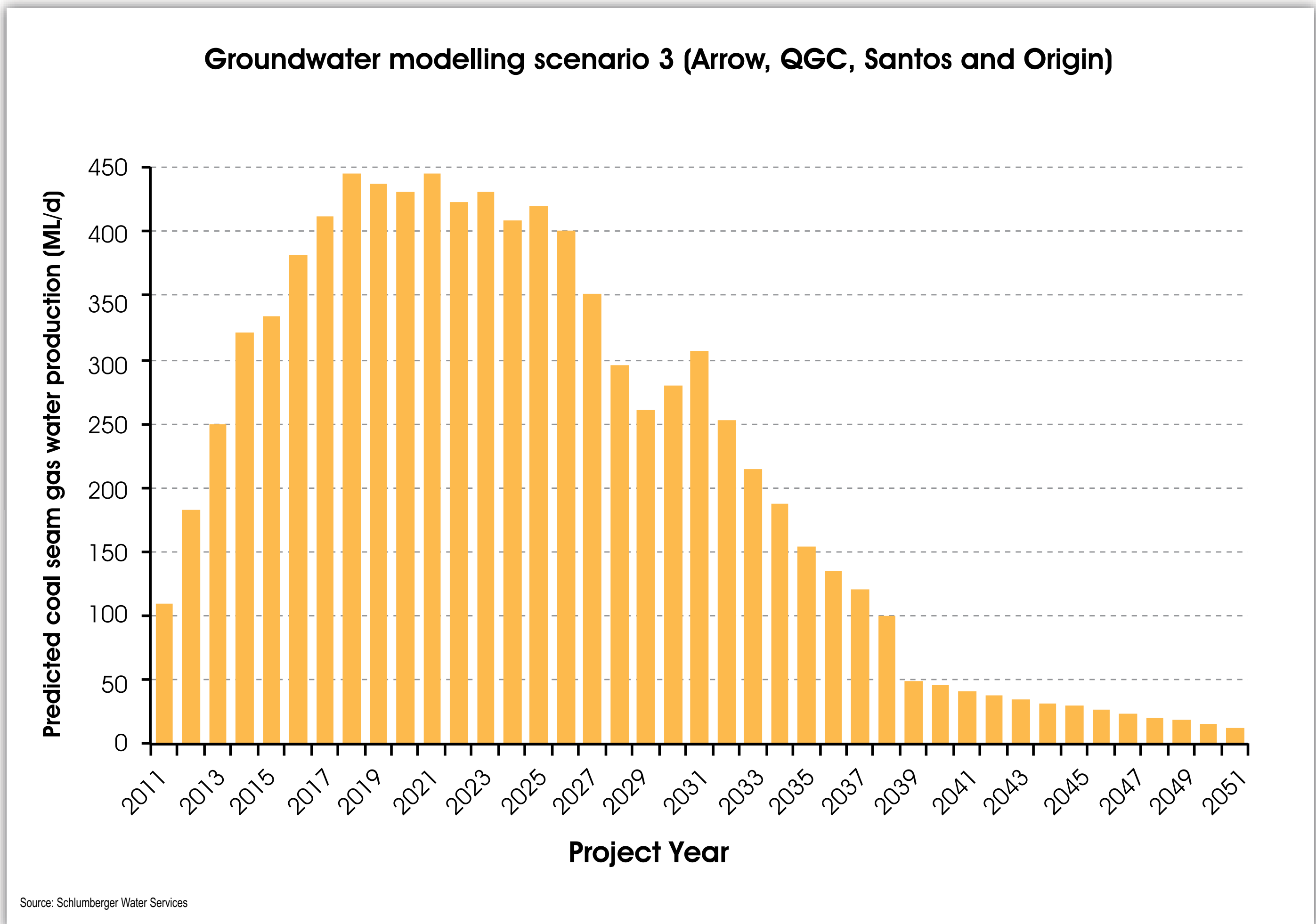


Figure 15 Total predicted coal seam gas water extraction – modelling scenarios 1 and 3

The Queensland Government, through conditions applied to other coal seam gas developments, has requested the Queensland Water Commission to facilitate the establishment of a regional groundwater monitoring network and oversee monitoring to facilitate adaptive management of groundwater resources in the area identified as the Surat Cumulative Management Area, which includes the project development area.

A technical advisory panel will be established to review the monitoring data quarterly and, along with an industry advisory panel comprising members from the coal seam gas industry and, more importantly, members from the agriculture, environment and community sectors, will advise the commission on appropriate responses to observed groundwater system behaviour.

Land subsidence is a potential impact of aquifer depressurisation, particularly in land overlying unconsolidated formations. The Walloon Coal Measures and most other groundwater systems within the project development area exist in consolidated formations, and consequently surface subsidence is unlikely. Contamination of groundwater systems from drilling and well workover activities, while possible, will be managed through effective implementation of existing industry procedures and drilling techniques.

7.2 Social and Economic

The social and economic impact assessment notes that proposed projects in the region are expected to amplify the impacts identified in the EIS. The impacts will be most pronounced in areas where several projects use a common service centre or where the hinterlands from which they draw services and labour overlap. Dalby, Chinchilla, Miles and Wandoan are expected to experience the most pressure for those reasons.

Adverse cumulative impacts are expected to manifest themselves in increased accommodation and housing costs, increased demand for health and community services, and increased competition for skilled labour with consequential impacts on local businesses. While the larger towns will be more resilient to change, it is expected smaller towns like Chinchilla and Wandoan will experience greater stresses, as they make the transition from principally supporting an agricultural base to supporting a diversified agricultural, commercial and industrial base.

The availability, conversion and development of land to meet the demand for residential, commercial and industrial zoned land is a notable cumulative impact, as the anticipated accelerated growth is expected to exceed previous forecasts of the volume and rate required to meet natural growth.

Coordination of the proponents' requirements, local government planning processes and Queensland Government regional development programs will be necessary to expedite bringing land onto the market and to ameliorate the short-term impacts on the affected communities. A detailed workforce accommodation strategy is expected to lessen these stresses during construction; but with a stated desire to employ locally and attract workers to the region, planning for the operations phase will need to be expedited to ensure the short-term stresses do not become long-term impacts.

Although relatively close to Brisbane, the Darling Downs, like most of rural Queensland, has generally struggled to attract skilled health professionals, particularly doctors and other specialists. Along with the demand for skilled labour (technicians and trades persons), this issue is perhaps the most difficult to address. Arrow and the other coal seam gas proponents will provide a range of emergency and first aid services at their sites, depots or camps and will fund the recently established aero-medical service based out of Roma with support from Toowoomba to, in part, address this issue. Participation by the proponents in Queensland government, local government, and coal seam gas industry forums will further assist the Queensland Government to develop and implement programs to attract health professionals and skilled labour to the region, as well as providing for training and apprenticeships.

The social impact management plan includes commitments that action the summarised management measures. Periodic updates of the social impact management plan will ensure experience from developments already under way will enable existing and proposed programs to be refined to maximise the benefits to the community.

The Surat Gas Project and other mining and coal seam gas projects will also have positive cumulative effects. The economic benefits of increased government revenue, improved balance of trade, increased household income, increased employment and business opportunities, and greater diversity of the economic base are expected to increase the overall prosperity of the region. The economic activity is expected, over time, to provide tangible social benefits in improved levels of government and community services, a less volatile housing and accommodation market (insulated from rural downturns and construction-phase pressures), and more locally based technical and industrial services.

7.3 Roads and Traffic

While generally geographically separate, proposed coal seam gas and mining developments in the region rely on the arterial road network that connects the region to Brisbane and major centres along the Queensland coast and to the major towns within the region.

Modelling conducted as part of the EIS indicates Surat Gas Project–generated traffic will be within expected natural growth across the region. The EIS states that some roads will experience increased traffic during the construction of production facilities. These localised impacts will be exacerbated when taken into consideration with the other proposed developments.

Roads expected to experience increased traffic are:

- Warrego Highway from Toowoomba to Miles.
- Chinchilla–Tara Road southwest of Chinchilla to Kogan–Condamine Road.
- Dalby–Kogan Road from Dalby to Kogan.
- Kogan–Condamine Road to Chinchilla–Tara Road.
- Moonie Highway southwest of Dalby to the Surat Developmental Road.

Increased traffic will affect the efficiency of the road network and the safety of road users. It might also accelerate deterioration of road formations and pavements. The Queensland Government is facilitating a strategic review of roads and traffic in the region in conjunction with coal seam gas and mining proponents to better understand the overall impacts on the road network. This will enable road safety and programmed and unplanned upgrade works to be prioritised to ensure the efficiency of the road network is maintained and the safety of road users is protected.

8 ENVIRONMENTAL MANAGEMENT

Environmental management of Arrow's coal seam gas development will be achieved through maintenance of an environmental management system, integration of the environmental framework (see Section 8.2) with that system, and the development and implementation of environmental management plans for construction and operations activities.

8.1 Environmental Management System

Arrow maintains an integrated health, safety and environmental management system (HSEMS) based on the principles of international standard ISO 14001, Environmental Management Systems - Requirements with Guidance for Use (ISO,1996), and Australian and New Zealand standard AS/NZS 4801:2001, Occupational Health and Safety Management Systems - Specification with Guidance for Use (Standards Australia, 2001).

The HSEMS incorporates an environmental policy that sets out Arrow's approach to the management of health, safety and the environment. Arrow's environmental policy will be implemented by:

- Seeking continuous improvement in managing significant environmental impacts by clearly defining objectives and targets and evaluating them through transparent review and implementation processes.
- Establishing programs to reduce environmental impacts, conserve and recycle resources, reduce waste and pollution, and improve processes to help protect the natural environment, as well as monitoring and measuring performance.
- Ensuring all activities comply with all applicable environmental laws and regulations.
- Promoting a culture in which employees and service providers are aware of environmental impacts affecting their work and promptly report any environmental impacts or incidents and that encourages improvements.
- Monitoring policy implementation at all relevant Arrow-controlled workplaces and periodically reviewing and updating.

The roles and responsibilities of Arrow in ensuring the performance of its employees and contractors is set out in Table 12.

8.2 Environmental Framework

Arrow has been developing coal seam gas resources for over 10 years and has a good understanding of the construction, operations and maintenance activities required to produce and transport gas and to treat water. This knowledge, coupled with exploration and pilot well results, informs gas field development planning, which will be staged over the life of the project, which is expected to be at least 30 years. A consequence of this process is uncertainty about the ultimate location of production wells and facilities and pipelines, i.e., where and when development will occur.

Arrow's environmental framework seeks to reduce the uncertainty about potential impacts of coal seam gas development by identifying environmental constraints to development and proposing environmental management controls that will apply to development, if it were to occur in a particular area. Environmental constraints to development are derived from the sensitivity of the environmental values identified in the EIS, with more sensitive values imposing a higher level of constraint. Constraints that can be defined spatially (e.g., endangered vegetation communities) are maintained in the project geographic information system and presented in maps. These include separation distances to ensure public health and safety, particularly from air emissions, noise and hazardous facilities.

The level of environmental constraint determines the types of activities permitted and the applicable environmental management measures as set out in Table 13.

Table 12 HSEMS roles and responsibilities

Role	Responsibility
Chief Executive Officer	• Performance of Arrow • Corporate environmental policy • Fostering a partnership that promotes 'ownership' of Arrow's environmental responsibilities
Chief Operating Officer	• Implementation of corporate and environmental policy • Systems and resources to ensure compliance with environmental policy
Vice President Health, Safety, Sustainability and Environment	• Performance measurement and reporting, including recommendations for improvement and corrective actions
General Manager: (Environment and Water)	• Authorised officer for signing environmental documentation • Ensuring management and monitoring practices and procedures are documented and clearly communicated within the organisation
General Manager: (Assets)	• Implementation of management and monitoring practices and procedures in all operation areas • Resourcing • Accountable for compliance
Environment managers	• Environmental approvals management • Development of operational procedures and practices relevant to the environment • Coordinating incident response • Reporting and compliance related issues
All site and field personnel	• Environmental approvals management • Development of operational procedures and practices relevant to the environment • Coordinating incident response • Reporting and compliance-related issues • Training in and implementing procedures, including those that address environmental management, at a site/operational level • Overseeing day to day activities • Carrying out specific activities that ensure compliance with environmental authority conditions, including monitoring and data collection

Table 13 Permissible project activities based on level of constraint

Level of Environmental Constraint	Environmental Management Control	Project Activity		
		Wells	Gathering Systems	Production Facilities
No go	Not applicable	No	No	No
High	Site-specific environmental management measures	Yes	Yes	No
Moderate	Specific environmental management measures	Yes	Yes	Yes
Low	Standard environmental management measures	Yes	Yes	Yes

Environmental management measures will be developed and incorporated in Arrow's HSEMS, which will provide the policy, management and audit framework for construction and operations environmental management plans. The measures will include a standard operating procedure that will describe the process and frequency of updates to the constraints maps, which are integral to the site and route selection standard operating procedure already being used by Arrow to plan development. The relationship between the environmental framework and Arrow's HSEMS and the key information flows are shown in Figure 16.

The environmental framework is an essential consideration in the planning process for coal seam gas field development. This planning process covers a range of activities which take approximately five years. The way in which the environmental framework is integrated with the planning process is set out below:

- **Step 1:** Analysis of geological and geophysical data to inform exploration program, including location of exploration wells. Exploration drilling program.
- **Step 2:** Analysis of exploration data. Installation of pilot wells to prove coal seam gas yields and coal seam gas water production.
- **Step 3:** Conceptual and preliminary design of gas field. Land access negotiations with landowners initiated. Consultation with landowners and key stakeholders on gas field development. Ecological and cultural heritage preconstruction clearance surveys and geotechnical investigations.
- **Step 4:** Detailed design of gas field and production facilities. Ongoing land access negotiations.
- **Step 5:** Detailed design of gas field and production facilities, revision or development of work plans, preparation of site-specific environmental management plans. Land access arrangements finalised.

8.3 Environmental Management Plans

An environmental management plan that incorporates the mitigation measures (commitments) proposed to address the potential environmental and cultural impacts of the Surat Gas Project is attached to the EIS. The social impact management plan that proposes measures to address social impacts of the proposed development is also attached to the EIS.

The environmental management plan attached to the EIS will form the basis of a series of environmental management plans: an EM Plan to support an environmental authority application and environmental management plans for construction activities and for operations and maintenance activities.

Arrow will apply to amend its current project environmental authority by preparation of an EM Plan that specifically addresses the requirements set out in the Department of Environment and Resource Management guideline 'Preparing an Environmental Management Plan for Coal Seam Gas Activities'. The project environmental authority is the principal regulatory document and sets out the conditions that apply to the construction and operation of the coal seam gas fields.

Management plans will be prepared by Arrow or its contractors for management of the identified environmental, cultural and social impacts during construction. Standard operating procedures or similar documents incorporated in Arrow's HSEMS will detail environmental management measures for operations and maintenance activities and will also be incorporated in or form the basis for construction environmental management plans.

Accountability for implementation of the environmental management measures and environmental management plans rests with Arrow, and it will ensure the performance of contractors through conditions in contracts.

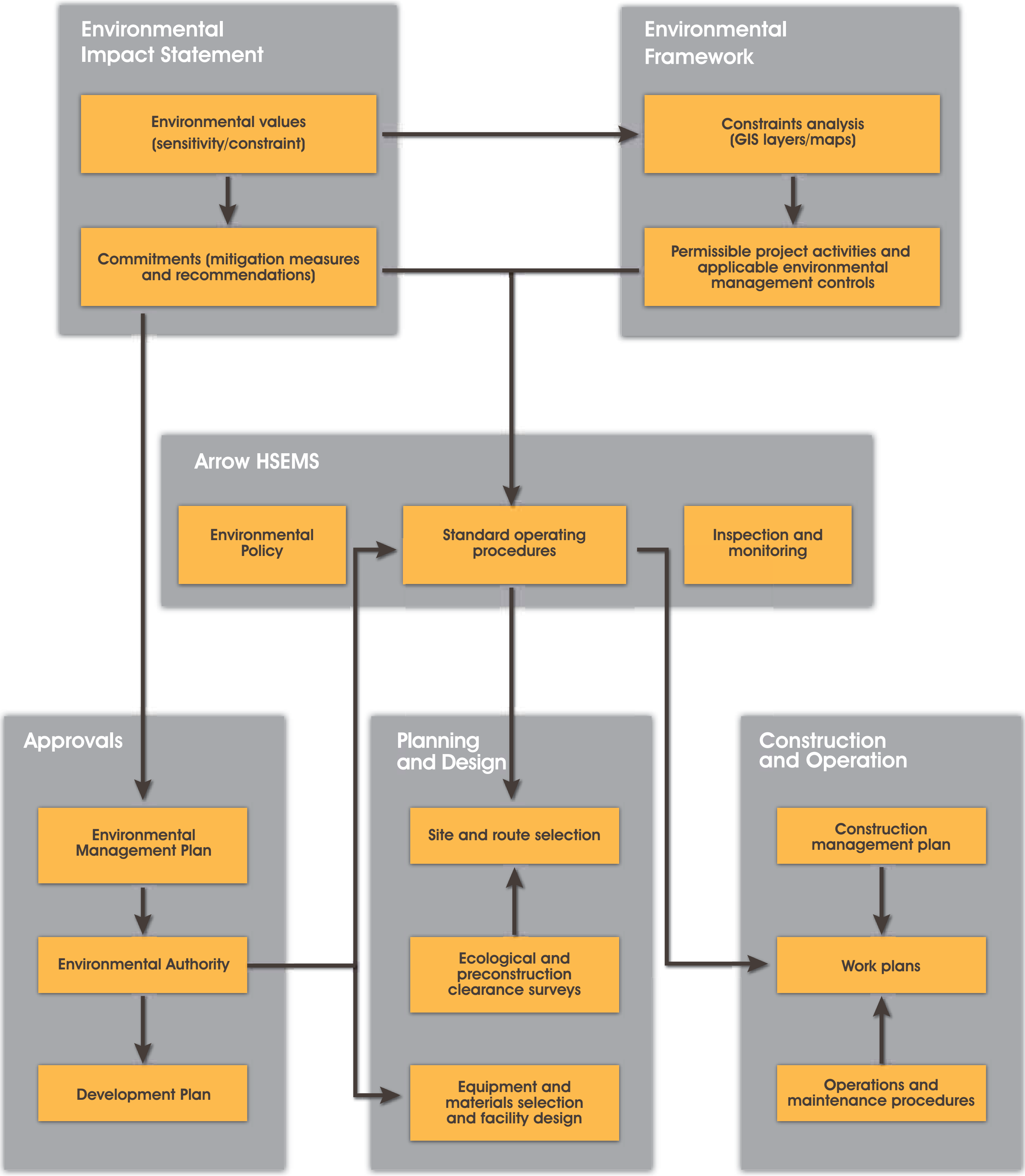


Figure 16 Relationship of the environmental framework to the Arrow HSEMS

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10 SUBMISSIONS

The EIS has been publically notified and the Chief Executive of DERM has allowed a 60 business day period for acceptance of public submissions on the EIS. The Chief Executive must accept all properly made submissions and may accept submissions even if they are not properly made.

It is a statutory requirement that all submissions will be forwarded to the proponent for consideration and provision of a response to DERM. The Chief Executive of DERM may require the Proponent to prepare responses to properly made submissions on the EIS.

The requirements for making a submission and the address to which all submissions, comments and enquiries regarding this EIS process should be sent are provided in Box 21.

Box 21 Requirements for public submissions

Submissions must:

- Be written and signed by or for each person (signatory) who made the submission.
- State the name and address of each signatory.
- Be made to the Chief Executive of DERM.
- Be received on or before the last day of the submission period.

Submissions will be forwarded to the proponent for consideration and provision of a response to DERM.

Submissions should be addressed to:

The Chief Executive

State-wide Impact Assessments

Department of Environment and Resource Management

Attention: The EIS Co-ordinator (Surat Gas Project)

Floor 3, 400 George Street, BRISBANE, QLD, 4000

GPO Box 2454, 400 George Street, BRISBANE, QLD, 4001

Guide to the EIS Volumes

Component	Volume	Title
Executive Summary		
Executive Summary	Stand alone	Executive Summary
EIS Main Report & Attachments		
Main Report	1 and 2	Main Report
Attachment 1	2	Surat Gas Project Final Terms of Reference
Attachment 2	2	Cross-reference with the Final Terms of Reference
Attachment 3	2	Matters of National Environmental Significance
Attachment 4	2	Project Relevant Legislation
Attachment 5	2	Environmental Management Plan
Attachment 6	2	Social Impact Management Plan
Attachment 7	2	Ecologically Sustainable Development
Attachment 8	2	EIS Commitments Summary
Attachment 9	2	Coal Seam Gas Water Management Strategy
Attachment 10	2	Constraints Maps
Supporting Studies		
Appendix A	3	Land Use and Planning Assessment
Appendix B	3	Consultation Report
Appendix C	3	Air Quality Impact Assessment
Appendix D	4	Greenhouse Gas Impact Assessment
Appendix E	4	Geology, Landform and Soils Impact Assessment
Appendix F	4	Agricultural Report
Appendix G	4	Groundwater Impact Assessment
Appendix H	5	Surface Water – Part A: Fluvial Geomorphology and Hydrology Impact Assessment
Appendix I	5	Surface Water – Part B: Water Quality Impact Assessment
Appendix J	5	Aquatic Ecology Impact Assessment
Appendix K	6	Terrestrial Ecology Impact Assessment
Appendix L	6	Landscape and Visual Impact Assessment
Appendix M	7	Road Impact Assessment
Appendix N	7	Noise and Vibration Impact Assessment
Appendix O	7	Economic Impact Assessment
Appendix P	7	Social Impact Assessment
Appendix Q	7	Aboriginal Cultural Heritage Impact Assessment
Appendix R	7	Non-Indigenous Heritage Impact Assessment
Appendix S	7	Preliminary Hazard and Risk Assessment

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