Joanne Kerr

From: sch4p4(6) Personal in <sch4p4(6) Personal i@arrowenergy.com.au>
Sent: Tuesday, 5 February 2013 3:40 PM
To: Keara Mcdonagh
Subject: RE: Notice of Additional Information Request for DXP PL230 amendment application to allow for a brine dam within a cat C ESA buffer

Follow Up Flag: Follow up
Flag Status: Completed

Hi Keara, I am hoping to have this to you just after lunch tomorrow.

Cheers

sch4p

From: Keara Mcdonagh [mailto:Keara.Mcdonagh@ehp.qld.gov.au]
Sent: Tuesday, 5 February 2013 12:47 PM
To: sch4p4(6) Personal in
Cc: Naylor Gillian; John.Frankish@ehp.qld.gov.au
Subject: FW: Notice of Additional Information Request for DXP PL230 amendment application to allow for a brine dam within a cat C ESA buffer

Hi sch4p,

Regarding the DXP amendment application for a brine dam within a cat C ESA buffer.

Just wondering if you know how long Arrow might need to compile/submit the additional information requested as the decision due date is on Thursday. I'm in the process of preparing an extension notice, if needed.

Thanks,

Keara.

From: Keara Mcdonagh
Sent: Thursday, 31 January 2013 4:37 PM
To: sch4p4(6) Personal in
Cc: Naylor Gillian; Frankish John (John.Frankish@ehp.qld.gov.au)
Subject: Notice of Additional Information Request for DXP PL230 amendment application to allow for a brine dam within a cat C ESA buffer

Good afternoon sch4p,

I email regarding Arrow Energy's amendment application for a brine dam within a category C ESA buffer on PL230 under Arrow's Dalby Expansion Project (PEN100449509).

Please find attached a Notice of Additional Information Request for the above mentioned application.

The decision due date is currently 7 February 2013. Please give a date as to when Arrow will provide the additional information requested.

If you have any questions, please do not hesitate to contact me by email or on (07) 3330 5618.

Kind regards,

Keara McDonagh

Environmental Officer

Energy Assessments Unit

Department of Environment and Heritage Protection (EHP)

Level 7, 400 George Street, Brisbane QLD 4000 | GPO Box 2454, BRISBANE QLD 4001

T: 07 3330 5618

F: 07 3330 5634

E: keara.mcdonagh@ehp.qld.gov.au

W: http://www.ehp.qld.gov.au

Please consider the environment before printing this email.

Environmental Management Plan

(Tenures 194, 198, 230, 238, 252, 258 and 260)

ARROW ENERGY PROPRIETARY LIMITED

ENVIRONMENTAL MANAGEMENT PLAN FOR THE DALBY EXPANSION PROJECT

Disclosure to third parties

The reports and documents disclosed are the property of Arrow Energy Proprietary Limited (and its related and subsidiary companies) (collectively Arrow Energy) and are provided to the Department of Environment and Heritage Protection solely for the purposes of determining the application. Except to the extent that the accompanying reports and documents are to be available to third parties pursuant to the public access provisions of the *Environmental Protection Act 1994* or any other Act or Regulation requiring disclosure to a particular third party, Arrow Energy requests that the reports and documents are not disseminated to third parties unless that party has made a valid application for the release of the report or documents pursuant to the *Right to Information Act 2009* and Arrow Energy has been given a reasonable right to respond to the request for documents considered for release.

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LIST OF APPENDICES

1. INTRODUCTION

Arrow Energy (Arrow) intends to increase the production capability of coal seam gas reserves within the Surat Basin. This expansion consists of an initial project development in the vicinity of existing gas fields near the township of Dalby in Southern Queensland. The project, known as the Dalby Expansion Project (DXP), is detailed in Section 3 of this document. Further expansion of production capabilities is proposed as part of a larger development known as the Surat Gas Project. A voluntary Environmental Impact Statement (EIS) for the proposed Surat Gas Project development was submitted to the former Department of Environment and Resource Management (DERM) in February 2012 and will form the basis of an additional EA application.

This Environmental Management (EM) Plan provides project specific information regarding potential environmental impacts and proposed mitigation measures associated with an expansion of DXP operations. Pursuant to Section 310U of the *Environmental Protection Act 1994* (EP Act), this EM Plan has been prepared in support of an application to DEHP to amend the existing Environmental Authority (EA) for the DXP (PEN100449509). This amendment reflects changes to Arrow's proposed operations and requests changes to specific current EA conditions.

Arrow is the holder of seven Petroleum Leases (PLs) located west of Dalby (Figure 1). Petroleum activities on these PLs (PL194, PL198, PL230, PL238, PL252, PL258 and PL260) are at varying stages of development for the exploration, appraisal, production and transportation of coal seam gas. Arrow is currently authorised to conduct petroleum activities on these tenures under existing EA PEN100449509 (Appendix A).

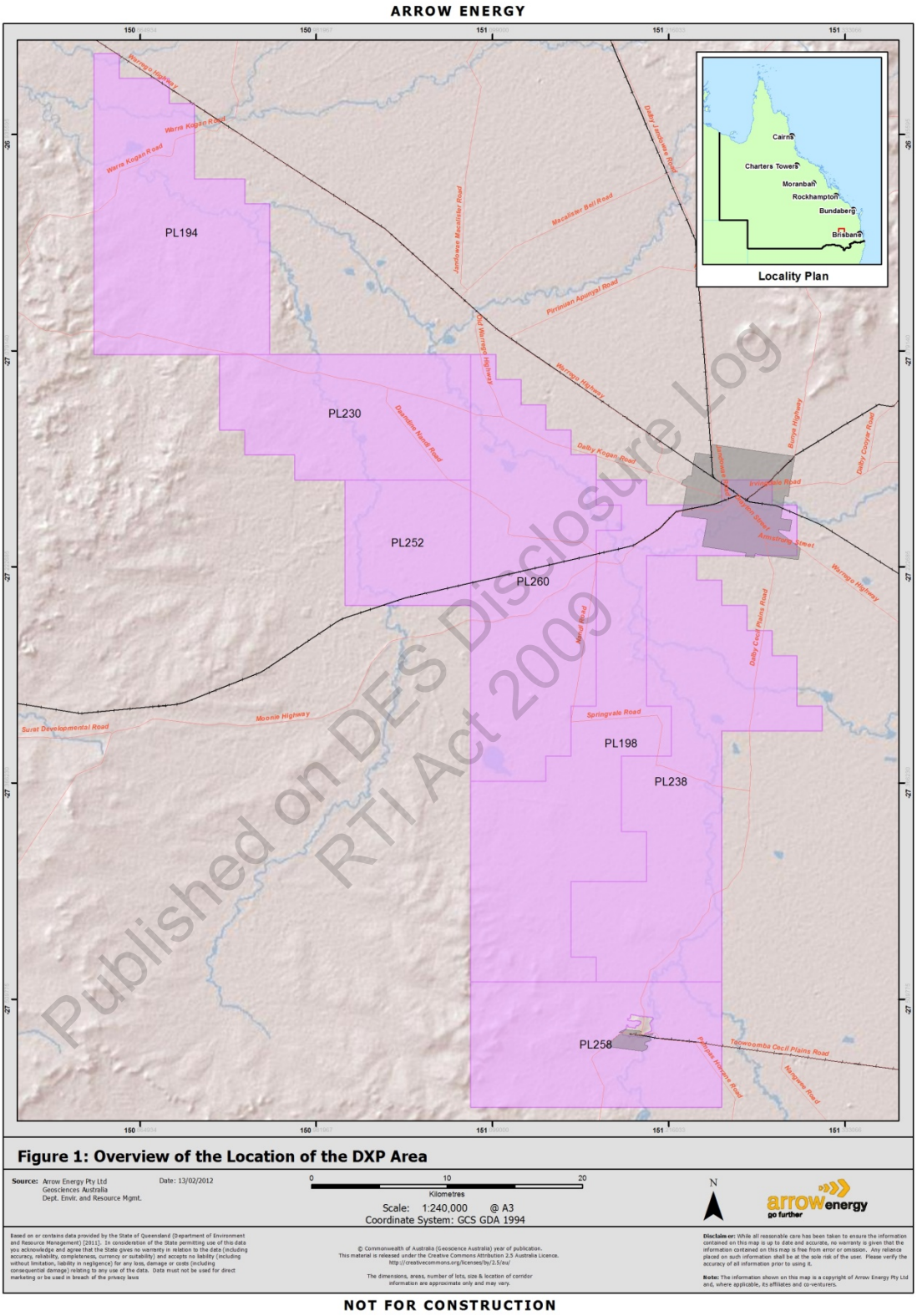


Figure 1: Overview of the Location of the DXP Area

1.1 PROJECT PROPONENT

Arrow is an integrated energy company with interests in coal seam gas field developments, pipeline infrastructure, electricity generation and a proposed liquefied natural gas (LNG) project.

Arrow is a Queensland-based wholly owned subsidiary of Arrow Energy Holdings Pty Ltd, representing 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 has had a presence in Australia since 1901. Current operations include petroleum refining, sale of petroleum products and retail businesses. The company maintains equity in the exploration and development of large gas resources off the coasts of Western Australia and the Northern Territory. Royal Dutch Shell is an internationally recognised leader in LNG production and has delivered some of the world's largest and most complex LNG projects, including facilities in Qatar, Nigeria, Russia and Southeast Asia. Through its subsidiary, Shell International Trading and Shipping Company Limited, Royal Dutch Shell 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, being one of the world's largest oil companies. PetroChina was incorporated as a joint stock company in 1999 and has extensive experience in exploration, refining and marketing of oil and natural gas in China and other countries.

Arrow has interests in more than 65,000 km^2 of petroleum tenures, mostly within Queensland's Surat and Bowen basins. The company has interests in the Clarence-Moreton (including northern New South Wales), Coastal Tertiary, Ipswich, Styx and Nagoorin Graben basins.

Arrow's petroleum tenures are located close to Queensland's three key energy markets: Townsville, Gladstone and Brisbane. The Moranbah Gas Project in the Bowen Basin and the Tipton West, Daandine, Kogan North and Stratheden projects in the Surat Basin near Dalby comprise Arrow's existing coal seam gas production operations. These existing operations account for around 20% of Queensland's overall domestic gas production. Arrow's tenures are shown on Figure 2.

Arrow supplies gas to the Daandine, Braemar 1 and 2, Townsville and Swanbank E power stations, which participate in the National Electricity Market. With Arrow's full ownership of Braemar 2 and commercial arrangements in place for Daandine and Townsville power stations, Arrow has the ability to supply approximately 600 MW of power generation capacity.

In addition, Arrow has a joint venture partner, Stanwell, for PL 194.

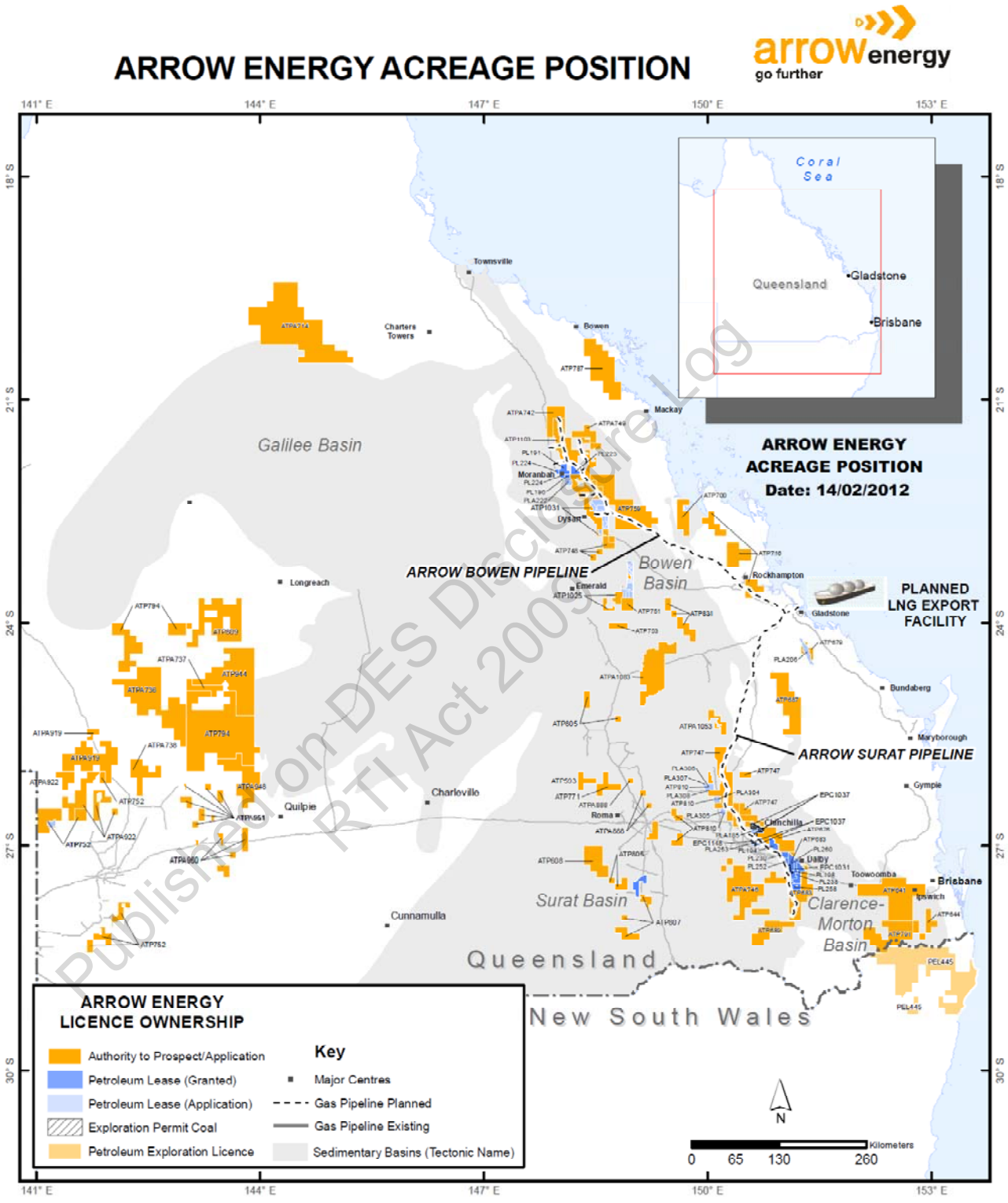


Figure 2: Overview of Arrow Energy Petroleum Acreage in Queensland

2. PURPOSE AND SCOPE OF EM PLAN

2.1 PURPOSE

This EM Plan and accompanying appendices have been prepared to fulfil the legislative information requirements stipulated in Section 310U of the EP Act. The purpose of the EM Plan is to provide Department of Environment and Heritage Protection (DEHP) (formerly DERM) with sufficient information to enable DEHP to assess the application and determine suitable conditions to be applied to the amended EA.

This EM Plan provides a description of the proposed activities within the DXP area and their potential impacts on the environment.

2.1.1 EM Plan Scope

This EM Plan describes Arrow's approach to the management of potential environmental impacts associated with the current and future exploration, appraisal and production of coal seam gas as part of the DXP. This EM Plan has been developed in accordance with the DERM guideline entitled 'Preparing an environmental management plan for coal seam gas activities', dated 31 March 2010, and the provisions of Section 310D of the EP Act.

Specifically, this document is structured to:

- Provide an introduction to the project, identify the relevant resource authorities and outline the financial assurance requirements.
- Describe Arrow's health, safety and environmental management system (HSEMS).
- Outline existing and proposed activities on the DXP highlighting changes that have occurred since the project was first approved in December 2010 (the current EA PEN100449509 was issued on 17 December 2010 and then revised in June 2011).
- Describe the existing environment within the DXP area, including the identification of the relevant environmental values.
- Identify potential impacts arising from the petroleum project activities on the identified environmental values.
- Describe environmental management measures to minimise the identified potential environmental impacts.

A summary of the specific requirements of the EM Plan within Section 310D of the EP Act including references to where these requirements are addressed in the EM Plan are presented in Table 1below.

This EMP is also accompanied by a CSG Water Management Plan (WMP) for activities in the Surat Basin, Queensland. The plan is entitled 'Arrow Energy Coal Seam Gas Water Management Plan – Surat Basin (refer to Appendix E) and has been developed in accordance with the EHP "Guideline for Preparing an Environmental Management Plan for CSG Activities" and the Queensland government's Coal Seam Gas Water Management Policy.

Arrow has developed a CSG Water Management Strategy, also provided in Appendix F, to define and communicate the management framework for CSG water. This strategy and the associated CSG water management plans for individual projects have been developed to maximize beneficial use and minimize the environmental impacts associated with waster use and disposal.

Table 1 Requirements of Section 310D of the EP Act

EM Plan Requirement	Section Reference
Description of the relevant resource authority for the environmental authority	Section 1
Description of all relevant activities that are the subject of the application	Section 3
Description of the land on which the activities are to be carried out	Section 1
Description of the environmental values likely to be affected by the activities	Sections 4 to 12
Description of the potential adverse and beneficial impacts of the activities on the environmental values	Sections 4 to 12
State the quantity of coal seam gas water reasonably expected to be generated in connection with carrying out each relevant coal seam gas activity	Arrow Energy Coal Seam Gas Water Management Plan – Surat Basin (Appendix E)
State the flow rate at which the applicant reasonably expects the water will be generated	
Describe the quality of the water, including changes in the water quality that the applicant reasonably expected will happen while each relevant coal seam gas activity is carried out	
Discuss the proposed management of the water including the use, treatment, storage or disposal of the water	Arrow Energy Coal Seam Gas Water Management Strategy (Appendix F)
State the measurable criteria against which the effectiveness of the management of the water will be monitored and assessed	
State the action that is proposed to be taken, if any of the management criteria are not satisfied, to ensure that criteria will be able to be satisfied in the future	
State environmental protection commitments for activities to protect or enhance the environmental values under best practice environmental management	Sections 4 to 13
Present enough other information to allow the administering authority to decide the application and conditions to be imposed on the environmental authority	Sections 1 to 14
Address any other matter prescribed under an environmental protection policy or regulation	Sections 1 to 14
Include a rehabilitation program for land proposed to be disturbed under each relevant resource authority for the application	Section 14
Propose an amount of financial assurance for the environmental authority.	Section 2.6

2.2 ENVIRONMENTAL AUTHORITIES AND ENVIRONMENTALLY RELEVANT ACTIVITIES

Arrow is the holder of the Level 1 EA PEN100449509 (Appendix A). Pursuant to Section 310U of the EP Act, Arrow is applying to amend EA PEN100449509 to provide for revised project activities and associated infrastructure. These existing and revised project activities are further discussed in Section 3.

It is intended that EA PEN100449509 will remain a level 1 EA as prescribed under section 23(1) of the *Environmental Protection Regulation 2008.* In addition to the Chapter 4 ERA's already approved this application proposes inclusion of ERA 58 – regulated waste treatment.

Petroleum activities under Schedule 5 item 8 are required under this application.

The following table lists all Chapter 4 ERA's (both current and proposed) which will apply to the DXP.

Table 2: Chapter 5 item 8 - Applicable Chapter 4 ERA's

ERA	Description	Applicable Project Activities
ERA 8 – chemical storage	10 m^3 or more of chemicals of class C1 or C2 combustible liquids under AS 1940 (Standards Australia, 2004b) or dangerous goods class 3.	Storage of chemicals.
ERA 14 – electricity generation	Electricity generation (the relevant activity) consists of generating electricity by using gas at a rated capacity of 10 megawatt (MW) electrical or more.	Power generation to supply gas compression and water treatment facilities.
ERA 15 – fuel burning	Fuel burning (the relevant activity) consists of using fuel-burning equipment that is capable of burning at least 500 kg of fuel in an hour.	Compressor units, generators, power generation, etc.
ERA 58 – regulated waste treatment	Regulated waste treatment (the relevant activity) consists of operating a facility for receiving and treating regulated waste or contaminated soil to render the waste or soil non-hazardous or less hazardous.	Coal seam gas water treatment, solid waste treatment.
ERA 60 – waste disposal	Operating a facility for disposing of more than 200,000 t of regulated waste.	Temporary storage of waste; both solid and liquid.
ERA 63 – sewage treatment	Operating one or more sewage treatment works at a site that has a total daily peak design capacity of more than 21 equivalent persons.	Sewage treatment facilities at construction camp sites or at production facility sites.
ERA 64 – water treatment	Water treatment (the relevant activity) consists of carrying out any of the following activities in a way that allows waste, whether treated or untreated, to be released into the environment: a. Desalinating 0.5 ML or more of water in a day. b. Treating 10 ML or more of raw water in a day. c. Carrying out advanced treatment of 5 ML or	Coal seam gas water treatment process.

	more of water in a day.	

2.2.1 Notifiable Activities

Notifiable activities are activities listed in Schedule 3 of the EP Act. Under the Act, landowners and local governments must inform DEHP that land has been or is being used for a notifiable activity. Land that has been or is being used for a notifiable activity is recorded on the Environmental Management Register (EMR), which is maintained by DEHP.

Where notifiable activities are identified, Arrow will submit the appropriate notifications in accordance with legislative requirements.

2.3 PETROLEUM TENURE

The DXP is located west of Dalby. A map presenting the location and general details of these petroleum tenures are shown in Figure 1.

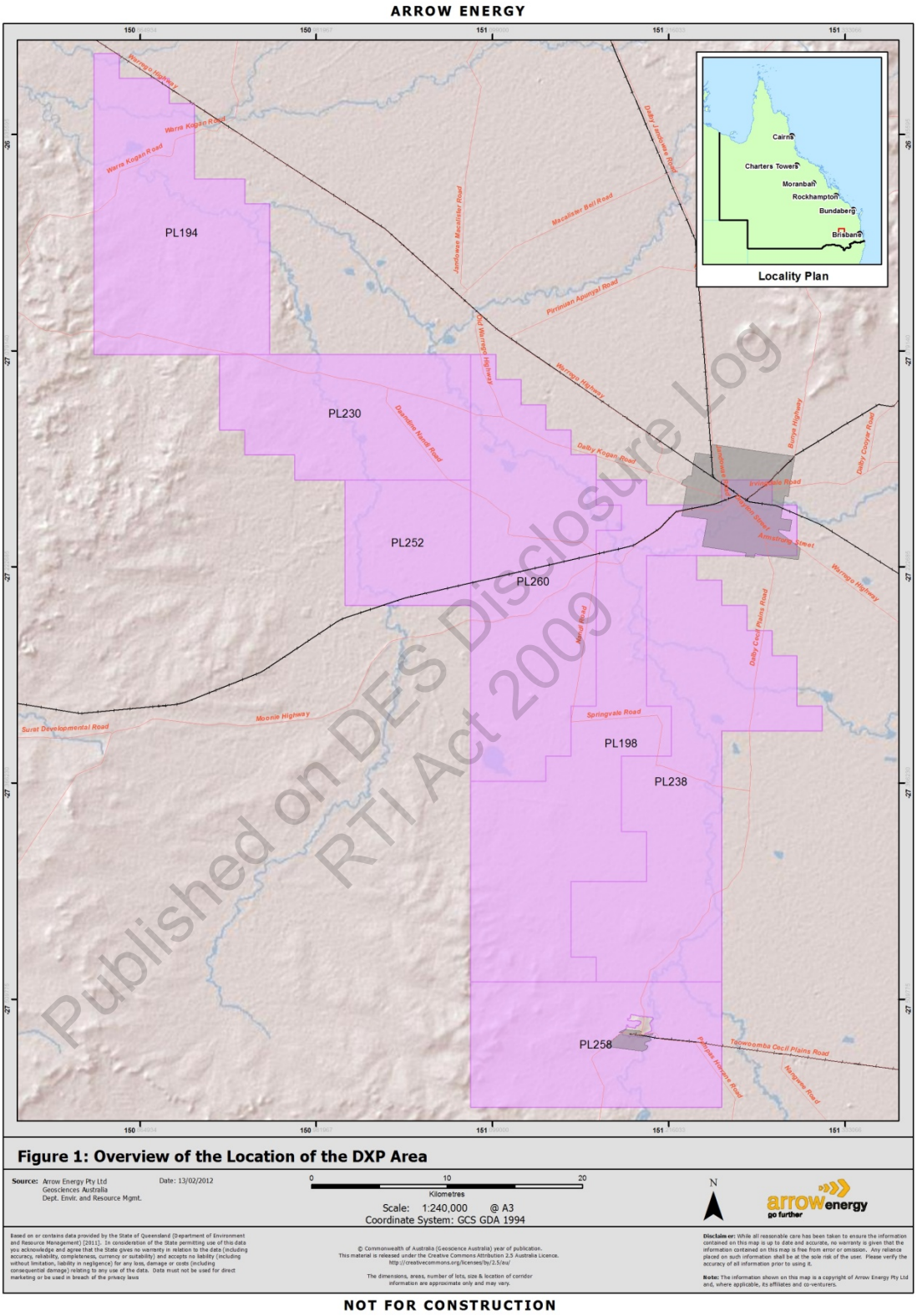


Figure 1: Overview of the Location of the DXP Area

NOT FOR CONSTRUCTION

Figure 1The DXP extends approximately 45 km south, 30 km north and 50 km west of Dalby. The DXP covers an approximate area of 127,103 hectares and is comprised of a

total of 417 Block Identification Map (BIM) sub-blocks. The area and relevant sub-blocks for each of the DXP tenures are shown in Figure 3.

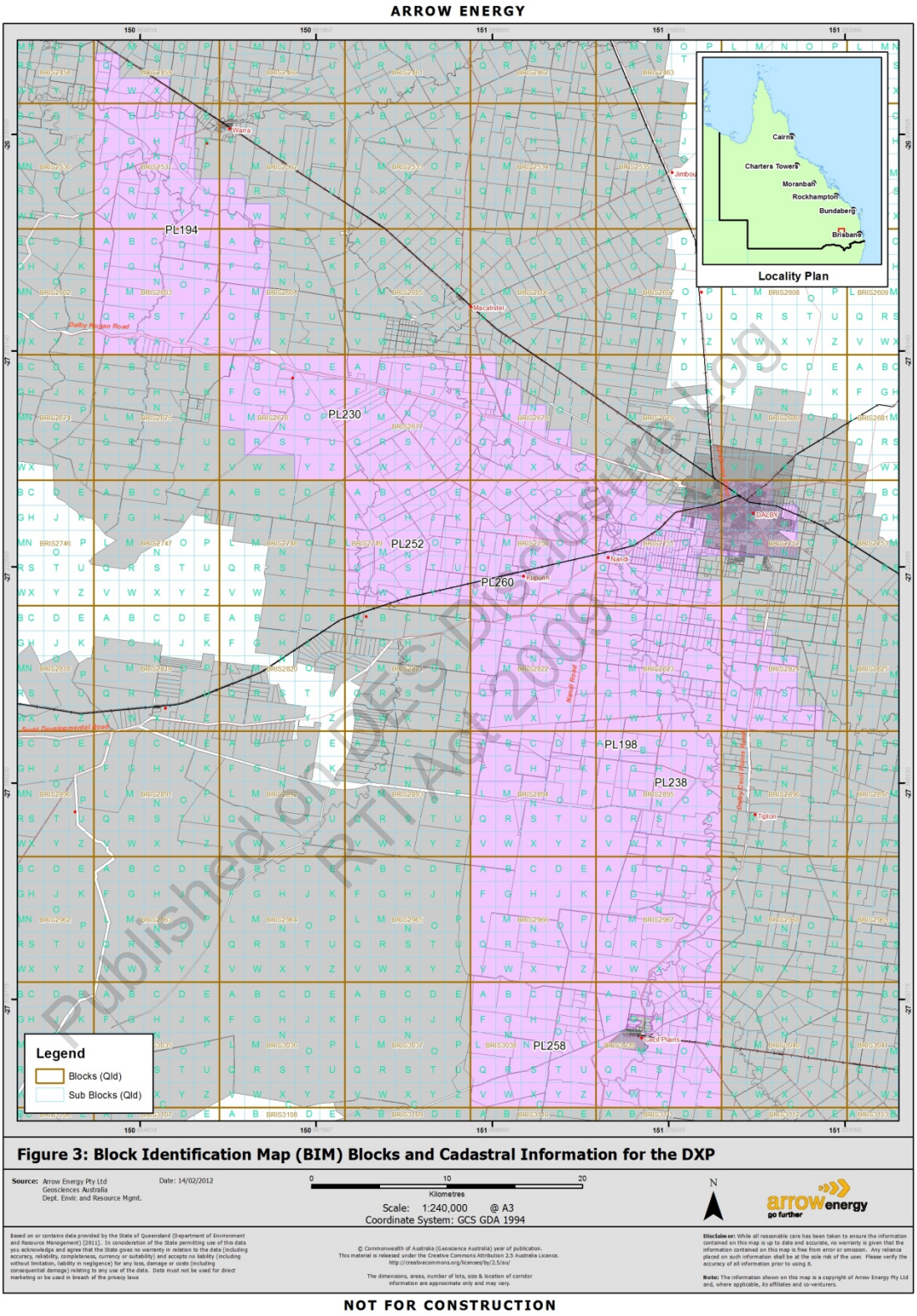


Figure 3: Block Identification Map (BIM) Blocks and Cadastral Information for the DXP

2.4 POTENTIALLY AFFECTED PROPERTIES

The identification, ground-truthing and mapping of sensitive receptors within the DXP area is ongoing and integral to the assessment of environmental impacts. As part of environmental and social impact assessments conducted by Arrow topographic maps, aerial photographs, satellite imagery, local knowledge, and information from stakeholder consultation were all used to identify potential sensitive receptor locations. Sensitive receptor locations were then ground-truthed in the DXP area in October 2009 by Coffey Environments (Australia) Pty Ltd (contracted by Arrow Energy). Approximately 400 potential sensitive receptors (buildings) have been identified within the DXP area, excluding the townships of Dalby and Cecil Plains. Sensitive receptor locations ground-truthed and mapped within the DXP area are shown in Figure 4.

Arrow Energy have contracted Coffey Environments to update the identification, ground-truthing and mapping of sensitive receptors in the DXP area and this work is due for completion late-2012.

Potential sensitive receptors are located throughout the DXP area and will consequently be an important consideration when planning project activities. As required, detailed planning and studies will be carried out to assess impacts at these locations to limit impacts, and environmental risk assessments will be carried out prior to construction.

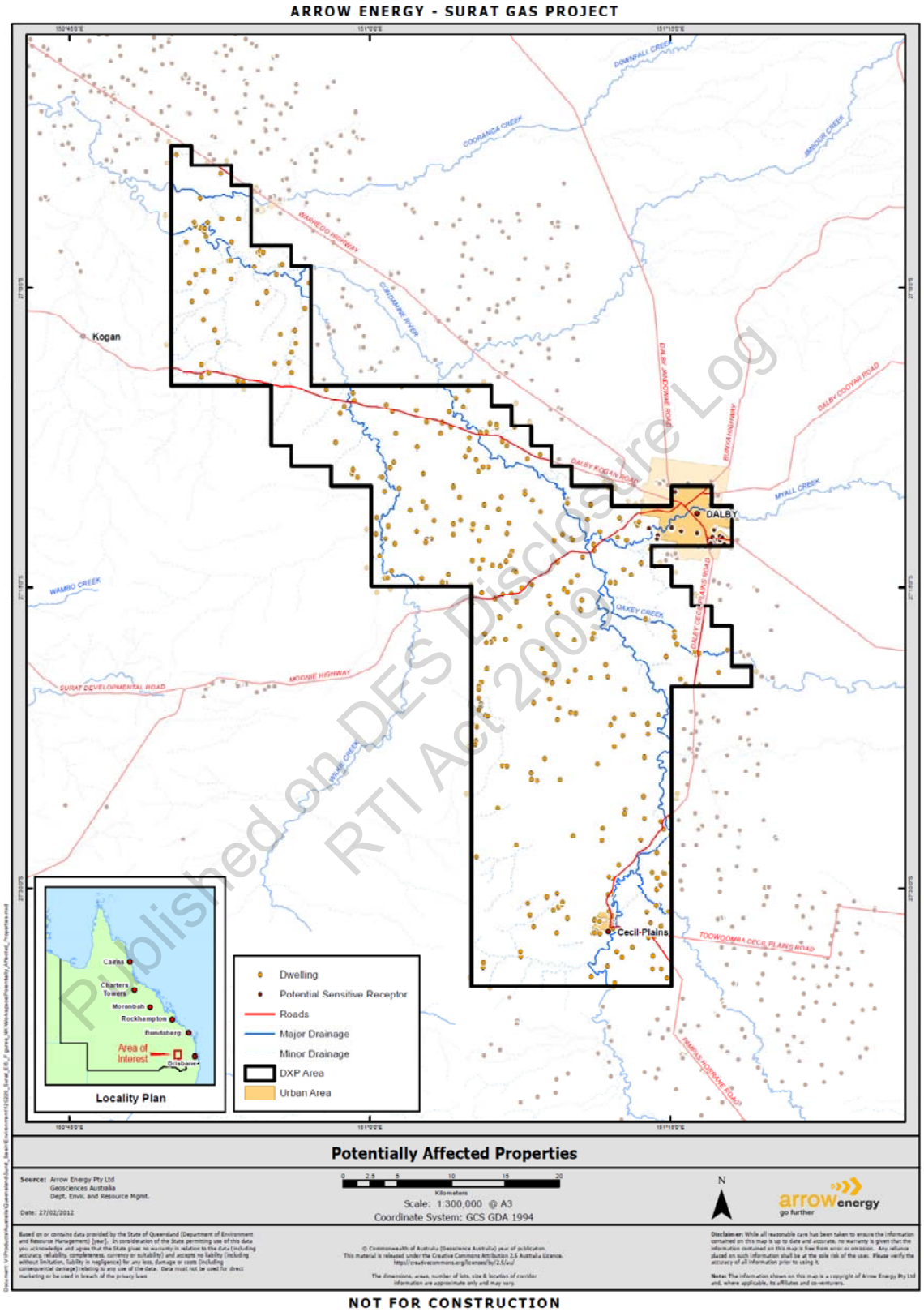


Figure 4: Sensitive Receptors mapped within the DXP (October 2009)

2.5 EIS TRIGGERS

As outlined in the DERM Guideline "Assessment and approval process for environmental authorities for Chapter 5A activities" the Environmental Impact Statement (EIS) triggers for petroleum activities are:

Will the proposed Chapter 5A activities:

a) Have a significant impact on Category A or B environmentally sensitive areas?

b) Involve activities in a marine area?

c) Involve activities less than 500m from the highest astronomical tide?

d) Involve the construction of a new pipeline of more than 150km under a petroleum authority?

e) Include an environmentally relevant activity with an aggregate environmental score of greater than 165?

f) Involve activities under a GHG injection and storage lease under the Greenhouse Gas Storage Act 2009?

g) Involve the construction of a petroleum refining or processing facility?

It is not anticipated that activities proposed under this application will have a significant impact on Category A or B environmentally sensitive areas (see Section 8). Similarly, the proposed project will not involve:

- Activities in a marine area.
- Activities within 500 m of the highest astronomical tide.
- The construction of a new petroleum pipeline greater than 150km.
- Greenhouse gas injection or storage.
- An ERA with an aggregate environmental score greater than 165.
- The construction of a petroleum refining or processing facility.

Therefore, it is considered that this application does not require assessment through an EIS process.

All field development relating to the provision of gas for the proposed Arrow Energy LNG Plant on Curtis Island will be subject to a detailed Environmental Impact Statement (EIS) process, and will be done in full consultation with DEHP and other relevant government agencies and stakeholders. A separate EA application will be submitted at a later date in association with the Surat Gas Project EIS (Arrow, 2012) process.

2.6 FINANCIAL ASSURANCE

Sections 312O and 312P of the EP Act provide the administering authority with the power to require the holder of an Environmental Authority (EA) (Chapter 5A Activities) to provide a new or amended Financial Assurance. The purpose of Financial Assurance is to ensure compliance with the conditions of the EA and to guarantee sufficient funds are

available to the State Government should the company default on their environmental requirements or become bankrupt.

EHP requires that financial assurance is lodged for all Level 1 EA's (DERM 2011). The financial assurance estimate is required as a component of an EM Plan as prescribed under Section 310D of the EP Act. A granted EA will not be issued until the appropriate financial assurance has been received by EHP and the financial assurance will remain in force until EHP is satisfied that no claim on the assurance is likely. Financial assurance must be calculated to ensure that funds available to the government are commensurate with the level of activity as the project develops.

EHP presently holds $17,144,697.50 of financial assurance for EA PEN100449509. However, given this EA amendment application is seeking the approval of additional petroleum activities for the DXP, Arrow is determining a new financial assurance estimate that includes the current amendment application proposed activities.

The financial assurance will include costs associated with the decommissioning and rehabilitation of all existing and proposed site infrastructure and associated disturbances to land undertaken as part of DXP activities.

The financial assurance estimate will based on independent, third-party unit rates developed for key tasks using a conservative set of assumptions for each task. All costs have been developed in accordance with EHP requirements for Level 1 petroleum activities. It should be noted that the calculations will be completed in accordance with the EHP Guideline Calculating financial assurance for Level 1, Chapter 5A petroleum activities (January 2012), in particular adopting the EHP recommendations on costing of progressive rehabilitation.

3. ENVIRONMENTAL MANAGEMENT SYSTEM

Arrow is committed to the sound management of health, safety and the environment throughout all of its business activities. The company maintains an integrated HSEMS based on the principles of ISO 14001, Environmental Management Systems - Requirements with Guidance for Use (Standards Australia, 2004a) and AS/NZS 4801:2001, Occupational Health and Safety Management Systems - Specification with Guidance for Use (Standards Australia, 2001). The key elements of Arrow's HSEMS are further described in the following sections.

3.1 ENVIRONMENTAL POLICY

A copy of Arrow's environmental policy is attached as Appendix B. This policy governs the development and implementation of Arrow's HSEMS, and together these documents are the key tools used by Arrow to engage in activities and to supply services in an environmentally sustainable manner. By implementing the Arrow HSEMS and site based Environmental Management Procedures, Arrow will endeavour to:

- Conduct operations in compliance with all relevant environmental legislation, regulations, licences, permits, standards, approvals and authorities.
- Clearly allocate responsibilities for environmental performance at all levels within Arrow and its business associates and build environmental competency through provision of structured environmental training to its employees, contractors and other service providers.
- Seek continuous improvement in environmental performance through setting objectives and targets for environmental performance, provide sufficient financial and human resources to meet these objectives and targets, apply research and development and cleaner production principles and, where applicable, use environmentally sustainable products and resources.
- Apply best industry practice in the management, supply and delivery of coal seam gas.
- Communicate with the community and customers about commitments to this vision, its application and their view of Arrow's performance.

3.2 ENVIRONMENTAL MANAGEMENT PROCEDURES

As part of the Environmental Management Framework, a series of procedures have been developed detailing how operations shall be conducted to manage risks to the environment. These procedures outline specific considerations and controls that apply when planning for an activity and when carrying out the activity. Monitoring and staff responsibilities for specific actions are also discussed in each procedure, as are a list of other documents that may assist in the proper conduct of the activity. A list of Environmental Management Procedures relevant to DXP activities are presented in Table 3.

Table 3: Current Arrow Energy Environmental Management Procedures

Procedure	Document Number
Erosion and Topsoil Management Procedure (previously Erosion Controls and Rehabilitation of CSG Operations)	99-H-PR-0045
Operating Procedure for Sampling Associated Water	99-V-PR-0002
Environment Document Control Procedure	99-V-PR-0003
Aboveground Storage Tanks Procedure	99-V-PR-0004
Competence - Environmental Aspects Procedure	99-V-PR-0005
Development of Environmental Documents Procedure	99-V-PR-0006
Environmental Alert Procedure	99-V-PR-0007
Environmental Corrective Actions Procedure	99-V-PR-0008
Environmental Document Deviation Procedure	99-V-PR-0009
Environmental Regulatory Compliance Procedure	99-V-PR-0010
Office Environmental Aspects Procedure	99-V-PR-0011
Environmental Noise and Vibration Management Procedure	99-V-PR-0013
Land Clearing and Ground Disturbance Procedure	99-V-PR-0014
Rehabilitation Procedure	99-V-PR-0015
Traffic and Transport - Environmental Aspects Procedure	99-V-PR-0016
Visual and Landscape Procedure	99-H-PR-0076
Waste Management Procedure	99-V-PR-0018
Water Management Procedure	99-V-PR-0019
Weed and Pathogen Management Procedure	99-H-PR-0030
Air Emissions Procedure	99-V-PR-0022
Environmental Audit and Inspection Procedure	99-V-PR-0024
Procedure for reporting Methane Gas Releases	99-V-PR-0027
Ecological impact assessment procedure- upstream activities	99-H-PR-0081
Wildlife and Stock Management Procedure	99-H-PR-0075
Fauna Spotter/Catcher Procedure	99-H-PR-0048
Chemical Management Procedure	99-H-PR-0016
Fire Prevention Procedure	99-H-PR-0020
Relocating Wildlife Procedure	99-H-PR-0030
Incident Reporting Recording and Investigation Procedure	99-H-PR-0010
Soil Management Procedure	99-H-PR-0044

3.3 Roles And Responsibilities

Arrow is accountable for the ongoing environmental management of DXP activities; however all employees and contractors are responsible for the environmental

performance of their activities and must demonstrate compliance with Arrow procedures and policies and with any commitments made as part of the HSEMS and this EM Plan.

Key personnel have specific responsibilities with respect to environmental management. These personnel and their responsibilities are presented in Table 4.

Table 4: Arrow Personnel and Environmental 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, 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 organization.
General Manager: Assets (South)	• Implementation of management and monitoring practices and procedures in all operation areas. • Resourcing. • Accountable for compliance.
Southern Operations Manager	• Environmental approvals implementation. • 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 or operational level.
Employees and Contractors	• Following procedures that implement the requirements of the Arrow Energy HSE Standards; • Compliance with relevant environmental procedures and standards. • Coordinating incident response. • Reporting all incidents, defects, hazards and inadequacies of procedures so that appropriate review and corrective action can be taken;

	• Overseeing day to day activities. • Carrying out specific activities that ensure compliance with environmental authority conditions, including monitoring and data collection.

3.4 TRAINING, AWARENESS AND COMPETENCE

Environmental awareness training and inductions appropriate to the level of risk and type of work being performed will be provided to all employees, contractors and visitors. Training plans will be developed to attain, improve and maintain personnel competencies and the overall environmental performance of Arrow. Additionally, plans will be reviewed following change, incident investigations and hazard studies. Training will generally:

- Cover all emergency response procedures.
- Review hazards and control measures.
- Review environmental standard operating procedures.
- Present consequences and impacts of departure from hazard and control measures.
- Reinforce the role of hazard and control measures in achieving company and business unit objectives and targets.
- Be regularly evaluated to ensure the required learning outcomes are being achieved.

Records of trainee assessments will be maintained to demonstrate achievement of competence. Re-training and other professional development activities will be identified and implemented as necessary to ensure personnel have the capacity to adequately perform their duties and carry out effective environmental management.

3.5 INCIDENT MANAGEMENT

Incident reporting and management is reinforced through environmental management procedures and incident reporting guidelines and are included and emphasised during training of personnel.

Environmental incidents are reported through the management line and are investigated to establish immediate response and system (root) causes and corrective actions, which are subsequently applied to prevent recurrences. The Asset Manager will ensure that external environmental reporting requirements in the event of any incident are fulfilled.

Arrow has plans and procedures for preparedness and response to emergencies. These are applied to both environmental and safety events.

3.6 MONITORING AND ASSESSMENT

Monitoring and reporting provides a direct measure of the project's impacts and/or consequences of its operations, together with an indication of the effectiveness of Arrow's HSEMS. Planned monitoring includes the following:

- Monitoring implementation of management plans.
- Regular inspection of construction and operational activities.
- Environmental monitoring of potential impacts over time (e.g. photo-monitoring, baseline and repeated assessments and audits).
- Reporting and analysis of regulated discharges, emissions and waste disposal.
- Any other prescribed monitoring in accordance with the conditions of the relevant EA.

3.7 AUDITING

Internal monitoring is undertaken as both scheduled and unscheduled activities. Regular audits are conducted for aspects of operations in conjunction with site Environmental Improvement Plans and review meetings. In addition, spot audits are undertaken during ad hoc site visits. External audits will be undertaken when required to evaluate compliance with the EA conditions and the HSEMS.

3.8 COMPLAINTS

Arrow is committed to managing all complaints in an accountable, transparent, timely and meaningful way. Arrow has in place a complaints management system which outlines how staff must handle, report and address complaints, which is consistent with the Australian Standard ISO 10002-2006 'Customer satisfaction – Guidelines for complaints handling in organisations'.

Complaints will be recorded in the complaints management system database. All complainants shall be treated courteously, and kept informed of the progress of their complaint throughout the complaint management process.

By monitoring complaints and recording their outcomes, Arrow will ensure continued improvement in its operations and activities through responding to complaints with meaningful feedback regarding potential improvements.

3.9 CONTINUOUS IMPROVEMENT AND CORRECTIVE ACTION

The HSEMS will be updated proactively and in response to the following:

- Audit outcomes and subsequent corrective actions,
- Changes in activities,
- Changes in procedures

- Improved technology.

Updates will reflect legislative amendments together with relevant project changes or issues that arise during petroleum project activities.

4. DESCRIPTION OF PETROLEUM ACTIVITIES

This EM Plan describes the following activities associated with the DXP:

- Approved and existing activities.
- Approved activities which are not yet developed.
- Proposed activities which have not yet been approved and are not yet developed.

The key existing and proposed DXP petroleum activities are summarised in Table 5 below. A more detailed description of existing and proposed activities is included in Sections 3.1 and 3.2. The locations of the major items of existing infrastructure within the DXP are illustrated in Figure 5.

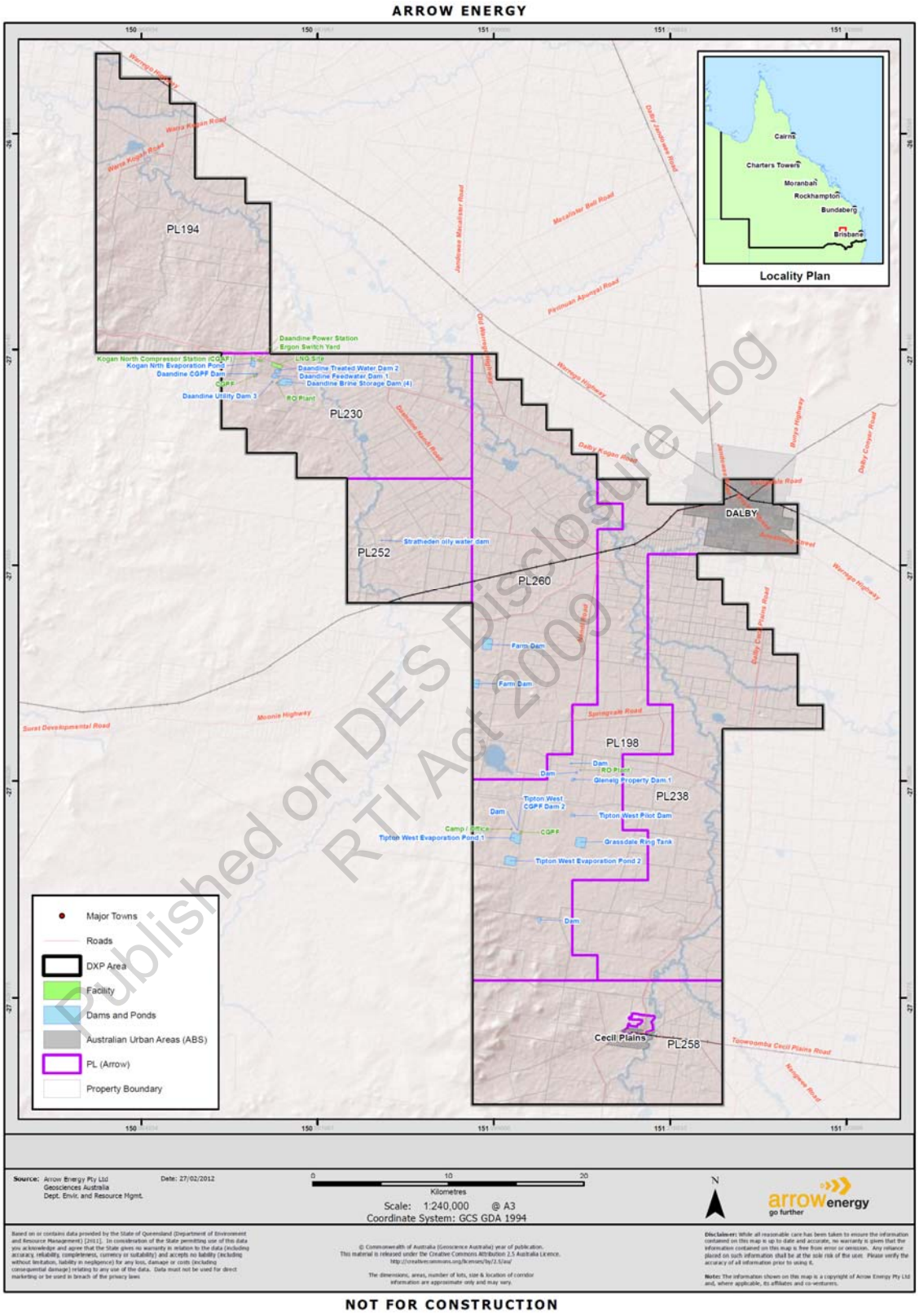


Figure 5 Location of existing large infrastructure associated with the DXP

Table 5: Summary of Existing and Proposed Activities and Infrastructure on the DXP

Activity	Approved and existing	Approved but not yet developed	Proposed (Not yet approved and not yet developed)
Coal seam gas exploration and production			
Seismic surveys (km)	0	0	200
Wells	455	236	0
Borrow pits (ha)	4		
Fuel burning and power generation			
Compressors *	13	27	0
Power station (40 MW)	0	2	0
Water storage and treatment			
Regulated Dams (>401 ML)**	8	7	0
Regulated Dams (<400 ML)**	7	1	0
Water treatment facilities (reverse osmosis) (>10ML/day) ***	2	0	0
Sewage and wastewater			
Sewage Treatment Plants/Wastewater Treatment Systems (21 to 450 EP)	0	2 (<450 EP)	0
Sewage Treatment Plants/Wastewater Treatment Systems (< 21 EP)	0	3	0
Release to waterways			
Discharge of treated coal seam gas water to a watercourse		Discharge to an un-named tributary of Wilkie Creek under wet weather conditions	Change of discharge point to Wilkie Creek on a variable flow basis
Groundwater injection			
Injection of groundwater into suitable aquifers			Undertake shallow and deep groundwater injection trials

*4 stage 5.89 TJ/d reciprocating compressors

**'Dams' include aggregation dams, brine storage dams, treated water dams and process dams.

***Daandine WTF is currently operational, and Tipton WTF is under construction.

4.1 APPROVED ACTIVITIES

This section provides information regarding the existing project activities that are approved for the DXP.

4.1.1 Drilling and Well Installation

There are 455 wells existing within the DXP, including exploration, appraisal and production wells in addition to monitoring bores.

A further 236 wells were approved under the current EA PEN100449509. These wells will be drilled as land access and other approvals are obtained and existing gas supply contracts require additional production to be brought online.

Production wells drilled on the DXP are predominantly vertical wells which are described further in Section 4.1.1.4.

4.1.1.1 Exploration Drilling

Exploration wells determine the location, extent, thickness, gas content and gas saturation of coal seams. Locations for drilling exploration wells are determined using a desktop assessment of geological, social, landholder and environmental factors.

Well locations are cleared and levelled to provide a platform for the drilling rig, allow the safe movement of vehicles and machinery and to provide a barrier to bush and grass fires. Access roads, a safety flare unit and a storage facility for produced water will also be constructed at the drill site. In most cases storage tanks will be used to hold drilling water. The site will be fenced for safety and to provide a barrier to cattle or other livestock.

The typical area of disturbance associated with an exploration well site is 8,100 m^2 (90 m x 90 m). Disturbed areas consist of the compacted well pad (for drilling machinery) and an area for the temporary storage of vegetation, top soil and spoil.

There are two main forms of exploratory drilling, being exploration wells and appraisal wells (also known as pilot wells) as discussed below.

4.1.1.2 Exploration Wells

Drilling rigs used to establish exploration wells are generally slightly larger than standard water bore drilling rigs. Throughout the drilling process, drilling fluids are circulated down the drill hole to balance underground pressure and to bring drill cuttings back to the surface. Arrow does not utilise oil or synthetic oil based drilling fluids in this process.

Following the drilling of the exploration well, a series of downhole tests are conducted. Each well is designed and installed in accordance with relevant industry regulations.

Once drilling is complete and all data has been gathered, the well is 'plugged and abandoned'. This involves sealing the hole from the bottom to the surface using cement. The steel casing is cut off 1.5 m below the surface, sealed with a metal identification plate and buried. The land is then rehabilitated to its pre-disturbed form using topsoil that was stockpiled as part of the preparation of the drill site.

Alternatively, an exploration well can be converted into a permanent monitoring bore to measure reservoir pressures within the coal seams and/or water pressures within known aquifers. Depending on the well's location relative to current producing wells or future production fields, the monitoring well can provide baseline readings prior to the development of a coal seam gas field. Additional regulations apply when converting wells to water monitoring bores.

4.1.1.3 Appraisal or Pilot Wells

Appraisal or pilot wells are used to determine the most effective way of producing coal seam gas. A pilot is designed to mimic a small-scale production field to gather information about maximum gas and water production rates, to trial the most effective well design at that location and also to measure the quality of water that is produced. Appraisal testing involves drilling a cluster of wells in one area in a diamond or square pattern with one central well and several wells surrounding it at approximately 200-250m apart. However, this can vary depending on the characteristics of the specific gas field and the land available for drilling. The close proximity of the wells allows the quickest drawdown within the coal seam to minimize the time required for testing as well as to determine estimated gas rates for the area.

As is the case with exploration wells, appraisal wells each have a specific design that is required to comply with strict regulatory requirements and long established petroleum industry techniques. The well is designed so that it isolates any known aquifers behind steel casing and is held in place with pressure tested cement.

Each well is completed with a downhole pump and production tubing which is used to extract water from the coal seam. By extracting water from the coal seam the well lowers the hydrostatic pressure on the seam which allows the gas to flow into the well and to the surface. Pumping from the well usually lasts between three and twelve months or until sufficient data on gas and water rates can be obtained. In some cases approval for an extended production test is requested from the administering authority, to allow for further testing of the gas and water reserves past twelve months. The gas from each well is collected and flared at each pilot location. A lined dam is generally associated with the pilot and is constructed to receive and store the produced coal seam gas water. The size of the dam is determined using information collected during exploration and built large enough to store water for the entire testing period. In some instances, the coal seam gas water can be connected into the existing water gathering system and sent to one of the major aggregation dams on site.

The data collected from the pilot is analysed and used to determine if the area can support a viable gas field. The data would then be used in future gas field development planning by optimising well spacing, water & gas infrastructure, water treatment options and pump sizes.

4.1.1.4 Production wells

Production wells are drilled to produce gas to sell to market and fulfil domestic gas supply contracts. Production wells are optimally set out in 900 m grid spacing; however this may range from 800 m to 1000 m dependent on the constraints present. Drilling is generally conducted 12 to 24 hours per day, seven days a week for approximately 14

days, subject to landowner and labour availability. Production wells are nominally drilled 300 to 800 m deep, however total depth is dependent on the coal reserves. To prevent the loss of water from upper groundwater aquifers, the top section of each well is cased with steel and cement. The casing of the upper strata in this way also serves to prevent cross contamination between aquifers.

Once the well is installed, the well site footprint is reduced to a size sufficient (approximately 12 m x 12 m) to accommodate the wellhead, electric drive rotating screw pump, wellhead gas/water separator, control valve, monitoring, metering and communications equipment and connection to gas and water gathering lines. Operational well sites are fenced and signposted to prevent public, stock or wildlife access to the well head. Once installed, Arrow's current modelling suggests an average well life of 15 to 20 years. Well workovers typically take place every 1 to 5 years during a well life. Workover activities are similar to those conducted during the construction of a production well with an associated disturbance area of 90 m x 90 m typically required.

To promote gas and water flow in the well, a number of different drilling techniques can be used. These include using an under-reamer at target depths in the well to ream out cavities in the coal seams, or accessing multiple coal seams through the drilling of multi-lateral or vertical wells accessed through the primary central bore hole.

No hydraulic fracturing (fraccing) will be carried out on the DXP. Hydraulic fracturing which is the process of creating cracks in underground coal seams to increase the flow and recovery of gas or oil out of a well.

4.1.2 Drilling Technology Trials

Arrow is in the process of describing and designing an area within the DXP area called the Surat Tek Park. The aims of the Surat Tek Park is to trial and prove drilling technologies that will minimise landholder impact, environmental impact, land disturbance, cost and drilling duration.

The Surat Tek Park will consist of 14 wells, seven of which will be drilled on two separate drill pad locations in Quarter 3 2012. The Surat Tek Park and both drill pads are located on the Arrow Energy owned property Statheden on PL252.

On each pad, seven wells will be drilled consisting of one vertical well and six slant or deviated from vertical wells. The current surface layout concept involves placing the wells in a single line on a pad site measuring 190 m x 70 m, with the seven wellheads approximately 15 m to 25 m apart. Details of the two well pads, drilling methods and artificial lift types are provided below and presented in Figure 7 and Figure 8:

- Pad 1 – This pad will test well types that are deviated from the vertical using injected gas to artificially lift coal seam water from the well.
- Pad 2 - This pad will test conventional well types with electric submersible pumps to artificially lift coal seam water from the well. Wells drilled within this pad are expected to be approximately 475 m deep (vertical depth measured from ground surface).

The specific location of each drilling trial (and which drilling types are to be trialled at each location) will be dependent on coal depths in the area. Slant wells are most suited to deeper coal seams as they allow for the greatest amount of coal to be intersected with the least surface disturbance (due to the greater horizontal step out achieved over the increased depth to the coal). Wells that are deviated from the vertical (i.e., drilled at a greater angle from the vertical) are accordingly more suitable for accessing shallower coal seams.

The drilling of both deviated from vertical and the slant wells will use conventional drilling techniques; however a heavier than normal mud weight may be required to lift cuttings to surface along the slant or deviated section of the well.

Pitless drilling will be employed in the drilling technology trails to deliver and process drilling mud, thereby avoiding the need for surface storage pits. Surface mounted tanks, coarse filtration systems and pumps are used to recycle mud throughout the drilling process.

Water and gas will be handled via existing Arrow Energy infrastructure where capacity exists. Water will be handled via the existing Stratheden water line to the Daandine reverse osmosis treatment plant. Produced gas will be piped to the nearby Daandine Gas Compression Facility.

The techniques proposed as part of these drilling trials do not vary greatly from those currently used for the conventional vertical wells drilled by Arrow. The management measures described in this EMP are also applicable to activities on the Surat Tek Park. As such the drilling trials at Surat Tek Park are not anticipated to introduce any additional impacts on environmental values.

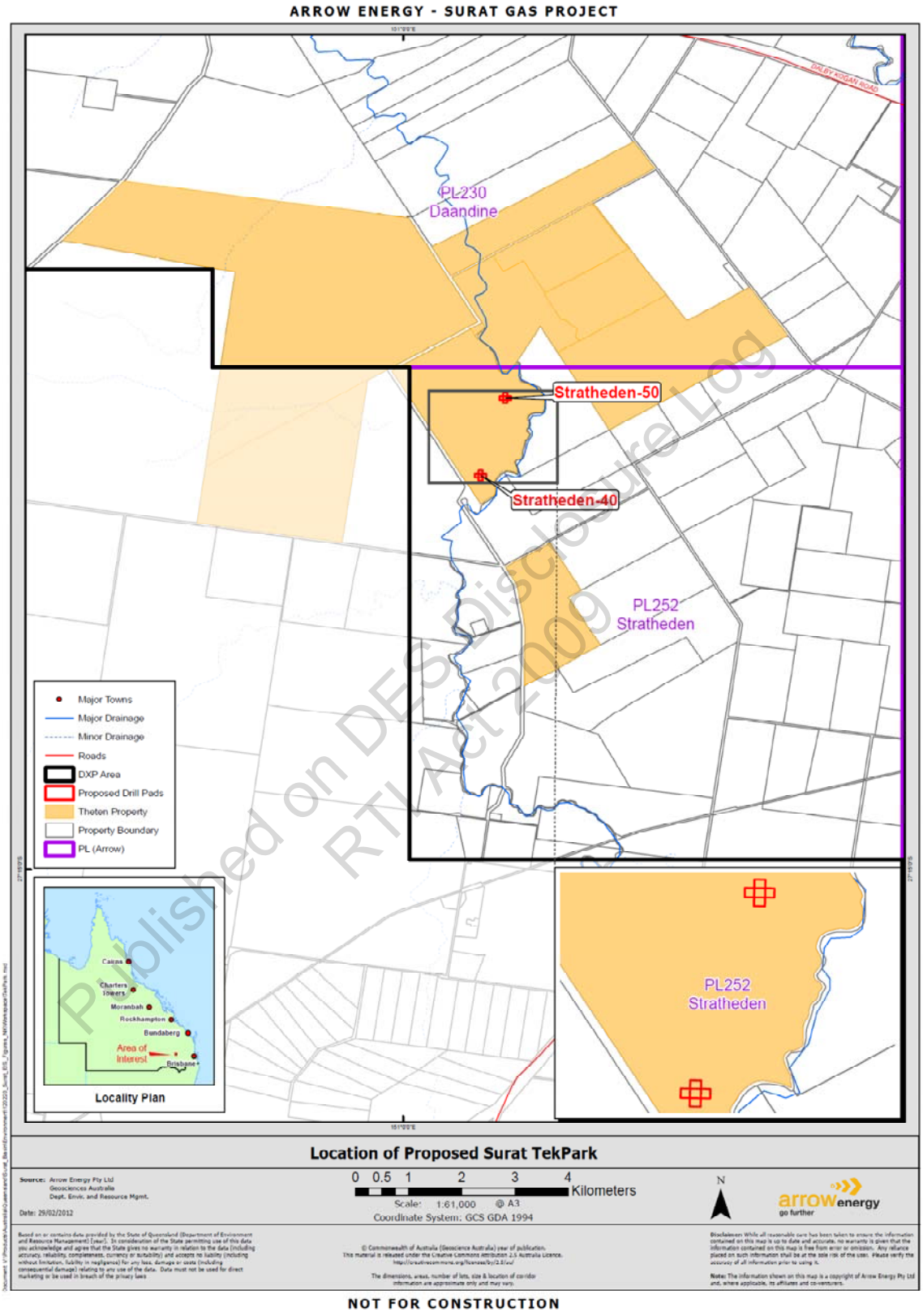


Figure 6: Location of Proposed Surat Tek Park

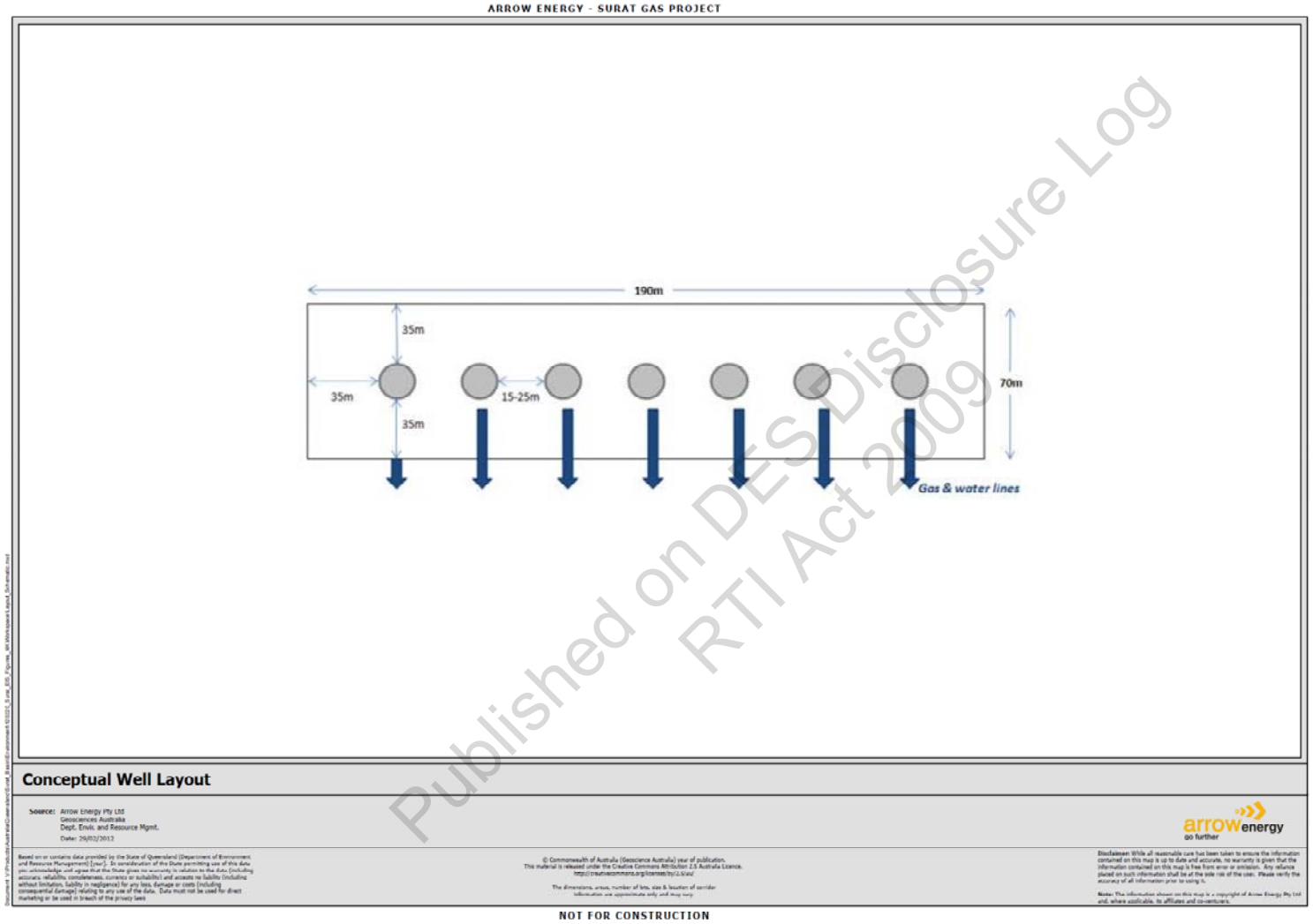


Figure 7: Well Layout Schematic for Proposed Surat Tek Park

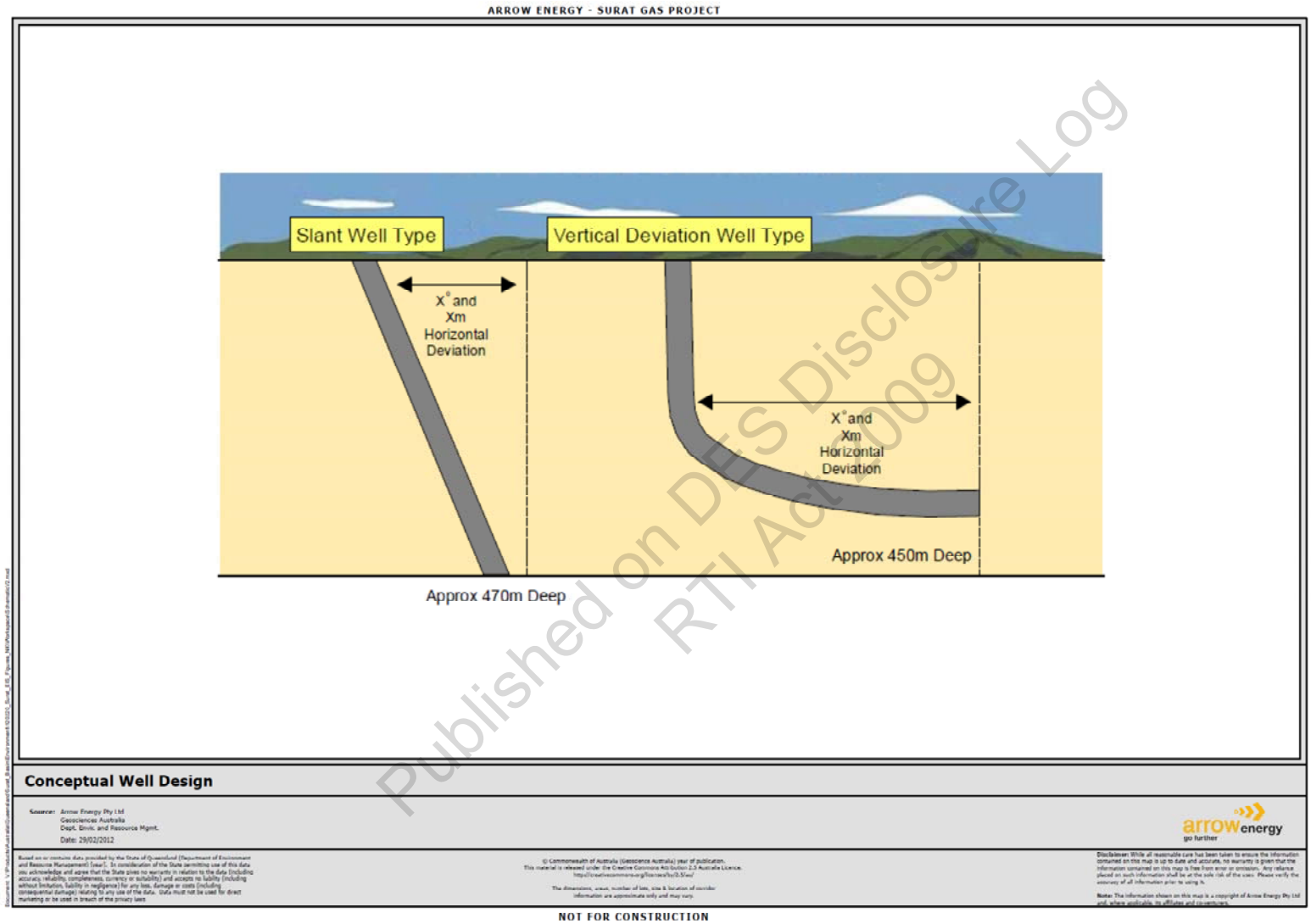


Figure 8: Surat Tek Park Well Type Schematic

4.1.3 Exploration and Production Related Infrastructure

4.1.3.1 Gathering Lines

The existing gathering system for the DXP consists of gas gathering lines and water gathering lines flowing from the well heads to gas compression and to water storage facilities, respectively. Gathering lines are typically 110 to 630 mm diameter High Density Poly Ethylene (HDPE) buried within maintained cleared corridors.

Additional gathering lines required in accordance with this proposed EA amendment will be constructed as land access and other approvals are obtained and additional wells and water treatment facilities are brought online.

Water gathering lines include high point vents to collect any gas not separated from the water at the wellhead. Gas gathering lines similarly incorporate low point drains for the removal of water from the gas. High point vents operate automatically.

4.1.3.2 Access Tracks

Access tracks are required on the gas fields to allow the servicing of well sites and other supporting infrastructure. Already established access tracks are used wherever possible, however purpose built access tracks will be required to be constructed where existing tracks are not suitably located.

Typical access tracks are up to 12 m in width and are constructed with take-off drains to divert water away from the access corridors. Take-off drains are typically located at regular intervals along a track and extend for approximately 20m. Construction of dual carriageway roads require up to 20 m width and take off drains may be installed where required to decrease erosion.

4.1.3.3 Borrow Pits

Borrow pits are typically required as a source of gravel and other materials necessary for the construction of well sites, access tracks, dams and storage areas. There are a number of existing borrow pit locations across the DXP area, comprising approximately four hectare in area.

4.1.4 Fuel Burning and Power Generation

4.1.4.1 Fuel Burning

There are two existing compressor facilities (containing 13 compressor units in total) within the DXP. These existing facilities are the Tipton West Central Gas Processing Facility (CGPF) and the Daandine CGPF as described below.

A further 27 reciprocating compressors have been approved under the current EA PEN100449509. The compressor units will be constructed as additional wells are brought online and additional compression capacity is required.

Tipton West CGPF

This facility is operational and has the capacity to process up to 35 TJ of gas per day supplied from the existing gas fields within the DXP area. The CGPF is comprised of six

gas-driven oil lubricated reciprocating compressor units, a Triethylene glycol (TEG) dehydration unit, a cold vent, storage tanks, an oily water dam, a control centre and gas metering and control facilities. The approximate disturbance footprint associated with the CGPF is approximately four hectares.

Gas from the production wells is received by the CGPF and is subject to four stages of compression to achieve a pressure of approximately 10,200 kPag. The compressed gas is directed to a coalescing filter to remove entrained oil and water droplets before the gas is dehydrated in a TEG contacting column. The dry gas is directed to metering and distribution infrastructure and sent via high pressure gas pipelines to fulfil ongoing domestic sales agreements. Oily water is directed to the on-site oily water dam.

The TEG used to dehydrate the compressed gas is continually regenerated by distilling off the absorbed water at low pressure.

Daandine CGPF

This facility is also operational and is similar in design to the Tipton West CGPF. It has a slightly larger capacity (processing up to 42 TJ of gas per day) and is comprised of seven reciprocating compressor units, compared to the six present at the Tipton West CGPF.

4.1.4.2 Power Stations

Arrow has approval to develop two 40 MW power stations to power compression facilities and well heads. A power generation facility will likely comprise a series of high-efficiency coal-seam-gas-fired reciprocating engines with lean-burn technology to achieve high-efficiency generation (greater than 40%) with reduced emissions (low nitrogen oxide combustion technology). Each engine will be coupled to alternators generating directly at 11 kV. Power generation facilities will be located within or in close proximity to production facilities. An estimated 80m by 150m footprint will be required to accommodate a power generation facility. These facilities will supply power for gas compression, dehydration and water treatment.

4.1.5 Water storage and treatment

Arrow currently has approximately 300 to 350 existing gas production wells at Tipton West, Daandine, Stratheden and Kogan North across the associated PLs. Arrow currently manages the coal seam gas water generated in association with gas production from these fields with a 12 ML/day water treatment facility and associated storage at Daandine and a facility of similar capacity at Tipton is currently under construction. This will facilitate the treatment and beneficial use of coal seam gas water generated through production activities, in accordance with Arrow's Coal Seam Gas Water Management Strategy Basin and Coal Seam Water Management Plan - Surat (Appendix E). Further detail on the management of coal seam gas water and associated potential impacts on environmental values within the DXP are provided in Sections 6 and 12.

4.1.5.1 Regulated Dams

There are currently 16 regulated dams located in the DXP area. The locations of existing dams are illustrated in Figure 5.

These existing dams are utilised for a range of coal seam gas water management purposes including raw coal seam gas water aggregation, brine disposal and treated coal seam gas water storage as shown in Table 6.

A further seven regulated dams (>401 ML) have been approved under the current EA PEN100449509.

Table 6: Regulated Dams Located within the DXP (Source: URS May 2012, Daandine, Tipton, Kogan and Stratheden Regulated Dam 2011 Annual Inspections Report)

Dam Name	Dam Purpose	Area (ha)	Volume (ML)	Hazard Category	Date of Construction
Tipton West Aggregation Pond 1	Aggregation	34.13	1782	High	2006
Tipton West Aggregation Pond 2	Aggregation	44.60	2502	High	2007
Tipton West Pilot Dam	Aggregation	3.8	126	Significant	2004
Tipton West CGPF Dam 1	Process	0.27	4.18	Significant	2006
Tipton West CGPF Dam 2	Process	0.42	2.44	Low	2007
Tipton West Feedwater Dam	Aggregation	11.77	424	Significant	2011
Tipton West Treated Water Dam	Treated Water	11.77	424	N/A	2012
Tipton West Brine Storage Dam	Brine Storage	32.16	1072	High	2012
Tipton West Utility Dam	Process	2.94	54	Significant	2011
Kogan North Aggregation Dam	Aggregation	12	427	Significant	2005
Daandine Feedwater Dam	Aggregation	11.50	458	Significant	2009
Daandine Treated Water Dam	Treated Water	7.80	247	Significant	2009
Daandine Brine Storage Dam	Brine Water	38.10	1458	Significant	2007
Daandine Utility Dam	Process	1.3	48	Significant	2009
Daandine CGPF Dam	Process	0.63	22	Significant	2009
Stratheden Transfer Dam	Aggregation	0.63	22	Significant	2009

All of Arrow's dams associated with the management of coal seam water are operated and authorised in accordance with legislative requirements. This includes completing a hazard assessment for all dams that hold untreated coal seam water to determine if they are a Low, Significant or High hazard dam in accordance with DERMs Manual for Assessing Hazard Categories and Hydraulic Performance of Dams.

Details of significant or high hazard dams are maintained in Arrow's Regulated Dam Register. Dam design and operation are discussed in further detail in Section 6.

4.1.5.2 Water Treatment Facilities

Details of the two water treatment facilities associated with the DXP are provided below.

Daandine Water Treatment Facility

Arrow currently has an operational water treatment facility located at Daandine on PL230. Water treatment is achieved through a process of microfiltration (MF) and Reverse Osmosis (RO). The facility has a treatment capacity of 12 ML/day and it is expected to operate at a recovery rate of approximately 85% (dependent on feed water quality). Based on this rate of recovery and the plant availability rates, it is anticipated that there will be a maximum output of approximately 10 ML/d or 3,450 ML/year (based on operating 345 days/year). The approximate disturbance footprint of the MF/RO facility is 10,000 m^2.

Infrastructure associated with the water treatment facility includes:

- Feed Water Dam.
- Treated Water Dam.
- Brine Dam.
- Utility Dam.
- Groundwater monitoring bores (to detect seepage).
- Interconnecting pipelines (approximately 3 km).
- Export pipeline (approximately 12 km) from the water treatment facility to Arrow's Theten property.

Due to the high sodium absorption ratio (SAR – ratio of sodium to calcium and magnesium) of the treated coal seam gas water, SAR adjustment using calcium chloride may be required as part of the water treatment process to lower the SAR to ensure that treated water is suitable for beneficial use or disposal. Existing approvals under the *Queensland Environmental Protection (Waste Management) Policy 2000* provide for beneficial use of water from the Daandine facility for irrigation, stock watering, coal washing, industrial cooling and dust suppression.

Tipton Water Treatment Facility

A water treatment facility is currently under construction on PL198 in accordance with the current EA PEN100449509. Water treatment will be achieved through a process of microfiltration (MF) and Reverse Osmosis (RO). Pre-treatment will consist of disk filtration to remove the residual organics that have been identified in the feed supply. The facility will have a treatment capacity of 12 ML/day and is expected to operate at a recovery rate of between 85 to 90% (dependent on feed water quality). Based on this rate of recovery and the plant availability rates, it is anticipated that there will be a

maximum output of approximately 10 ML/d or 3,450 ML/year (based on operating 345 days/year). The approximate disturbance footprint of the MF/RO facility is 10,000m^2.

Infrastructure associated with the water treatment facility includes:

- Feed Water Dam.
- Treated Water Dam.
- Brine Dam.
- Utility Dam.
- Groundwater monitoring bores (to detect seepage).
- Interconnecting pipelines (approximately 11 km).

As per the process used at the Daandine water treatment facility, the quality of the treated water will be amended as required for beneficial use or disposal.

Current and proposed beneficial uses of water from the Tipton water treatment facility include irrigation, stock watering, coal washing, industrial cooling processes, urban use, construction and dust suppression.

The water treatment facility at Tipton is scheduled to be commissioned by October 2012.

4.1.6 Sewage and Wastewater

Temporary drilling camps with capacity for approximately 20 people may be located on the existing PL's to support seismic, exploration or appraisal activities. Sewage generated from these camps will not be released to land. Instead all sewage will be stored in tanks at the camp location and regularly trucked off-site for disposal at a licensed facility.

Arrow has approval under the current EA PEN100449509 for the construction of two Sewage Treatment Plants (<450 EP). These would only be constructed if deemed necessary to manage larger volumes of sewage such as may be associated with accommodation camps.

4.1.7 Rehabilitation

Arrow undertakes progressive rehabilitation across the DXP as soon as practicable after the completion of an activity causing disturbance to land. This typically includes (but may not be limited to) the following rehabilitation measures as part of DXP activities:

- Backfilling of flowline trenches after pipe laying.
- Removal of compacted areas by mechanical means.
- Removal of drilling sumps and reducing the disturbed area around the completed operational well pad. This will include ensuring a stable surface around the operational well pad is maintained.
- Implementing erosion and sediment control measures, where required.

- Remediating contaminated land.
- Re-profiling significantly disturbed land to a stable landform similar to the original land contours.
- Re-establishing surface drainage lines on significantly disturbed land.
- Re-establishing vegetation diversity and cover and appropriate fauna habitat.

Final decommissioning and rehabilitation will occur at the end of individual infrastructure life, taking into consideration a variety of final land use options. The final land use will be determined by considering a number of factors, including but not limited to the following:

- Relevant legislative and regulatory requirements.
- Surrounding land uses.
- Landowner requirements.
- Surrounding sensitive receptors and receiving environment.
- The environmental, social and cultural values of the area.

All rehabilitation activities will be undertaken in accordance with Arrow's Rehabilitation Procedure 99-V-PR-0015 (Appendix D), regulatory requirements and industry standards.

4.2 PROPOSED ACTIVITIES FOR APPROVAL

Activities on the DXP are presently a mixture of exploration and appraisal activities. These activities are designed to better understand the extent and characteristics of coal seam gas reserves present and to inform future field development activities. Arrow proposes to continue with this program of activities and it is anticipated that this will involve:

- The undertaking of 200 km of seismic surveying.
- The change to the location of the discharge point for the existing approved release of treated coal seam gas water from an un-named tributary of Wilkie Creek, under wet weather conditions, to Wilkie Creek on a variable flow basis.
- The undertaking of groundwater injection trials.

4.2.1 Seismic Survey

Arrow proposes to undertake 200 km of seismic survey throughout the DXP area. Seismic surveys are a surface based activity utilised to assess subterranean geological formations within a petroleum tenure. A seismic survey typically consists of a number of trucks or tractors with generators and vibrator pads which produce seismic waves. These waves are reflected back from different layers in the geological profile and are recorded by geophones. Geophones are installed into the shallow subsurface at regular intervals moving away from the source of the seismic waves. The geophones generally form a linear geometric distribution, or array, and the installation of the geophones can involve vegetation clearance and ground disturbance.

Seismic is recorded in lines in a grid pattern. The data is later analysed to determine the most appropriate location to drill a well. In some circumstances, small shallow wells known as upholes, may be required to be drilled to accurately determine the depth of the shallow geological strata and generate more accurate seismic depth maps.

Disturbances to the environment resulting from seismic activities are minimal. Seismic trucks have the ability to navigate around significant vegetation and will utilise open spaces as far as practicable. Some site preparation may be required in certain instances which may consist of slashing grass, shrubs and small trees, stick raking and light grading where necessary to allow the safe access of the truck or tractor and seismic personnel. Every effort is made to minimise disturbance.

4.2.2 Amendment to Location of Discharge Point to Wilkie Creek

In circumstances where beneficial use options such as irrigation and coal washing are not available, an alternative means for the management of storage levels of treated water in dams may be required, particularly during wet weather events. Where beneficial use options are not available, Arrow's preferred water management options include a controlled release of treated water into Wilkie Creek under various weather and creek flow conditions. Discharge of treated water is currently approved under EA PEN100449509, however, the discharge point is into an un-named tributary of Wilkie Creek, and discharge is licensed under wet weather conditions. This amended EA application proposes to change the location of the discharge point to Wilkie Creek and the conditions to be on a variable flow basis.

The new location (E 303,004; N 6,995,465) of the discharge point is proposed to be included in the EA. The outlet into Wilkie Creek will be designed to minimise potential erosion and scouring at the point of discharge into the watercourse. The outlet will be inspected as required during operation for evidence of significant scouring / erosion and to ensure its appropriate function.

The proposed maximum rate of discharge of treated coal seam gas water to the Wilkie Creek is 115 L/second which equates to 10 ML/day. During each release event, treated coal seam gas water will discharge to Wilkie Creek for periods after storm events or river flows when the trigger flow rates have been exceeded.

A description of the existing environment, potential impacts and mitigation measures and recommendations are included in the Arrow Daandine Water Release Studies (refer to Appendix G).

4.2.3 Injection Trials

Arrow is currently addressing the option of injecting coal seam gas water into suitable aquifers. In order to address this option, an aquifer injection feasibility study is being undertaken, and will be followed by a deep injection trial in the course of the next 12-24 months. This is addressed in more detail in Section 12.4.2.1.

5. AIR

5.1 EXISTING ENVIRONMENT

The existing air quality environment within the DXP area is diverse and reflects the wide variety of land use within the DXP area and surrounding region. The air quality within the DXP area is influenced by proximity to anthropogenic activities such as coal and gas fired power stations, mining and industrial manufacturing. These activities are interspersed amongst predominately agricultural land use and bushland. Rural road networks connect a number of sparsely distributed small, regional towns. On occasion the DXP area is subject to regional air quality events associated with bushfires and dust storms. Sensitive places within the DXP area are shown in Figure 4.

A network of ambient pollutant monitoring stations is maintained by DEHP throughout southeast Queensland and other major centres throughout the state. The closest monitoring station is located in Toowoomba, east of the DXP area. Toowoomba has a relatively large population, approximately 125,000, while the largest population centre in the DXP area is Dalby, with a population of approximately 13,000.

A description of the key pollutants potentially occurring within the DXP area are detailed below in Table 7.

Table 7: Key pollutants potentially occurring within the DXP area.

Pollutant	Description/Potential Impact
Nitrogen oxides (NO_x)	Nitrogen oxides (NO_x) from the DXP are principally associated with combustion of fuels including coal seam gas. Nitrogen oxides refers to a family of compounds formed by the combination of oxygen with nitrogen (principal components of air). Other sources include power generation, motor vehicles, soil, the use of nitrogen based fertilisers, and bush fire emissions. Nitrogen oxides can be associated with adverse health effects and ecological impacts. Excessive release of nitrogen oxides into the air can contribute to acid rain, eutrophication (increased nutrient load) of watercourses and formation of photochemical smog. Nitrogen dioxide (NO_2) is the most significant oxide of nitrogen in relation to human health impacts. Nitrogen dioxide exists in the atmosphere under complex chemical equilibrium with other nitrogen oxides, atmospheric oxidants (particularly ozone), photochemically active volatile organic compounds and sunlight.
Particulate matter	Particulate matter refers to suspended solids or liquids in air. Particulate matter is emitted from the DXP area via mechanical processes such as wind erosion, earth works, vehicle movements (particularly on unsealed surfaces) and incomplete combustion. Combustion of gas is generally not associated with high levels of particulate matter emission in comparison to other fuels. Particulate matter can be formed as a secondary product of photochemical smog. Particulate matter <10 micrometre (µm) (PM_{10}) and particulate matter <2.5 µm ($PM_{2.5}$) can remain suspended in the air for many days and are generally associated with greater health impacts than larger particle sizes. These small sized particles can enter the respiratory tract and impact human

	health. Larger particulate tends not remain airborne for extended periods under most conditions but can still create environmental impacts. Deposited particulate matter (dust) can impact amenity and create nuisance via the accumulation on surfaces, laundry and cars.
Volatile organic compounds (VOC)	The term VOCs is employed to describe a family of organic (carbon based) compounds emitted from natural and anthropogenic processes (including incomplete combustion and the use of petrol). Some species of VOC are toxic and can contribute to the formation of photochemical smog. Coal seam gas contains negligible VOCs since it is comprised primarily of methane, which does not exhibit the levels of toxicity or photochemical reactivity typical of some VOCs.
Photochemical smog	Photochemical smog is a complex mixture of pollutants formed by reactions between pollutants within the atmosphere. Ground level ozone (O_3) is the key pollutant of concern associated with photochemical smog and is commonly employed as an indicator of smog. Photochemically active VOCs can contribute to reactions that form ozone by reacting with nitrogen oxides in the presence of sunlight. Ozone is a strong oxidiser and is active in converting nitric oxide to the more hazardous nitrogen dioxide. The key to controlling the formation of photochemical smog is to control primary pollutants such as oxides of nitrogen and VOCs.
Sulfur dioxide (SO_2)	SO_2 is formed when substances containing sulfur are burnt. The combustion of diesel and the operation of large coal-fired power stations within the DXP area will produce emissions of SO_2. Significant emissions of SO_2 are not associated with the DXP activities. Coal seam gas contains negligible quantities of sulfur. Diesel fuel employed within Australia is subject to strict sulfur limits.
Carbon monoxide (CO)	Produced from the incomplete combustion of carbon-based materials (including coal seam gas) potentially harmful to human health when exposed to sufficient concentrations. High levels of carbon monoxide are generally associated with heavy traffic. Well maintained gas operated equipment is not associated with significant carbon monoxide emissions.
Odour	Odour can lead to annoyance and some potential health effects. Hydrogen sulfide is a key odorant commonly associated with natural; however no significant hydrogen sulfide concentrations have been associated to date with coal seam methane. It is not anticipated that odour will be associated with key DXP operations but may be associated with ancillary operations such as sewage treatment.

5.2 ENVIRONMENTAL VALUES

The environmental values to be enhanced or protected in and around the DXP area in accordance with the *Environmental Protection (Air) Policy 2008* include:

- The qualities of the air environment that are conducive to protecting the health and biodiversity of ecosystems.
- The qualities of the air environment that are conducive to human health and wellbeing.
- The qualities of the air environment that are conducive to protecting the aesthetics of the environment, including the appearance of buildings, structures and other property.
- The qualities of the air environment that are conducive to protecting agricultural use of the environment.

5.2.1 Air Quality Objectives

The air quality objectives for the DXP are:

- To construct and operate in a manner that minimises impacts on ambient air quality.
- Ensure the Environmental Protection (Air) Policy 2008 and National and National Environmental Protection Measures are met at sensitive receptors to maintain human and environmental health.

5.2.2 Sensitive Receptors within the DXP

As detailed in Section 2.4 a survey conducted in 2009 identified approximately 400 potential sensitive receptors (buildings) within the DXP area, excluding the townships of Dalby and Cecil Plains. Sensitive places ground-truthed and mapped within the DXP area are shown in Figure 4

Arrow Energy have contracted Coffey Environments to update the identification, ground-truthing and mapping of sensitive receptors in the DXP area and this work is due for completion late-2012. Potential sensitive receptors are located throughout the DXP area and will consequently be integral to the assessment of potential noise and air quality impacts.

5.3 POTENTIAL IMPACTS ON ENVIRONMENTAL VALUES

Activities associated with the DXP that have the potential to adversely impact air quality include:

- Combustion exhausts from the burning of fuel gas at the compressor facilities (4 stage 5.89TJ/day reciprocating compressors) and well heads.
- Combustion exhausts from the flare during well testing, appraisal and development.
- Fugitive emissions from vehicles and plant.
- Dust emissions from earthworks and vehicular activity.

5.3.1 Emissions

Air quality can potentially be impacted during construction and operations through to eventual decommissioning. Table 8 shows emission sources associated with each phase of the project.

Table 8: Emission sources associated with each phase of the project

Project Activity/ Emission Source	Phase	Source Characteristics	Type	Emissions
Production well installation	Construction	Once-off at each well location	Fugitive or point	Combustion emissions associated with drilling equipment and fugitive dust associated with vehicle and material movement.
		Stationary sources	Point	Combustion emissions. Ramp-up flaring prior to facility commission. Flaring would occur at the nearest facility.
Gas and water gathering line installation	Construction	Once-off associated with construction	Fugitive	Combustion emissions associated with construction equipment and fugitive dust associated with vehicle and material movement.
Production facility installation (and construction camps)	Construction	Once-off associated with construction	Fugitive	Combustion emissions associated with construction equipment and fugitive dust associated with construction.
Medium- and high-pressure gas pipeline installation	Construction	Once-off associated with construction	Fugitive	Combustion emissions associated with construction equipment and fugitive dust associated with vehicle and material movement.
Production well operation (wellhead engines): gas combustion and fugitive emissions	Operations	Continuous stationary sources	Point	Combustion emissions and unburnt gas (e.g., from valves, periodic emissions from well workovers).

Processing facility operation: pilot flaring and upset conditions flaring	Operations	Continuous stationary sources	Point	Combustion emissions.
Production facility operation: fugitive emissions	Operations	Continuous stationary sources	Fugitive	Unburnt gas (e.g., from valves, flanges, compressors and pumps).
Production facility operation: tri-ethylene glycol reboiler	Operations	Continuous stationary sources	Point	Combustion emissions and unburnt gas.
Production facility operation (power generation): gas combustion	Operations	Continuous stationary sources	Point	Combustion emissions.
Transport	Operations	Intermittent mobile sources	Fugitive	Combustion emissions and fugitive dust.
Production well, gathering line and pipeline decommissioning	Decommissioning	Once-off	Fugitive	Combustion emissions and unburnt gas, fugitive dust emissions associated with vehicle or material movement.
Production facility decommissioning	Decommissioning	Once-off	Fugitive	Combustion emissions and unburnt gas, fugitive dust emissions associated with vehicle or material movement.

5.3.1.1 Greenhouse Gases

Arrow Energy has legal obligations in relation to greenhouse emissions and energy management with respect to its DXP activities.

Arrow triggers corporate reporting thresholds under the Commonwealth *National Greenhouse and Energy Reporting Act (NGER) 2007*. This act requires Arrow to report its greenhouse emissions, energy production and energy consumption in line with methodologies set out under the regulations. These reports are subject to audit by the Commonwealth Department of Climate Change and Energy Efficiency. Emissions reported under the NGER legislation will be employed to determine Arrow's carbon liability under the *Clean Energy Act 2011*.

Key greenhouse emission sources from DXP activities may include:

- Fugitive emissions associated with the operation and maintenance of the gas gathering systems and well heads.
- Greenhouse emissions associated with the fuel and electricity employed to compress the produced coal seam gas.
- Energy employed to treat coal seam gas water.
- Vehicle emissions.

Arrow Energy has been reporting under this legislation since 2008/2009 and has developed systems and methodologies to gather and report the required information.

The *Clean Energy Act 2011* establishes a price on greenhouse emissions. Arrow will be required to hold emissions permits equal to its carbon liability from 1 July 2012. Arrow has a clear economic incentive to minimise the greenhouse emissions associated with its operations.

As a large energy user, Arrow also has obligations under the *Energy Efficiency Opportunities Act 2006*, which requires companies that use more than 0.5 PJ of energy (which includes Arrow Energy) to identify evaluate and publically report energy efficiency opportunities for projects which have a payback time of less than two years. The energy efficiency opportunities are identified via energy assessments. The timing and scope of the energy assessments is agreed with the Department of Resources Energy and Tourism in an Assessment and Reporting Schedule for each five year assessment period. Arrow has committed to complete energy assessments on the processes employed within the DXP area.

5.4 MANAGEMENT OF POTENTIAL IMPACTS

5.4.1 Control Strategies

Key control strategies to address potential impacts associated with air quality though all phases of the DXP are shown in Table 9.

Table 9: Control Strategies for Potential Impacts to Air Quality and Greenhouse Gases

Environmental Protection Objectives	
• To construct and operate in a manner that minimises impacts on ambient air quality. Ensure relevant air quality guidelines are met at sensitive receptors to maintain human and environmental health. • To minimise greenhouse gas emissions generated by project activities throughout the life of the project.	
Environmental Issue	**Control Strategies**
• Decline in air quality through fuel combustion, fugitive emissions and dust generation from project	*Planning and design:* • Conduct site-specific air quality modelling once site locations are known to ensure project-related air emissions meet EPP (Air) objectives at the nearest sensitive receptor. • Select equipment with consideration for low emissions to air

activities. • Contribution to greenhouse gas emissions.	(NO_x), high energy efficiency and fuel efficiency. • Design facilities to meet relevant EPP (Air) objectives at sensitive receptors. • Minimise fuel consumption of vehicles by optimising transport logistics. • Select gaskets, seals and vehicle exhaust systems that are suitable for the task. • During all project phases, minimise greenhouse gas emissions by optimising transport logistics and minimising the footprint of disturbance. *Construction, operations and decommissioning:* • Ensure all engines, machinery equipment and pollution control mechanisms are efficiently maintained and operated. • Implement dust suppression measures for roads and construction sites to ensure that dust does not cause a nuisance. • Consider handling of dust-generating materials prior to transportation. • Consult with potentially affected landowners prior to undertaking activities. • Minimise the disturbance footprint and vegetation clearing. *Construction:* • Clear areas progressively and implement rehabilitation as soon as practicable following construction activities. • Minimise venting and flaring of gas as far as practicable and where safe to do so. Operations: • Minimise venting and flaring of gas as far as practicable and where safe to do so. *Decommissioning:* • Clear areas progressively and implement rehabilitation as soon as practicable following decommissioning activities. • Regular monitoring of rehabilitated areas will be undertaken until a stable landform is achieved.
Monitoring Requirements	
• Air quality assessment of combustion plant to ensure that the ground-level concentrations of relevant pollutants do not exceed EPP (Air) objectives throughout the lifetime of the project. • Scheduled emissions testing of fuel burning equipment and combustion equipment to ensure values do not exceed limits set in the air quality assessments • Operational equipment will be monitored for contaminants within 3 months after commissioning and biennially thereafter. • Assess the energy-efficiency opportunities and estimate greenhouse gas emissions associated with the project in accordance with regulatory requirements. Calculate annual greenhouse gas emissions as required under the *National Greenhouse and Energy Reporting*	

Act 2007 (Cwlth) and Energy Efficiency Opportunities program.
Performance Indicators
• Compliance with project air quality objectives at sensitive receptors. • Compliance with relevant greenhouse gas programs. • Complaints are recorded, managed and responded to.

6. DAMS

Dams are necessary for the storage of coal seam gas water and brine that are produced as part of coal seam gas extraction and coal seam gas water treatment for the DXP. In addition, water used for hydro-testing may be diverted to holding dams.

Water storage dams are assessed using the Manual for Assessing Hazard Categories and Hydraulic Performance of Dams prepared by DERM (2011a). If a dam is assessed as being in the significant or high-hazard category, it is considered a regulated dam and therefore registered with DEHP.

6.1 DESIGN STANDARD FOR REGULATED DAMS

Regulated dams must be constructed in accordance with the following internal and external standards and specifications:

- DERM, Manual for Assessing Hazard Categories and Hydraulic Performance of Dams, Version 2, June 2011.
- Environmental Authority PEN100449509.

6.2 ENVIRONMENTAL VALUES

Environmental values will vary with each proposed dam location, however, general environmental values to be protected may include:

- Land use capability, including maintaining the agricultural values of the land.
- The life, health and wellbeing of people.
- The diversity of ecological processes and associated ecosystems.
- The biological integrity of aquatic ecosystems and the suitability of waters for primary industry or recreational purposes.
- The suitability of groundwater for use in agriculture.

6.3 POTENTIAL IMPACTS ON ENVIRONMENTAL VALUES

Potential impacts of dams from associated project activities include:

- Dust and noise emissions from earthworks and vehicular activity.
- Loss of vegetation or habitat due to clearing requirements.
- Fauna mortality due to entrapment in dams.
- Salinisation of land surrounding dams due to spills, leaks and the inappropriate containment of coal seam water or brine.
- Salinisation of shallow groundwater in the vicinity of dams due to the long-term seepage and migration of coal seam water or brine.
- Disruption of overland flows.

- Surface water degradation and injury to people or property from a catastrophic release of a water storage dam.
- Loss of productive land through construction of dams.
- External events, such as flooding, extreme rainfall events, earthquake or land subsidence, causing dam overflow and subsequent surface water degradation.

The majority of potential impacts to the environment occur during construction activities, where noise and dust nuisance issues can become problematic if not managed correctly and disturbed earth is vulnerable to erosion from stormwater run-off. Larger volumes of fuels and potentially other hazardous substances (e.g. oils, lubricants etc.) may also be on-site during construction, which increases the potential for spills and land contamination (where not remediated) from activities such as re-fuelling.

Potential environmental impacts associated with the operation of dams are predominantly related to the lack of containment of coal seam gas water. A lack of containment may occur through uncontrolled releases of coal seam gas water from the dam (i.e. dam overtopping or dam failure) or through leaks and/or seepage through the floor and walls of the dam into shallow groundwater and the surrounding soils.

6.4 MANAGEMENT OF POTENTIAL IMPACTS

The primary mitigation measure is to design, construct and monitor dams in accordance with the Manual for Assessing Hazard Categories and Hydraulic Performance of Dams (DERM, 2011a), Queensland standards and DERM guidelines.

Dam locations are selected in consideration of all relevant environmental, social and safety factors to best minimise long-term disturbance to the environment and/or the identified environmental values. The location of existing dams within the DXP is illustrated in Figure 5.

Dam safety is controlled through dam safety guidelines, which apply for all facilities forming part of the DXP. Dams are accordingly designed and sized to account for predicted flood conditions and each dam is subject to separate approvals by the regulating authority. Each approval requires the incorporation of general and specific controls to avoid, mitigate or manage threats associated with flooding.

Potential environmental impacts associated with the construction of new dams are readily mitigated through the use of basic construction site controls, such as limiting construction hours, implementing stormwater diversions and erosion and sediment controls, correctly storing and handling fuels and hazardous substances and using dust suppressants. These impacts are only temporary in nature, thereby reducing the potential for significant long-term adverse impacts on the identified environmental values.

6.4.1 Control Strategies

Key control strategies to address potential impacts associated with dams though all phases of the DXP are shown in Table 10.

Table 10: Control Strategies for Potential Impacts Associated with Regulated Dams

Environmental Protection Objectives	
To ensure no uncontrolled release or leakage occurs; and that coal seam gas water and brine in regulated dams is appropriately managed.	
Environmental Issues	**Control Strategies**
• Impacts on land use relative to the footprint of the dam. • Hazard to people and infrastructure if the dam overtops or fails. • Impacts from salinity through leakage of untreated coal seam gas water or of brine. • Loss of habitat relative to the footprint of the dam. • Diminished surface and groundwater quality if the dam overtops or fails.	*Planning and design:* • Consider local biological, groundwater and surface water conditions when identifying sites for coal seam gas water dams and brine dams. • Design water dams in accordance with relevant legislation and Queensland standards and DERM guidelines. • Leak detection systems will be installed on brine dams. • Design and size dams to account for predicted flood conditions. *Construction:* • Line banks of dam with an impervious lining. • Design dams to have an egress (escape point) for wildlife. *Operations:* • Establish maintenance and operational controls in accordance with the Dam Operating Plan. • Weekly, monthly and annual inspections to ensure and/or identify dam integrity issues. • Annual maintenance strategy to ensure preparedness for wet season. • Water production and offtake forecasts to identify any potential short or long term water inventory concerns. *Decommissioning:* • Implement a decommissioning and rehabilitation plan in accordance with the dam design plan.

Monitoring Requirements
• Implement the Dam Operating Plan. • Routinely monitor water quality in dams. • Monitor dam levels. • Have a suitably qualified person routinely monitor the integrity and available storage of dams.
Performance Indicators
Operated and maintained in accordance with the certified design plan.

7. GEOLOGY, LAND AND SOILS

7.1 EXISTING ENVIRONMENT

7.1.1 Terrain

The Condamine River and its tributaries in the region have been influential in the development of the landform of the Darling Downs. The waterways show signs of channel migration, with clear meander scars and evidence of major channel avulsion. The combined processes of the degradation of the underlying sedimentary strata, channel meandering and migration, erosion from nearby igneous outcrops, and deposition from flooding events have generated a landform that comprises broad expanses of gently undulating land with some outcrops that have been resilient to the deposition and erosion processes.

The landscape of the DXP area is strongly linked to the underlying geology and geomorphological evolution of the area and is characterised by the Great Dividing Range highlands, the Kumbarilla Ridge uplands and the Condamine-Culgoa Drainage Basin (Condamine River and Balonne River). The following landforms and geomorphological processes were identified within the DXP area and contribute to the general features of the landscape:

- Upland features.
- Steep slopes.
- Gilgai.
- Gully erosion.
- Watercourses.

7.1.2 Geology

The Surat Basin is one of the major sedimentary basins within the Great Artesian Basin (GAB). Deposition of sediments into the Surat Basin began approximately 200 million years ago (Ma), in the Early Jurassic. During the Early Jurassic, deposition was mostly associated with river and lake environments (fluviolacustrine). By the Middle Jurassic, swamp environments predominated over much of the basin.

As the end of the Middle Jurassic approached (approximately 150 Ma), river systems again predominated and continued until the earliest Cretaceous. In the period following, the area experienced a marine transgression (inundation by the ocean), and shallow fresh water and marine sediments were deposited. The subsequent marine regression caused a fairly abrupt return to river and lake environments and swamp/marsh environments before sedimentation ceased in the Early Cretaceous, approximately 110 Ma. It is estimated that the maximum sediment thickness of the Surat Basin is 2,500m.

About 100 conventional (i.e. liquid crude oil and natural gas) petroleum accumulations have been discovered in the Surat Basin, of which approximately half are producing fields. Most accumulations occur in the Early Jurassic sands, with occasional gas

occurrences in the Middle and Late Jurassic. However, all are sourced from the Permian non-marine sediments of the underlying Bowen Basin and are not associated with the Walloon Coal Measures of the Surat Basin.

Organic material deposited in the swamp environments eventually became compressed organic layer(s) that over geological time became transformed into coal. The Surat Basin accordingly has a number of coal seam gas fields. These fields are presently exploited for gas supply to the domestic market, including a number of power stations and the Roma to Brisbane Pipeline.

Coal seam gas exploration and production is focussed on the Walloon Coal Measures, which formed during the Middle Jurassic. The Walloon Coal Measures are characterised by carbonaceous mudstone, siltstone, minor sandstone and coal, and contains the following formations:

- Juandah Formation.
- Tangalooma Sandstone.
- Taroom Coal Measures.
- Euromah Formation.

Of these four formations the Juandah and the Taroom Coal Measures are targeted for exploration and production and generally range in depth from 150m to 750m below ground surface across the DXP area. Surface geology within the DXP area is shown in Figure 9.

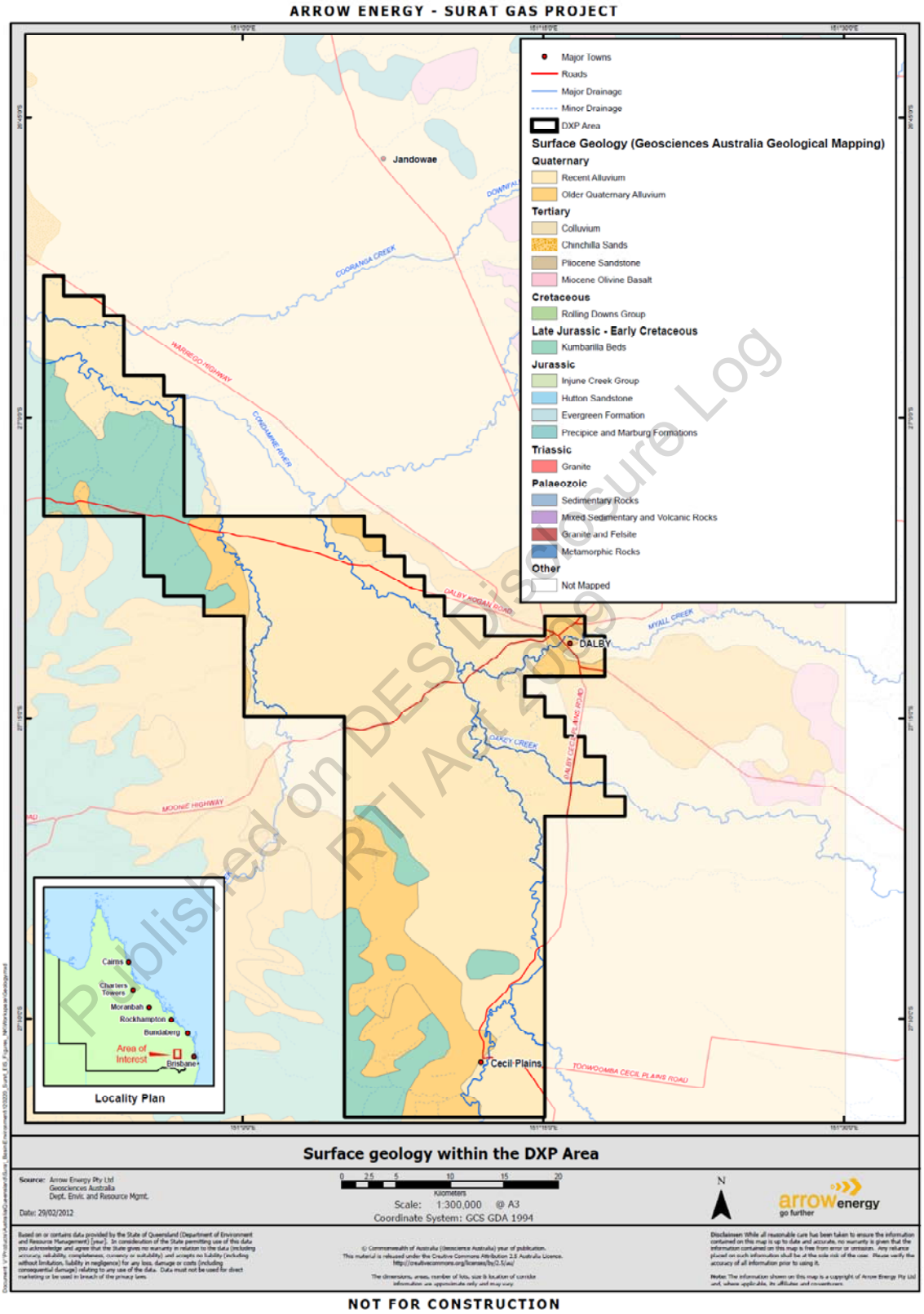


Figure 9 Surface geology within the DXP Area

Properties of the Walloon Coal Measures that influence the production of coal seams include:

- Geological factors, including structure, depth, faulting and cleating.
- Coal seam and confining strata porosity and permeability.
- Gas content, gas sorption capacity and pressure

7.1.3 Soils

Soil characteristics are strongly linked to formation process, relief and parent material. Seven broad soil types were identified in the DXP area and are characterised below (listed in the order of most to least clay content). They have been classified under the Australian Soil Classification System (Isbell, 2002). The geology, landform and soil characteristics contribute to terrain units, and represent the landscape environmental values and their sensitivity (i.e., how the landscape responds to disturbance). The distribution of terrain units and their association with soil types across the DXP area is shown Figure 10.

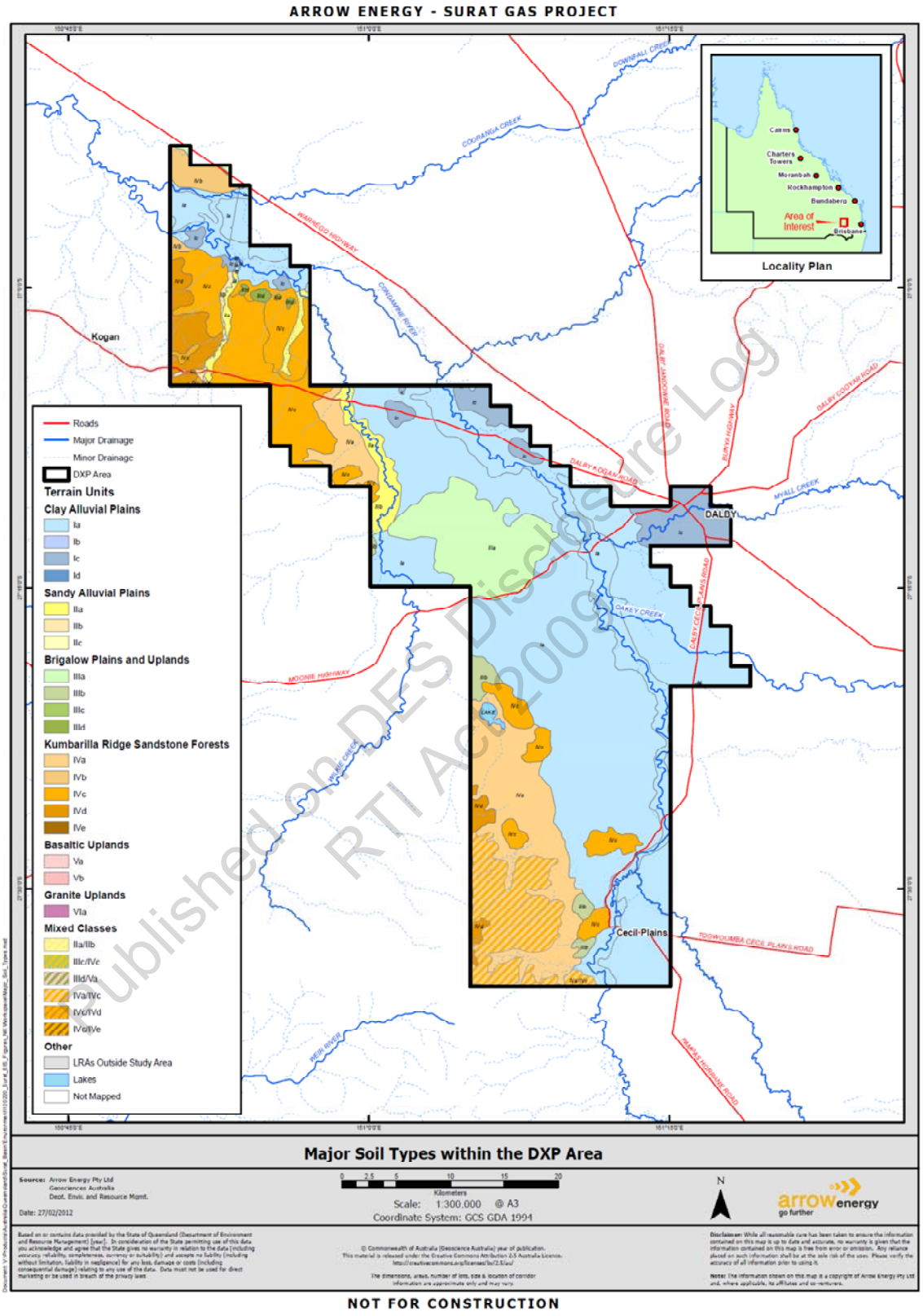


Figure 10 Major soil types within the DXP area

- Gilgai Clays: Gilgai clays occur on flat to gently undulating ground, usually on older alluvial sediments subject to seasonal flooding. These soils are characterised by a deep profile, which can be greater than 1.5 m thick. Gilgai clays are poorly drained and often water is retained within the gilgai depression. They are classified as Vertosols. This soil type is found within the Brigalow Plains and Uplands terrain unit.
- Cracking Clays: These clays are widespread throughout the DXP area, with two types identified:
  - Black cracking clays, which are of high value for agricultural production, are the dominant soil type along the Condamine River valley within the vicinity of Dalby, and to the south and east of Cecil Plains. They are generally well structured and have a deep to very deep profile. The shrink/swell properties of the clay minerals cause them to swell when wet and produce cracks greater than 5 mm wide, which can be observed when dry. They are classified as Vertosols. This soil type is found within the Clay Alluvial Plains and Brigalow Plains and Uplands terrain units.
  - Uniform cracking clays, which occur in areas around Miles, Chinchilla, Kogan and Brigalow on gentle slopes on a range of materials derived from alluvium, basalt and deeply weathered materials. These clays have poor internal drainage with variably deep profiles and are classified as Vertosols. This soil type is found within the Clay Alluvial Plains, Brigalow Plains and Uplands and Kumbarilla Ridge Sandstone Forests terrain units.
- Uniform Non-cracking Clays: These clays occur on gently undulating plains and rises, and upper slopes of hills. Although these soils are agriculturally highly productive, they can require erosion control measures. They usually have deep uniform or gradational profiles. These clays are classified as Dermosols. This soil type is found within the Sandy Alluvial Plains and Brigalow Plains and Uplands terrain units.
- Texture Contrast Soils: These soils are characterised by an abrupt textural contrast between the surface and subsoil horizons. In general, these soils have little agricultural value but are used for low-density grazing in some areas. Two types of texture contrast soils were identified in the DXP area:
  - Dispersive texture contrast soils, which are typically deep, prone to erosion and can be hardsetting. The subsoils are usually sodic and may be acidic. These soils are classified as Sodosols and Kurosols. This soil type is found within the Clay Alluvial Plains, Sandy Alluvial Plains, Brigalow Plains and Uplands and Kumbarilla Ridge Sandstone Forests terrain units.
  - Non-dispersive texture contrast soils, are common along undulating to moderately sloping land on the edges of the Kumbarilla Ridge. The profile is typically moderately deep to deep. They can be poorly drained, with a hardsetting surface. They are classified as Chromosols and Kurosols. This soil type is found within the Clay Alluvial Plains, Sandy Alluvial Plains,

Brigalow Plains and Uplands and Kumbarilla Ridge Sandstone Forests terrain units.

- Uniform Loams and Clays: Two types were identified within the DXP area:
  - Loams and clay loams found along the upper slopes and crests of the Kumbarilla Ridge and other uplands, and also along alluvial drainage channels. These soils can be bleached or gravelly, with acidic subsoils above a transitional zone into weathered rock. They are classified as Tenosols and Kandosols. This soil type is found within the Sandy Alluvial Plains and Kumbarilla Ridge Sandstone Forests terrain units.
  - Clays loams and clays that occur on the lower slopes and edges of sandstone uplands, in depressions and along drainage channels. They are classified as Rudosols, Tenosols and Kandosols. This soil type is found within the Sandy Alluvial Plains and Kumbarilla Ridge Sandstone Forests terrain units.
- Sands and Sandy Loams: These soils have a uniform or weakly gradational sandy texture. Two types were identified within the DXP area:
  - Alluvial sands, comprising alluvial and colluvial deposits, are found along sandy alluvial plains. They are typically loose-grained sandy soils with a moderately deep profile. These soils are classified as Rudosols and Tenosols. This soil type is found within the Sandy Alluvial Plains terrain unit.
  - Residual sands and sandy loams that are formed from quartzose sandstone and found on eroded plateau margins, uplands and sometimes on lower slopes. They are variable in depth and underlain by weathered rock. Subsoils are often acidic. These soils are classified as Rudosols, Tenosols and Kandosols. This soil type is found within the Sandy Alluvial Plains and Kumbarilla Ridge Sandstone Forests terrain units.
- Skeletal, Rocky or Gravelly Soils: These soils generally occur adjacent to rock outcrops in upland areas. They are typically shallow, with over 60% coarse fragments. They are classified as Rudosols and Tenosols. . This soil type is found within the Kumbarilla Ridge Sandstone Forests terrain unit.

7.1.3.1 **Acid Sulfate Soil**

Acid sulfate soils usually occur below 20m AHD, and are associated with anoxic, highly organic environments close to saline water. Although these conditions do not exist within the DXP area, acid sulfate soils can also occur at higher elevations inland in river and lake beds, irrigation channels, and in saline seepage areas where there are organically rich deposits. Some regional mapping presented in the National Acid Sulphate Soils Atlas (Geoscience Australia, 2011), shows areas of potential acid sulfate soils within the DXP area. However, these areas are of limited extent and are considered to represent locations associated with wetlands and watercourses where conditions

may be suitable for the formation of acid sulfate soils, rather than groundtruthed and proven instances of acid sulfate soils within the DXP area.

The combination of saline groundwater tables rising and salt becoming mobilised via surface water flows, can lead to the salinisation of inland aquatic ecosystems. In these instances, where there are high levels of salt in the landscape, high concentrations of sulfate, and therefore acid sulfate soils, can occur. Acid sulfate soils have been found in the uppermost reaches of the Condamine River catchment (located to the southeast of the DXP area), in effluent ponds and some north-draining streams and wetlands (EPHC & NRMMC, 2011), however it is reasonable for the project to progress on the assumption that acid sulfate soils will not be encountered during project activities. Should geotechnical investigations and testing during the course of the development encounter potential acid sulfate soils, site-specific control measures will be adapted accordingly.

7.1.4 Good Quality Agricultural Land

There are four classes of agricultural land defined in Queensland, as outlined in Table 11.

Table 11: Agricultural Land Classes

Class	Description
A	Cropland. Land suitable for current and potential crops. None to moderate limitation levels to production. Considered GQAL in all areas.
B	Limited cropland. Land marginal for current and potential crops due to severe limitations. Engineering and/or agronomic improvements may be required before the land is considered suitable for cropping. Suitable for pastures. Considered GQAL in most areas.
C	Pasture land. Land suitable only for improved or native pastures due to limitations that preclude continuous cultivation for crop production. Some areas may tolerate a short period of ground disturbance for pasture establishment. Not considered GQAL.
D	Non-agricultural land. Land not suitable for agricultural uses due to extreme limitations. This may be undisturbed land with significant habitat, conservation and/or catchment values or land that may be unsuitable due to very steep slopes, shallow soils, rock outcrop or poor drainage. Not considered GQAL.

The DXP area lies within the Darling Downs, an area of national agricultural importance (traditionally grain and cotton production). Clay soils, which have higher water-holding capacity and fertility, are considered to have a higher cropping potential than sands or shallow soils. The spatial distribution of GQAL within the DXP area is shown Figure 11 .

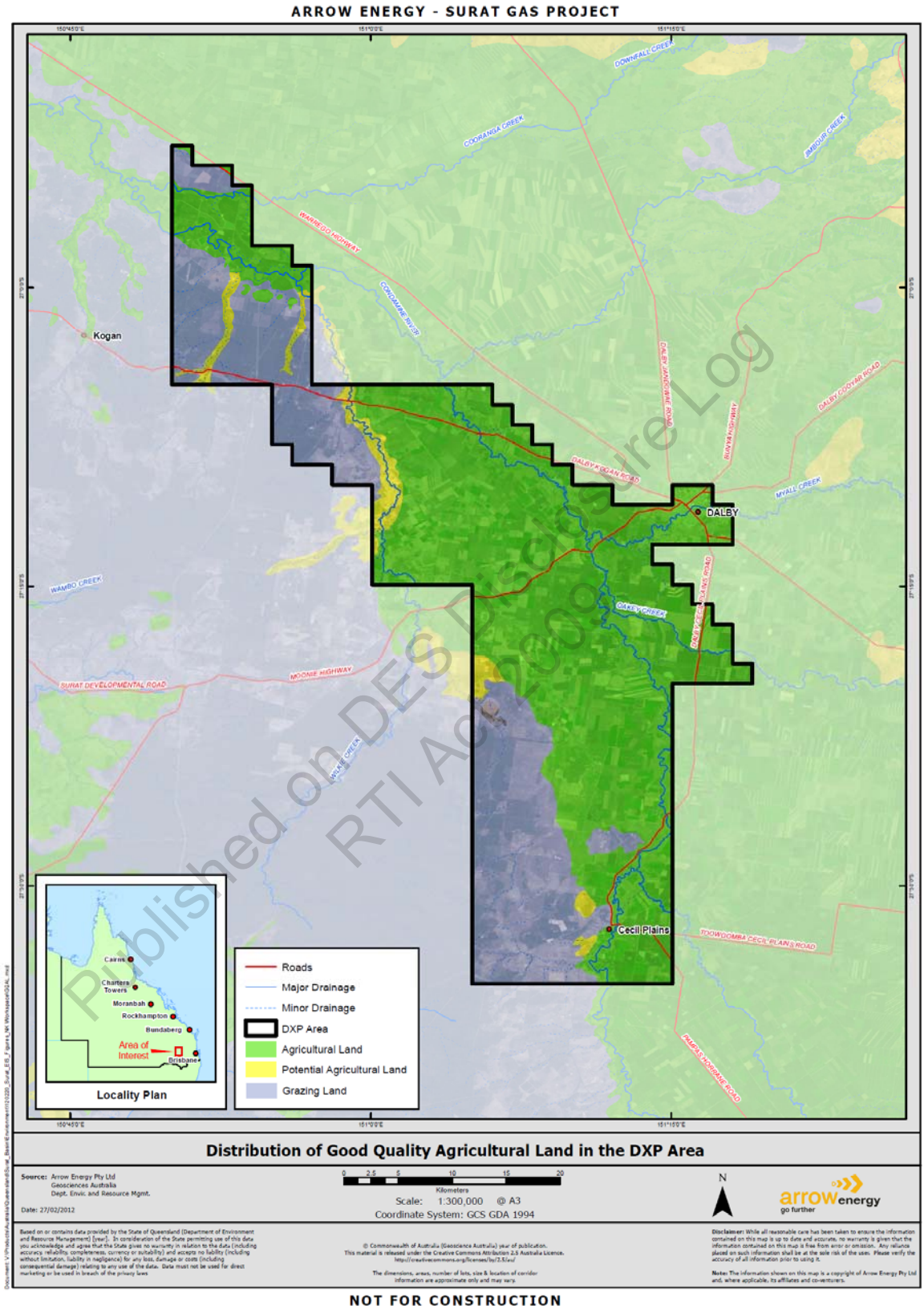


Figure 11 Distribution of good quality agricultural land in the DXP Area

Most of the GQAL is located along the river valley floor of the Condamine River, as it has deep, cracking clays. Although it is prone to erosion, most of the GQAL is being used intensively within the DXP area.

Class C land occurs along the sandstone uplands of the Kumbarilla Ridge to the west of the DXP area and in the north on plateau areas. It is extensively used for cattle grazing.

7.1.5 Strategic Cropping Land

Strategic cropping land (SCL) is recognised by the Queensland Government as "an important, finite resource that is subject to competing land uses from the agriculture, resources and urban development sectors. The government aims to strike a balance between these sectors to help maintain the long-term viability of our food and fibre industries, and support economic growth for regional communities" (DERM 2011b).

On the 30 January 2012 the *Strategic Cropping Land Act 2011* (SCL Act), Strategic Cropping Land Regulation 2011 and State Planning Policy 1/12: Protection of Queensland's Strategic Cropping Land commenced. The purposes of the SCL Act are to:

(a) protect land that is highly suitable for cropping;

(b) manage the impacts of development on that land; and

(c) preserve the productive capacity of that land for future generations.

An SCL trigger map has been produced that is indicative of where SCL may potentially occur (DERM 2011c). Typically SCL is closely aligned to the GQAL categorisation and this is supported by its' indicative presence within the DXP as shown in Figure 12

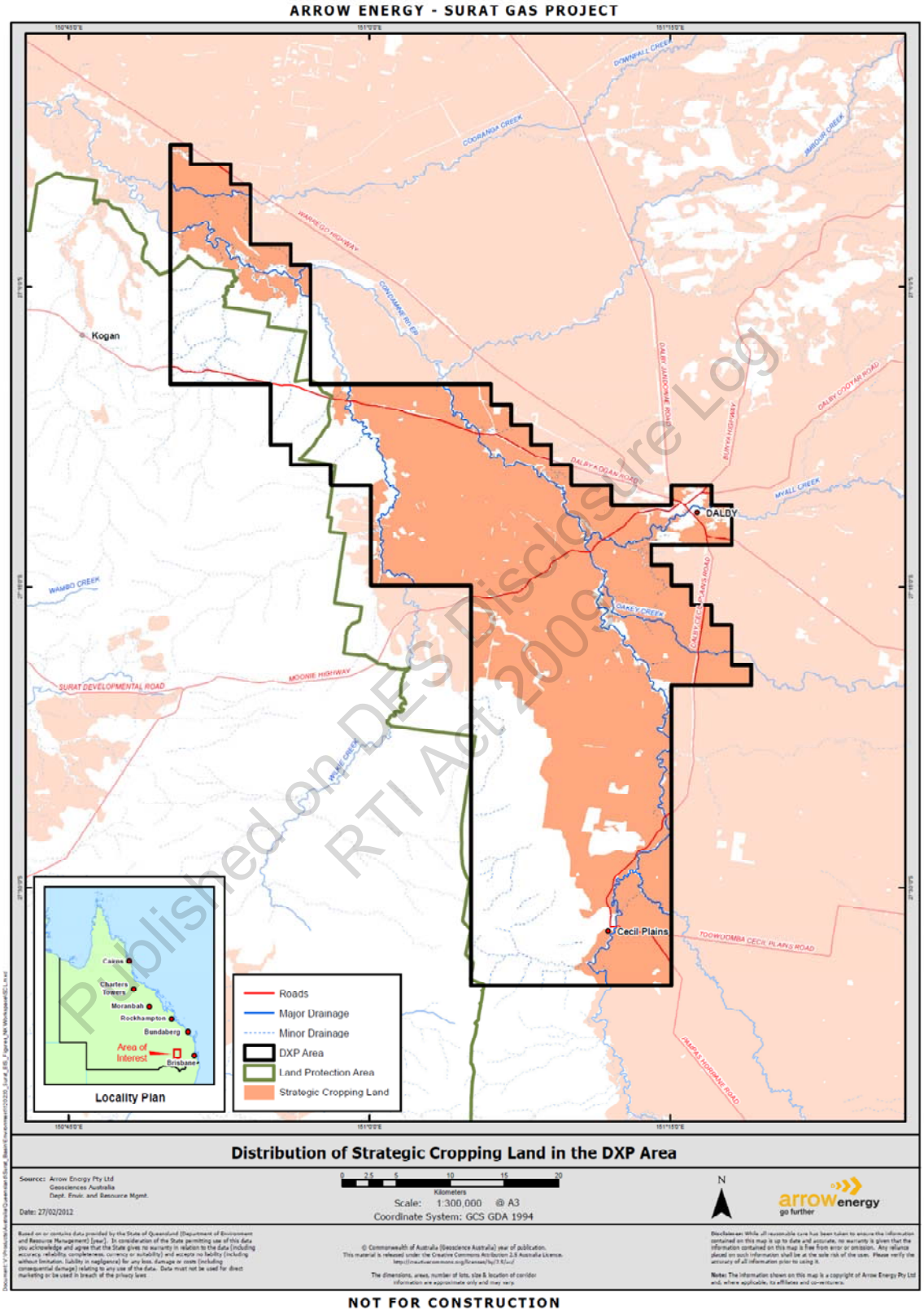


Figure 12 Potential strategic cropping land located within the DXP

The actual proportion of land classified as SCL within the DXP area, will be determined at a property level via ground level assessments against criteria defined in Schedule 1 of the SCL Act.

The DXP area is predominately located within the Eastern Darling Downs zone, with a small area near Kogan located within the Western Cropping zone.

7.1.6 Agricultural Activities

The main soil types used for agriculture in the DXP area are the Vertosols and Dermosols (both black soils). Vertosols are light to heavy clays, fertile in a natural, undisturbed state with nutrient reserves, and have highly reactive shrink-swell properties. Dermosols are similar to Vertosols. Sandy alluvial plains with deeper, sandy Rudosols, Tenosols and Kandosols (i.e., sands, sandy loams, loams and clay loams) are also present in the DXP area and are included in soils that define good-quality agricultural land (GQAL).

Summer and winter crops are both grown in the region. However, as there is generally higher summer rainfall in the DXP area and greater economic returns are received for summer crops, summer crops are generally preferred. Stubble retention and strip cropping are carried out in flood-prone areas, and both irrigated and dryland cropping systems are used. Grain and cotton crops are grown, with raw cotton transported to Brisbane for export. Grain is used for human consumption, feedlots and in industrial plants. Crops such as cotton and wheat are grown across the Darling Downs region, as are speciality pulse crops such as Adzuki beans, which are used in high-value niche exports. Several certified organic farms operate in the region.

Current agricultural activities across the broader Darling Downs region include:

- Dryland Broadacre Farming.
- Irrigated Broadacre Farming.
- Horticulture.
- Fruit.
- Vineyards.
- Livestock Industries.
- Timber Production.

7.1.7 Contaminated Land

Land can become contaminated through a range of activities and land uses. The Queensland Government defines such activities as notifiable activities under the EP Act. Although many of the listed notifiable activities are ‘industrial’ in nature, a significant number may be reasonably expected in an environment where agricultural activities predominate. Accordingly, many notifiable activities will have been carried out somewhere within the DXP area. Some affected land parcels may be listed on the EMR and CLR administered by DEHP, but others will not have been identified or reported. In

addition to the specified notifiable activities, uncontrolled and otherwise unidentified activities may also have contributed to contamination of land within the DXP area.

7.2 ENVIRONMENTAL VALUES

7.2.1 Geology, Soils and Landform

There are several geological, landform or soils features that have been registered on the Australian Register of the National Estate (although this has since been superseded by the *Environment Protection and Biodiversity Conservation (EPBC) Act 1999*), or are indicative sites, which are (or were) being assessed for inclusion on the Register of the National Estate. Within the DXP area, the Lake Broadwater Conservation Park is considered to be of national environmental significance.

Located along the eastern flanks of the Kumbarilla Ridge approximately 20 km southwest of Dalby (see Figure 14), Lake Broadwater is one of the few inland wetlands in southern Queensland. The heavy clay soils surrounding the lake support vegetation communities typical of the Brigalow Belt South Bioregion. The Lake Broadwater Conservation Park covers 1,200 ha, and the lake itself is approximately 350 ha in size and 4m deep when full. The park has been protected under the *Nature Conservation Act 1992* (NC Act) since 1994.

Based on the description of geology, landform and soils, the DXP area can be divided into 'terrain units', which represent areas of the landscape that have broadly similar 'environmental values' (i.e., characteristics, properties and behaviours). The DXP area can be divided into four broad terrain units. Table 12 summarises the geological, landform and soil values relating to each terrain unit.

Table 12: Value of the existing environment: geology, landform and soils

Existing Environment	Characteristics Contributing to the Value
Terrain Unit I – Clay Alluvial Plains	• No geoheritage features. • GQAL and strategic cropping land. • Sodic, saline subsoils susceptible to water erosion. • Soft soils prone to waterlogging; susceptible to flooding near the Condamine River and its tributaries. • Soils generally high in fertility, well-structured, deep cracking clays, with areas of texture contrast soils. • Will be difficult to rehabilitate to predisturbance condition. Particular areas will be more challenging due to lower fertility and distinct soil profiles.

Terrain Unit II – Sandy Alluvial Plains	• GQAL and strategic cropping land close to rivers and creeks. • Sodic, saline subsoils susceptible to water erosion, except along some watercourses. Sandy soils susceptible to wind erosion. • Loose sandy soils or soft clays prone to waterlogging. • Low-fertility sandy soils with poor rehabilitation potential, or high-fertility, well-structured soils difficult to rehabilitate.
Terrain Unit III – Brigalow Plains and Uplands	• GQAL and strategic cropping land. • Sodic, saline subsoils susceptible to water erosion. Texture contrast soils moderately susceptible to wind erosion. • Soft soils prone to waterlogging. • Well-structured clay soils and gilgai deep cracking clays will be difficult to rehabilitate. Areas of lower fertility with distinct soil profiles will be difficult to rehabilitate.
Terrain Unit IV – Sandstone Ridge	• Contains Lake Broadwater. • Low-relief areas classified as Class C (pasture land). All other areas classified as Class D (non-agricultural land). • Sodic, saline soils susceptible or highly susceptible to water erosion, moderately susceptible to wind erosion and prone to waterlogging. • Steep slopes associated with jumpups, plateaux or mesa edges, and cuesta escarpments locally increase sensitivity. • Soil profile and moderate to low fertility reduces rehabilitation potential.

7.3 POTENTIAL IMPACTS ON ENVIRONMENTAL VALUES

Potential impacts to geology, landform and soils values from project activities may include:

- Land degradation: erosion and associated sedimentation, compaction, dust generation and reduction in soil quality.
- Land contamination:
  - Disturbance of existing contaminated land.
  - Potential to cause land contamination through project activities.

Potential impacts are further discussed in Sections 7.3.1 and 7.3.2 below.

7.3.1 Soils

7.3.1.1 Potential Land Degradation

Land can be degraded as a result of erosion and associated sedimentation, dust generation and reduction in soils quality. Activities with the potential to cause these impacts during the life of the project include:

- Deposition downslope or downstream of eroded sediment as flow velocities decrease as an indirect result of project activities that cause erosion (e.g., seismic surveys, construction of exploration and production wells, gathering lines, production facilities and associated infrastructure).
- Soil compaction potentially affecting long-term crop productivity from spoil placement or vehicular trafficking of access tracks and laydown areas.
- Topographic alteration from the construction of borrow pits for the use of rock in construction activities.
- Increased surface or subsurface erosion and waterlogging resulting from flow concentration due to differential settlement of pipeline backfill and padding.
- Reprofiling of microrelief leading to patchy exposure of sodic and saline subsoils from inversion of the soil profile during backfill of materials during rehabilitation.
- Imported materials for rehabilitation purposes, particularly in areas of GQAL, affecting agriculture production.

7.3.1.2 Potential Land Contamination

Issues relating to contaminated land and project activities may involve the exposure of project workers to contaminated land and/or the disturbance of contaminated land as infrastructure is constructed and installed. During the life of the project, there is also the potential for Arrow activities to result in the contamination of land while conducting a notifiable activity or through the generation of various waste streams.

In these scenarios, potential impacts relate to the exposure to, and disturbance or release of, contaminants of concern into the receiving environment, specifically into high- or very-high-value greenfield areas. Contamination may also involve the introduction of different contaminants (i.e., those that would otherwise not be present) into lower-value areas. Activities with the potential to cause these impacts during the life of the project include:

- Site selection of project infrastructure over contaminated land.
- Disturbance of contaminated soil during seismic surveys and the drilling of exploration and coal seam gas wells.

- Disturbance of contaminated soil during excavation of trenches for the installation of gathering infrastructure, gas pipelines and other utilities associated with the development.
- Disturbance of contaminated soil during civil works associated with the construction of production facilities and dams.
- Uncontrolled movement of contaminated soil after disturbance by project activities.
- Transport to the surface of groundwater that has become contaminated through notifiable or uncontrolled activities (creating an exposure pathway that would otherwise not exist).
- Leaks and spills from or of:
  - Onsite fuel storage tanks.
  - Onsite chemical storage facilities.
  - Fuels and lubricants from the operation of earthmoving, drilling, and associated equipment.
  - Waste generated through the drilling of coal seam gas wells (e.g., waste drilling muds).
  - Hydrotest waters generated during pipeline installation activities.
  - Lubricants and chemicals from the operation of gas compression and associated equipment.
  - Chemicals from the operation of coal seam gas water treatment facilities.
  - Brine generated as a by-product of the treatment of coal seam gas water.

7.3.2 Potential Impacts to Agricultural Land Use Suitability

Potential impacts to the environmental or agricultural values of the DXP area 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.

Project activities with the potential to cause adverse impacts on agricultural enterprises during the construction, operation and maintenance, and decommissioning phases of the project are described below:

- Loss of productive land (temporary and potentially permanently) from development of production facilities.
- Temporary or permanent disturbance and potential diminished productivity as a result of the development of wells, gathering systems, pipelines and access tracks.
- Reduced crop yield from unsuccessful rehabilitation.
- Disruption to farm operations such as tillage, planting, irrigation, weed control and harvesting from inappropriate placement of wells, gathering systems, pipelines and access tracks.
- Disruption to intensive farming enterprises including piggeries, chicken production, feedlots or dairy farming from inappropriate placement of production facilities, wells, gathering systems, pipelines and access tracks.
- Soil degradation from disturbance of the soil structure, resulting in impacts to fertility and biologic function and crop yield from all project activities.
- Changes to surface irrigation infrastructure including head ditches, bays and tail drains from placement of wells, gathering systems, pipelines and access tracks.
- Diversion of flows and changes to the hydrology of the landscape from poorly sited and constructed access tracks.
- Farm hygiene issues relating to weeds and disease management from construction and operation vehicles, plant and equipment.
- Site contamination from project activities.

7.4 MANAGEMENT OF POTENTIAL IMPACTS

7.4.1 Geology, Soils and Landforms

The primary means by which avoidance is achieved for potential geological-, landform- and soil- related impacts is through design and site selection. Arrow's level of control or influence over the management of contamination will depend on the tenure of the land on which they are conducting project activities. Where Arrow is the landowner, Arrow will have full responsibility for and control of management of any contamination that is

disturbed or caused. Otherwise, Arrow will have to consider the requirements of the landowner, while fulfilling its own obligations under the EP Act.

7.4.2 Agricultural Land Use Suitability

Each agricultural enterprise is unique and particular practices have been developed to maximise the productivity of the land. The planning, design and development of project infrastructure and undertaking of project activities will need to address the specific issues raised by each property i.e., coal seam gas development needs to be integrated with farm operation and development.

The primary mitigation for reducing potential impacts on agricultural land and agricultural enterprises will be through appropriate siting of infrastructure. Second to this will be the design and development of construction, operation and maintenance methods to enable the integration of project and farm activities.

The effectiveness of the proposed environmental management controls in addressing the identified impacts is being investigated through trials and case studies that are currently focussed on rehabilitation of black soils (Vertosols and Dermosols) and construction methods for work on those soils. Trials and case studies currently in progress include:

- A trial to demonstrate the effectiveness of the procedures developed for exploration chip and core drilling on black soils.
- Three separate case studies on different properties with different farming practices in intensively farmed land areas, involving working directly with the Arrow Intensively Farmed Land Committee and landholders to design coal seam gas developments on their land in a manner that minimises the impact on their land and farming activities.
- Drilling and development trials of techniques to reduce impacts on intensively farmed land, including:
  - The Surat Tek Park to trial drilling technologies to minimise landholder impact, environmental impact, land disturbance and drilling duration.
  - Implementing the use of surface tanks to manage drilling muds during the drilling process to eliminate the need to excavate pits in intensively farmed land areas.
  - Constructing and restoring a pipeline in black soils to demonstrate how existing surface profiles can be maintained and rehabilitated, reducing impacts on farming enterprises.

7.4.3 Control Strategies

Control strategies for the management of potential impacts on geology, soils and landforms within the DXP area are presented in Table 13 below.

Table 13: Control Strategies for Potential Impacts to Geology, Soils and Landforms

Environmental Protection Objectives	
Geology, Soils and Landforms: • To maintain or restore soils and stabilise landforms to support the intended land use. • To minimise alteration of drainage systems (natural and man-made). • To implement erosion and sediment control techniques to minimise project impacts. • To protect the Lake Broadwater Conservation Park from petroleum activities. • To avoid or minimise the disturbance of contaminated land. • To avoid the contamination of land or watercourses as a result of project activities (from construction to decommissioning). Agricultural Land Use Suitability: • To avoid or reduce adverse impacts to agricultural infrastructure. • To reduce adverse impacts to agricultural production (cropping and breeding). • To reduce adverse impacts to farming practices (i.e., day-to-day agricultural activities). • Maintain and/or restore soils to support the intended land use.	
Environmental Issue	**Control Strategies**
Geology, Soils and Landforms	
Land degradation – erosion and associated sedimentation, dust generation and reduction in soil quality.	**Common strategies for all phases of work:** • Develop and implement soil management procedures. • Develop and implement site specific erosion and sediment control plans. • Maintain the integrity of private roads and tracks and minimise dust generation, where appropriate, in consultation with relevant landowners and council. • Use existing roads and tracks, where practicable. • Implement dust suppression measures for roads and construction sites to ensure that dust does not cause a nuisance. • Strip, salvage and stockpile topsoil near the work site separately to subsoils (in consultation with landowners). Ensure topsoil stockpiles have a maximum height of 2 m, where the future use is intended for rehabilitation, and are protected from erosion where possible. • Where possible, mulch vegetation and reuse in site rehabilitation. • Stockpile cleared or mulched vegetation along the inside edge of the work sites (separate from soil stockpiles), to aid the control of runoff and ensure stockpiled vegetation does

	not pose a bushfire hazard. • Prevent subsurface water flows and erosion along the backfilled trench by appropriate means such as, trench blocks and compaction of backfilled soils. • Clear areas progressively and implement rehabilitation as soon as practicable following decommissioning activities. • Ensure erosion, drainage and sediment controls installed are appropriate to the nature of the activity undertaken (e.g. permanent or temporary controls required). **Exploration and appraisal:** • Exploration and appraisal drilling will occur only using a "pitless" drilling system. **Planning and design:** • Minimise the disturbance footprint and vegetation clearing. • Carry out ground investigations in soils prone to salinity prior to major earthworks to establish the depth at which saline conditions occur. • Design infrastructure located in cracking clays to withstand the differential shrink/swell ground movement. • Incorporate construction methods and treatments to deal with reactive gilgai and cracking clays in infrastructure design. • Time construction works and access to sites to avoid wetter periods, where practicable. • Design and plan the project to avoid steep slopes and areas dissected by gully networks, where practicable. Where these are unavoidable, ensure the required infrastructure (e.g., roads) is appropriately designed for erosion control purposes. **Construction:** • Avoid disrupting overland natural flow paths and, where avoidance is not practicable, maintain connectivity of flow in watercourses. • Do not disturb or remove flood banks and artificial levees except in consultation with parties benefitting from the structures and the relevant authorities. • Avoid disturbance of contour banks and irrigation bays. • Avoid mounding of soil along pipelines in irrigated paddocks, to the greatest extent practicable, allowing for settlement of backfill. • Conduct pipeline construction to minimise the duration of exposure of soils. • Backfill and rehabilitate excavations, particularly pipeline trenches and drilling sumps. Conduct backfilling in a manner that will promote successful rehabilitation, including capping

	of exposed subsoil with topsoil and replacement of the land surface to preconstruction levels to reduce trench subsidence and concentration of flow. Mounding of soils to allow for settling may be required in some areas. However, in laser-levelled paddocks, this may not be practicable, and backfilling will be carried out in consultation with the landowner. **Operations:** • Discharge water from project activities at a rate and location that will not result in erosion. Install additional erosion protection measures, including energy dissipation structures, at discharge outlets. • Remedy areas of differential settlement associated with buried infrastructure that interrupt the pre-existing surface water flow within intensively cultivated areas. • Excavate any saline material during rehabilitation of coal seam water dams or brine dams and select an appropriate option for management for the material (e.g., treat for reuse, or dispose of in a registered landfill). • Develop rehabilitation plans based on environmental sensitivities
Land contamination: • Disturbance of existing contaminated land. • Potential to cause land contamination through project activities.	**Common strategies for all phases of work:** • Apply appropriate international, Australian and industry standards and codes of practice for the handling of hazardous materials (such as chemicals, fuels and lubricants). • Develop and implement emergency response and spill response procedures to minimise any impacts that could occur as a result of releases of hazardous materials or any loss of containment of storage equipment. • Ensure appropriate spill response equipment, including containment and recovery equipment, is available on site. • Carry out corrective actions immediately upon the identification of any contamination of soil or groundwater that has occurred as a result of project activities. • Undertake an environmental site assessment in response to the identification of contamination that may have occurred as a result of project activities. • Complete excavation, remediation, characterisation and validation activities in response to the identification of contamination that may have occurred as a result of project activities. **Exploration and appraisal:** • Exploration and appraisal drilling will occur only using a "pitless" drilling system. This closed system will remove the need to dig pits to contain the drilling muds and all fluids

	and solids will be contained in tanks and either removed from site (solids) or reused for further drilling (muds/liquids). **Planning and design:** • Inspect and observe site locations for the presence of contamination prior to commencement of intrusive activities. • Apply appropriate Australian and industry standards and codes of practice for the design and installation of infrastructure associated with the storage of hazardous materials (such as chemicals, fuels and lubricants). • Avoid development on contaminated land through the completion of appropriate register searches and desktop investigations (i.e., avoid land or the contaminated portion of a parcel of land that is listed on the Contaminated Land Register or the Environmental Management Register, where practicable). **Construction:** • Avoid disturbance of contaminated soil and groundwater when it is identified or observed during intrusive works. **Operations:** • Incorporate into a discharge response plan or water management plan procedures for the controlled discharge of coal seam gas water under event conditions. Procedures will include conditions for discharge, stream flow data, notification and reporting.
Agricultural Land Use Suitability	
General	• Comply with the provisions of the P&G Act and the Land Access Code prior to accessing private land. All appropriate agreements will be in place prior to entry onto the land. Arrow will ensure all appropriate landowners are notified prior to access being required to allow stock to be moved and access routes to be cleared of machinery or materials. • Consult with landowners on the appropriate location for infrastructure and access routes (to well sites and to and along pipelines). Clearly identify the outcome of the discussions on scaled plans of the property and clearly indicate agreed access routes using signs, temporary fencing, barricade tape or traffic control measures. • Maintain the grievance process (complaint management system) for the community to register complaints, issues, comments and suggestions. • Ensure construction activities do not extend beyond the work site boundaries. • Design and install wells to meet the Code Of Practice • Ensure dams for untreated coal seam gas water and brine

	are not constructed on validated strategic cropping land (SCL) or good quality agricultural land (GQAL).
Reduced productivity and increased costs.	• Plan and integrate construction and operations activities in conjunction with all landholder activities. • Consult with landowners on the most appropriate method to minimise disruption to cultivation paddocks (including the introduction of additional headlands) and loss of productive land in controlled-traffic paddocks. • Maintain the integrity and efficiency of surface irrigation systems by adopting the following measures: – Locate infrastructure at or adjacent to the end of head ditches or tail drains and in a manner that does not significantly interfere with swept paths of boom irrigators to avoid severance or fragmentation of water delivery systems. – Locate wells, gathering lines and access tracks adjacent to boundary fences, where practicable. – Align gathering lines and access tracks perpendicular to the direction of head ditches and tail drains (i.e., parallel to the direction of surface flows and cultivation). • Investigate alternative drilling technologies such as using directional drilling to access coal measures, reducing gathering system pipe diameters and drilling multiple wells from one drill pad to potentially reduce the footprint on strategic cropping land. • Production well drilling will only occur using a "pitless" drilling system to manage drilling muds on black soils. • Remove sediment controls prior to cultivation and dispose in accordance with landowner requirements or in accordance with the waste management plan of the Arrow HSEMS.
Crop losses or disturbance to stock.	• Fence production well sites (i.e., 12m by 12m) to exclude unauthorized personnel, stock and wildlife from that area. • Inspect work sites and access routes for declared weeds and pest plants and animals prior to accessing the site. • Weed control will be undertaken as required. The method used will be dependent upon the type of weed identified, the degree of the infestation and the relevant landholder agreement. • Wash down vehicles and equipment that have potentially been in contact with weeds before entering new work sites. • Regrade work sites to original surface contours following reinstatement and ensure they are free-draining. • Maintain a minimum separation, as agreed with landowner, between animal enclosures and production wells and

	facilities. • Design access tracks in cultivation paddocks to maintain the existing hydrologic and hydraulic regime of the site, and in a way that does not cause erosion. • Locate pipelines to avoid or minimise impact on irrigation flow or current farming practices. If the ROW must cross actively farmed arable land, ensure soil cover above the pipeline is deep enough to allow normal cultivation practices to resume.
Soil disturbance.	• Develop site specific erosion and sediment control plans and install and maintain appropriate site-specific controls. • Maintain the operation and effectiveness of soil conservation structures by adopting the following measures: – Avoid breaching, diversion or disturbance of contour banks, waterways and dams. – Avoid earthworks that affect waterway function. – Locate wells, access tracks and gathering lines downhill and parallel to soil conservation structures. – Utilise existing access tracks and trafficked areas where possible. • Strip, salvage and stockpile topsoil near the work site separately to subsoils (in consultation with landowners). Ensure topsoil stockpiles have a maximum height of 2 m and are protected from erosion. • Stockpile imported fill for bedding of pipes adjacent to the trench and away from vegetation, topsoil and subsoil stockpiles. • Maintain sediment and erosion controls prior to and following storm events and periodically during long periods of rain. • Construct batters and embankments of drill pads and production facility benches at appropriate slopes and protect from erosion. • Suspend works when rainfall or storm events produce onsite conditions that, if trafficked or worked, would compromise the effectiveness of erosion and sediment control structures, or would lead to rutting and compaction of soils or mixing or inversion of soil horizons. • Backfill soils in the reverse order of removal where possible, and undertake backfilling progressively and regularly during pipeline construction. • Conduct backfilling in a manner that will promote successful rehabilitation. • Compact padding material and subsoils used to backfill pipeline trenches to reduce settling. Limit compaction to no

	deeper than 0.5 m below natural surface level. • Mounding of soils to allow for settling where required (e.g. may not be practical in laser-levelled paddocks and requires consultation with the landowner). • Remove excess imported fill and residual subsoil from the work site, and reuse or dispose in accordance with landowner requirements. • Deep rip and cross rip all construction areas and temporary access tracks to a depth of at least 0.4 m. Repeat following topsoil reinstatement to promote infiltration and assist the re-establishment of connections between soil horizons. • Visually inspect rehabilitated work sites for flow diversions and evidence of erosion associated with trench slumping or incomplete reinstatement of surface contours.
Loss of amenity.	• Clear areas progressively and implement rehabilitation as soon as practicable following construction and decommissioning activities. • Install gates of an appropriate standard to restrict access to authorised personnel, vehicles, plant and equipment.
Monitoring Requirements	
• Inspect erosion and sediment control measures as required in line with the Erosion and Sediment control procedure. • Inspect pipeline ROWs routinely until ground stabilisation and natural revegetation or pasture grasses or crops are established. • Conduct ground investigations in soils prone to salinity prior to major earthworks. • Undertake chemical monitoring of soils and groundwater where required. • Routinely inspect spill containment controls and spill response kits. • Visually inspect physical form downstream of watercourse discharge locations. • Review and resolve landowner grievances. • Ensure that the quality of coal seam gas water used for dust suppression meets the prescribed limits.	
Performance Indicators	
• Soil structure and landform conducive to natural revegetation and intended land use. • No long-term adverse impacts to the Lake Broadwater Conservation Park as a result of Arrow's activities. • Recovery or rehabilitation of all spilled contaminants. • Development activities (and infrastructure) integrated with farming operations and intensive farming avoided where possible. • Infrastructure sited to minimise loss of cultivated area and irrigation infrastructure. • Operation and effectiveness of soil conservation structures maintained. • Opportunities to schedule development and routine maintenance activities with the cropping cycle maximised. • Access tracks in cultivation paddocks designed to maintain the existing hydrologic and	

hydraulic regime of the site.

8. TERRESTRIAL FLORA AND FAUNA

8.1 EXISTING ENVIRONMENT

8.1.1 Bioregions

The DXP area falls within the Brigalow Belt Bioregion. Brigalow (*Acacia harpophylla* dominant and co-dominant) is a mosaic of open forest and woodland communities. Semi-evergreen vine thickets, heath and eucalypt open woodlands are scattered throughout this bioregion, with small pockets of eucalypt open forests.

The Brigalow Belt Bioregion has been heavily impacted over time, with the major impacts to biodiversity related to historical vegetation clearance, predominantly for agricultural purposes, the introduction and spread of weeds and animal pests, loss of habitat, changed fire regimes and altered hydrology. The major vegetation groups that have been cleared are acacia forests and woodlands, eucalypt woodlands, eucalypt open woodlands, tussock grasslands, rainforests and vine thickets (DSEWPC 2009).

8.1.2 Flora-Threatened Ecological Communities

The results of the Environment Protection and Biodiversity Conservation (EPBC) database search (Appendix C) identified five threatened ecological communities that may occur within the DXP area. These communities and their relative conservation status are listed in Table 14.

Table 14: Threatened Ecological Communities

Community Name	Status	Presence
Natural Grasslands on Basalt and Fine-textured Alluvial Plans of Northern New South Wales and Southern Queensland	Critically Endangered	Likely to occur within the DXP area
White Box -Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland	Critically Endangered	May occur within the DXP area
Brigalow (*Acacia harpophylla* dominant and co-dominant)	Endangered	Known to occur within the DXP area
Weeping Myall Woodlands	Endangered	Likely to occur within the DXP area
Coolibah - Black Box Woodlands of the Darling Riverine Plains and the Brigalow Belt South Bioregions	Endangered	May occur within the DXP area

The Natural Grasslands on Basalt and Fine-textured Alluvial Plains of Northern New South Wales and Southern Queensland are grasslands typically comprised of perennial native grasses. This ecological community occurs from the Darling Downs in Queensland to Dubbo in New South Wales and is listed as critically endangered under the EPBC Act

due to the significant reduction of its geographic distribution. These grasslands are typically found on soils that are fine textured, such as cracking clays on flat to low slopes (DSEWPC 2008a). No Queensland regional ecosystems (RE) that comprise this community type have been mapped as present within the DXP.

The White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland community is listed as critically endangered under the EPBC Act, with less than 5% of this community remaining. This community can occur as either a woodland or a derived grassland, with White Box, Yellow Box or Blakely's Red Gum typically dominating the community where a tree layer remains present (DSEWPC 2006). No Queensland regional ecosystems that comprise this community type have been mapped as present within the DXP area.

The Brigalow (*Acacia harpophylla* dominant and co-dominant) community is listed as endangered under the EPBC Act (DSEWPC 2009). In Queensland this ecological community is defined to include 16 regional ecosystems of which two are mapped within the DXP (RE 11.3.1 and RE 11.4.3).

The Weeping Myall Woodlands community is also listed as endangered under the EPBC Act. The Weeping Myall Woodlands occur in a range of formations from open woodlands to woodlands, generally 4 m to 12 m high, in which Weeping Myall (*Acacia pendula*) is the sole or dominant overstorey species (DSEWPC 2008). In Queensland, the Weeping Myall Woodlands ecological community is restricted to small patches that occur within two regional ecosystems; RE 11.3.2 and RE 11.3.28. Both of these ecosystems have an 'of concern' status with respect to both *Vegetation Management Act 1999* and biodiversity. Regional ecosystem RE 11.3.2 is mapped as present within the DXP area.

The Coolibah-Black Box Woodlands of the Darling Riverine Plains and the Brigalow Belt South Bioregions community is listed as endangered under the EPBC Act. The community is found on the grey, self-mulching clays of periodically waterlogged floodplains, swamp margins, ephemeral wetlands, and stream levees. Much of the Coolibah – Black Box Woodlands have been cleared and what remains is degraded. Data has shown that decline of the ecological community in Queensland has been approximately 82%. In Queensland, the community compromises five regional ecosystems and elements of it may extend into other regional ecosystems, such as parts of RE 11.3.27 Freshwater Wetlands, where the wetlands are associated with fringing woodland, sometimes with Coolibah. Within the DXP area, two regional ecosystesm (RE 11.3.27a and RE 11.3.27b) may potentially contain Coolibah-Black Box Woodlands.

8.1.2.1 **Queensland Regional Ecosystems**

A desktop review identified the presence of scattered remnants of not of concern, of concern and endangered regional ecosystems within the DXP area. Approximately 5% of the DXP area is comprised of remnants of endangered or of concern regional ecosystems. The distribution of endangered and of concern regional ecosystems are

illustrated in Figure 13. These regional ecosystems are described in further detail in Table 19.

8.1.2.2 Endangered, Vulnerable or Near Threatened Species

Flora – Threatened Species

The results of the EPBC and Wildlife Online database searches (Appendix C) identified 16 threatened flora species as potentially occurring within the DXP area, as listed in Table 16.

It should be noted that the results of the EPBC and Wildlife Online database searches are indicative only. The full results of the EPBC and Wildlife Online searches are attached in Appendix C.

8.1.2.3 Weed Species

The Commonwealth Government classifies Weeds of National Significance (WoNS) within Australia, based on their:

- Invasiveness and impact characteristics.
- Potential and current area of spread.
- Current primary industry, environmental and socio-economic impacts.

The results of the EPBC search indicate that there are seven WoNS potentially present within the DXP area. Details of these pest species including classification under the *Land Protection (Pest and Stock Route Management) Act 2002* are summarised in Table 15 below.

Table 15: Weeds of National Significance which may be Present within the DXP

Scientific Name	Common Name	Presence
Lantana camara	Lantana	L
Lycium ferocissimum	Boxthorn	L
Parthenium hysterophorus	Parthenium weed	L
Pinus radiata	Radiata Pine	L
Prosopis spp.	Mesquite	L
Salvinia molesta	Salvinia	L
Salix spp. except *S.babylonica, S.x calodendron* & *S.x reichardtiji*	Willows except Weeping Willow, Pussy Willow and Sterile Pussy Willow	L

L- Likely to occur within the DXP area

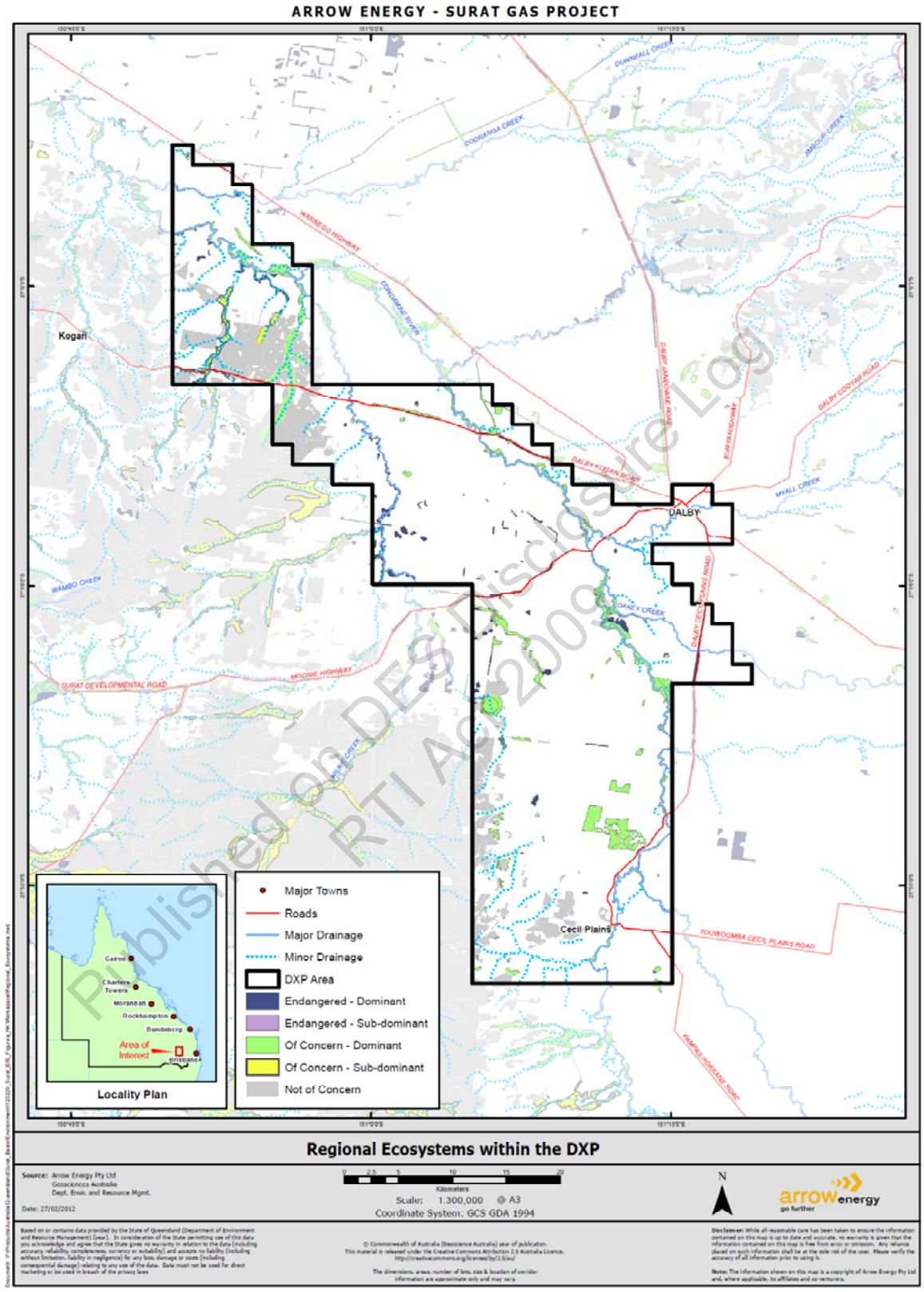


Figure 13: Regional Ecosystems within the DXP

Table 16: Threatened Flora Species Identified in the Vicinity of the DXP

Scientific Name	Common Name	EPBC Act Status	NC Act Status	Preferred Habitat	Occurrence
Bothriochloa biloba	Lobed Blue-grass	V	-	Grows in cleared eucalypt forests and relict grassland, often dominated by Purple Wiregrass (*Aristida ramosa*), Red-leg Grass (*Bothriochloa macra*), Red Grass (*B. decipiens*), Queensland Bluegrass (*Dichanthium sericeum*) or *Austrostipa aristiglumis*. Prefers heavier-textured soils such as brown or black clay soils.	R
Cadellia pentastylis	Ooline	V	V	Undulating terrain on a variety of soil types, between 300 metres and 450 metres.	L
Cymbonotus maidenii	-	-	E	Grows in isolated patches, mainly north of the Darling and Barwon Rivers, and in inland Queensland. Occurs on clay, usually in open grassland, along roadsides or beside waterholes or watercourses.	R
Dichanthium queenslandicum	King Blue-grass	V	V	Garnet south to Mundubbera.	L
Digitaria porrecta	Finger Panic Grass	E	NT	Native grassland, woodlands or open forest with a grassy understory on richer soils. Found along roadsides and travelling stock routes where there is light grazing and occasional fire.	L
Eleocharis blakeana	-	-	NT	Occurs on plains and low undulating country on poorly drained, clayey soils scrubs, and in small depressions along drainage lines in open forest and woodland communities.	R
Fimbristylis vagans	Wandering Fringe-rush	-	NT	Records found in Broadwater Conservation Park.	R
Homopholis belsonii	-	V	E	*Homopholis belsonii* occurs at elevations ranging from 200 m to 520 m above sea level. It is known to occur in dry woodland habitats on poor soils, such as those derived from basalt. It is generally found among fallen timber at the base of trees or shrubs, among branches and leaves of trees hanging to ground level or along the bottom of netting fences.	L
Philotheca sporadica	-	V	V	Known from south-east Queensland, from just north of Tara, to approximately 12 km east of Kogan. *Philotheca sporadica* is found on residual hills which are remnants of laterised Cretaceous sandstones, where the soils are shallow, uniform sandy loams to clay loams of extremely low fertility and poor condition (Dawson, 1972). It occurs primarily in low open forest of *Acacia burrowii*, *Eucalyptus exserta*, *E. crebra*, *E. fibrosa subsp. nubila* and *Callitris glaucophylla*.	R

Picris barbarorum	-	-	V	Uncommon, flowers July to November. Limited information on habitat is available.	R
Picris evae	Hawkweed	V	V	All recent collections appear to come from modified habitats such as weedy roadside vegetation. Its main habitat is open Eucalyptus forest and Dichanthium grassland, roadsides and cultivated areas (paddocks). Soils are black, dark grey or red-brown (specified as shallow, stony soil over basalt for one collection) and reddish clay-loam or medium clay soils. Hawkweed occurs in Eucalyptus open woodland with a grassy understorey composed of *Dichanthium spp*. Upper stratum species include Eucalyptus melliodora, E. crebra, E. populnea, E. albens, *Angophora subvelutina*, *Allocasuarina torulosa*, and *Casuarina cunninghamiana*.	L
Rhapanticum australe	Austral Cornflower, Native Thistle	V	V	On heavy clays derived from basalt. Austral Cornflower grows in eucalypt open forest with grassy understory on roadsides and on road reserves with *Chloris gayana*, *Cirsium vulgare*, *Eucalyptus tereticornis* and *Angophora floribunda* on black clay soil.	L
Solanum papaverifolium	-	-	E	Found on lateritised plateaux in ironbark-Acacia blakei forest associated with such species as *Croton insularis*, *Phebalium nottii*, *Bertya opponens* and *Philotheca ciliata*.	R
Solanum stenopterum	-	-	V	The species is now better known and its range is extended north to west of Townsville (Bean 2004) and it has been recorded from vine thicket, rainforest margins and Argyrodendron-dominated rainforest	R
Thesium australe	Austral Toadflax	V	V	Occurs in grassland or grassy woodland. Often found in damp sites in association with Kangaroo Grass (*Themeda australis*). A root parasite that takes water and some nutrient from other plants, especially Kangaroo Grass.	L
Tylophora linearis	-	E	E	*Tylophora linearis* grows in dry scrub, open forest and woodlands associated with *Melaleuca uncinata*, *Eucalyptus fibrosa*, *E. sideroxylon*, *E. albens*, *Callitris endlicheri*, *C. glaucophylla*, *Allocasuarina luehmannii*, *Acacia hakeoides*, *A. lineata*, *Myoporum spp*., and *Casuarina spp*.	L

E- Endangered, V- Vulnerable, NT- Near Threatened
L- Likely to occur within DXP, R- Recorded in DXP. Species detected in wildlife online or in Herbrecs are considered to be a record and are marked R.

8.1.3 Fauna - Endangered, Vulnerable or Near Threatened Species

The EPBC and Wildlife Online database searches identified 34 threatened fauna species or potential habitat for threatened fauna species recorded or likely to occur within the DXP and surrounding areas. Information on migratory and marine species likely to occur within the tenure was also collected. The results of the search are presented in Table 17.

The results of the database searches are indicative only. The complete DERM Wildlife online search results and EPBC results are located in Appendix C.

Table 17: Threatened Fauna Species Identified within the DXP area

Scientific Name	Common Name	EPBC Act Status	NC Act Status	Migratory	Marine	Occurrence
Birds						
Accipiter novaehollandiae	Grey Goshawk	-	NT	-	-	R
Anthochaera phrygia	Regent Honeyeater	E	E	Yes	-	R
Botaurus poiciloptilus	Australasian Bittern	E	-	-	-	R
Calyptorhynchus lathami	Glossy Black-Cockatoo	-	V	-	-	R
Ephippiorhynchus asiaticus	Black-necked Stork	-	NT	-	-	R
Erythrotriorchis radiatus	Red Goshawk	V	E	-	-	R
Geophaps scripta scripta	Squatter Pigeon	V	V	-	-	L
Grantiella picta	Painted Honeyeater	-	V	-	-	R
Lathamus discolor	Swift Parrot	E	E	-	Yes	L
Lophochroa leadbeateri	Major Mitchells Cockatoo	-	V	-	-	R
Lophoictinia isura	Square-tailed Kite	-	NT	-	-	R
Melithreptus gularis	Black-chinned Honeyeater	-	NT	-	-	R
Neochmia ruficauda ruficauda	Star Finch	E	E	-	-	L
Neophema pulchella	Turquoise Parrot	-	NT	-	-	R
Nettapus coromandelianus	Australian Cotton Pygmy-goose	-	NT	-	Yes	R
Poephila cincta cincta	Black-throated Finch	E	E	-	-	L
Rostratula australis (Rostratula benghalensis. lat.)	Australian Painted Snipe	V	V	Yes	Yes	R
Mammals						
Chalinolobus dwyeri	Large-eared Pied Bat	V	V	-	-	L
Chalinolobus picatus	Little Pied Bat	-	NT	-	-	R
Dasyurus hallucatus	Northern Quoll	E	-	-	-	L
Nyctophilus timoriensis	Eastern/Greater Long-eared Bat	V	V	-	-	L

Petrogale peniciliata	Brush-tailed Rock-wallaby	V	V	-	-	L
Phascolarctos cinereus	Koala	-	V	-	-	R
Amphibians						
Cyclorana verrucosa	Rough Frog	-	NT	-	-	R
Reptiles						
Anomalopus mackayi	Five-clawed Worm-skink	V	E	-	-	R
Delma torquata	Collared Delma	V	V	-	-	L
Egernia rugosa	Yakka Skink	V	V	-	-	R
Furina dunmalli	Dunmall's Snake	V	V	-	-	L
Hemiaspis damelii	Grey Snake	-	E	-	-	R
Paradelma orientalis	Brigalow Scaly-foot	V	V	-	-	L
Strophurus taenicauda	Golden-tailed Gecko	-	NT	-	-	R
Tympanocryptis pinguicolla	Grassland Earless Dragon	E	E	-	-	L
Invertebrates						
Jalmenus eubulus	Pale Imperial Hairstreak	-	V	-	-	R
Migratory and Marine Species						
Anseranas semipalmata	Magpie Goose	-	-	-	Yes	L
Anthochaera phrygia	Regent Honeyeater	E	E	Yes	-	R
Apus pacificus	Fork-tailed Swift	-	-	Yes	Yes	L
Ardea alba (Ardea modesta)	Great Egret	-	-	Yes	Yes	L
Ardea ibis	Cattle Egret	-	-	Yes	Yes	L
Gallinago hardwickii	Latham's Snipe, Japanese Snipe	-	-	Yes	Yes	L
Haliaeetus leucogaster	White-bellied Sea-Eagle	-	-	Yes	Yes	L
Hirundapus caudacutus	White-throated Needletail	-	-	Yes	Yes	L
Lathamus discolor	Swift Parrot	E	E	-	Yes	L
Merops ornatus	Rainbow Bee-eater	-	-	Yes	Yes	L
Myiagra cyanoleuca	Satin Flycatcher	-	-	Yes	Yes	L
Nettapus coromandelianus	Australian Cotton Pygmy-goose	-	NT	-	Yes	L
Rostratula australis (Rostratula benghalensis. lat.)	Australian Painted Snipe	V	V	Yes	Yes	L

E- Endangered, V- Vulnerable, NT- Near Threatened

L- Likely to occur within the DXP area, R- Recorded in the DXP area

Species detected in wildlife online search results are considered to be a record and are marked R.

8.1.3.1 Pest Species

The EPBC Protected Matters database search and wildlife online searches indicated the possible presence of five introduced pest animal species within and surrounding the DXP area, as shown in Table 18 below.

Table 18: Potentially Occurring Pest Species within the DXP

Scientific Name	Common Name	Presence
Bufo marinus	Cane Toad	R
Felis catus	Wild Cat	R
Oryctolagus cuniculus	Rabbit	R
Sus scrofa	Wild Pig	R
Vulpes vulpes	Fox	R

R-Recorded in the DXP. Species detected in wildlife online search results are considered to be a record and are marked R.

8.1.4 Wild Rivers

There are nine wild rivers declared under the *Wild Rivers Act 2005*. The DXP area is not located within, or in proximity to any of the nine wild river areas. As such, it is considered that petroleum activities carried out within the DXP area will not impact upon, or be a source of contamination to Wild River areas.

8.1.5 Biodiversity Offsets

The Queensland Biodiversity Offset Policy came into effect on 3 October 2011 and applies to level 1 petroleum and gas activities under chapter 5A of the EP Act. Arrow has considered the implications of the Queensland Biodiversity Offset Policy (version 1, 3 October 2011) in the context of DXP. Given the location of proposed infrastructure has yet to be finalised it cannot be determined at this stage whether these activities will require the clearing of any State significant biodiversity values. Arrow is currently in the process of finalising a Biodiversity Offset Strategy which will potentially include the engagement of specialist consultants to formulate strategies to meet the biodiversity offset requirements where circumstances require. Arrow anticipates that the biodiversity offset draft EA conditions (March, 2012) will be included in the EA amendment approval.

8.1.6 Environmentally Sensitive Areas

Environmentally sensitive areas (ESAs) are specific areas that are recognised to possess significant environmental values. ESAs are divided into three categories based upon the conservation values of each of the areas. Category A and Category B ESAs are prescribed in Sections 25 and 26 of the EP Regulation, whilst Category C ESAs are defined by the conditions of the EA.

ESAs within the DXP area were identified using the DERM ESA web mapping search tool (DERM, 2011d). The results of the search, as listed in Table 19, indicate the presence of Category A, B and C ESAs within the DXP area (Figure 14).

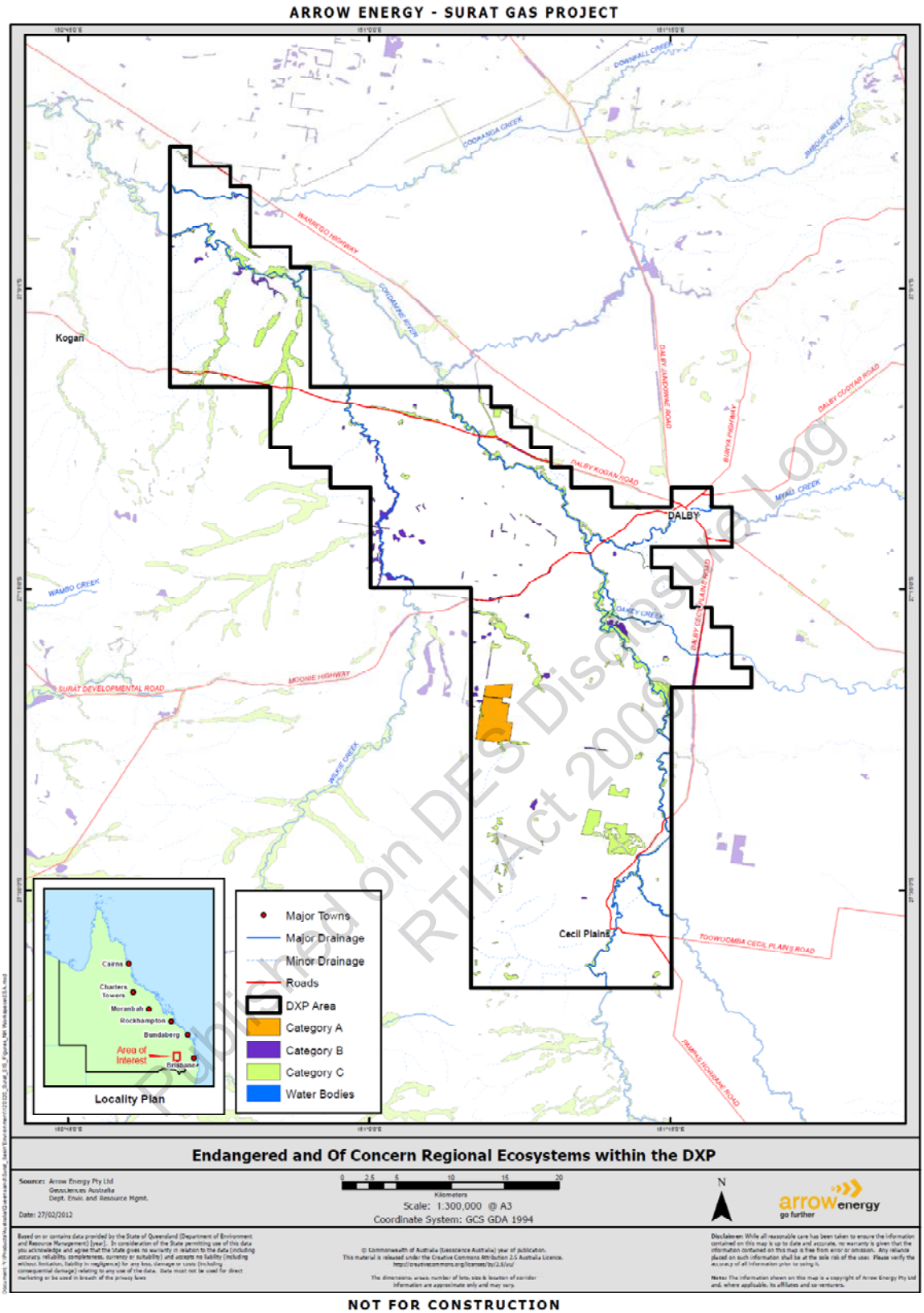


Figure 14: Environmentally Sensitive Areas within the DXP area

Table 19: Environmentally Sensitive Areas Identified within the DXP area

Environmentally Sensitive Area	Regional Ecosystem ID	Biodiversity Status	Vegetation Management Act Status	Description
Category A				
Lake Broadwater Conservation Area				
Category B				
Endangered Regional Ecosystem	11.3.1	Endangered	Endangered	*Eucalyptus cambageana* woodland to open-forest with *Acacia harpophylla* or *A. argyrodendron* on Cainozoic clay plains
	11.3.17	Endangered	Of Concern	*Eucalyptus populnea* woodland with *Acacia harpophylla* and/or *Casuarina cristata* on alluvial plains
	11.3.21	Endangered	Endangered	*Dichanthium sericeum* and/or *Astrebla spp*. grassland on alluvial plains. Cracking clay soils
	11.4.3	Endangered	Endangered	*Acacia harpophylla* and/or *Casuarina cristata* shrubby open forest on Cainozoic clay plains
	11.4.12	Endangered	Endangered	*Eucalyptus populnea* woodland on Cainozoic clay plains.
Category C				
Of Concern Regional Ecosystem	11.3.2	Of Concern	Of Concern	Eucalyptus populnea woodland on alluvial plains
	11.3.3	Of Concern	Of Concern	*Eucalyptus coolabah* woodland on alluvial plains
	11.3.4	Of Concern	Of Concern	*Eucalyptus tereticornis* and/or *Eucalyptus spp*. tall woodland on alluvial plains
	11.3.25	Of Concern	Least Concern	*Eucalyptus tereticornis* or *E. camaldulensis* woodland fringing drainage lines
	11.3.27a	Of Concern	Least Concern	Lacustrine freshwater wetland. Larger ephemeral - permanent water bodies (lakes).
	11.3.27b	Of Concern	Least Concern	Lacustrine freshwater wetland. Occurs on billabongs no longer connected to the channel flow.
	11.3.27d	Of Concern	Least Concern	Lacustrine freshwater wetland (e.g. vegetated swamp). Occurs fringing large lakes.
Essential Habitat	-	-	-	*Cymbonotus maidenii* Associated with RE 11.3.21 in PL238.

				Endangered in NC Act 1992.
	-	-	-	*Digitaria porrecta* (Finger Panic Grass) Associated with REs 11.3.2, 11.3.3, 11.3.4, 11.3.21 and 11.3.25 in PL238. Endangered in EPBC 1999 and Near-threatened in NC Act 1992.
	-	-	-	*Philotheca sporadica* Associated with REs 11.7.4 and 11.7.7 in PL194. Vulnerable in NC Act 1992. *Jalmenus eubulus* (Imperial Hairstreak) Associated with REs 11.3.1 in PL260. Vulnerable in NC Act 1992.
	-	-	-	*Solanum papaverifolium* Associated with REs 11.3.2, 11.3.21 and 11.3.25 in PL260. Endangered in NC Act 1992.
	-	-	-	*Solanum stenopterum* Associated with RE 11.3.2 and 11.3.21 in PL 258. Vulnerable in NC Act 1992.
				Grantiella picta (Painted Honeyeater) Associated with 11.3.1, 11.3.2, 11.3.3, 11.3.4, 11.3.17, 11.3.25, 11.3.27a/b/d, 11.4.3 and 11.4.12 in PL198 and PL260. Vulnerable in NC Act 1992.
				Chalinolobus picatus(Little Pied Bat) Associated with REs 11.3.1, 11.3.3, 11.3.4, 11.3.17, 11.3.25, 11.3.27a/b/d, 11.4.3 and 11.4.12 in PL198 and PL260 Near-threatened-NC Act 1992.
	-	-	-	*Cyclorana verrucosa* (Rough Frog) Associated with REs 11.3.2, 11.3.3, 11.3.4, 11.3.17, 11.3.25, 11.3.27a/b/d, 11.4.3 and 11.4.12 in PL198 and PL260 Near-threatened-NC Act 1992
	-	-	-	*Strophurus taenicauda* (Golden-tailed Gecko) Associated with 11.3.1, 11.3.2, 11.3.3, 11.3.4, 11.3.17, 11.3.25, 11.3.27a/b/d, 11.4.3 and 11.4.12 in PL198 and PL260. Near-threatened-NC Act 1992

	-	-	-	*Hemiaspis damelii* (Grey Snake) Associated with 11.3.1, 11.3.2, 11.3.3, 11.3.4, 11.3.17, 11.3.25, 11.3.27a/b/d, 11.4.3 and 11.4.12 in PL238 and PL260. Endangered in NC Act 1992.

8.1.6.1 **Access to ESAs**

Due to the nature of the activities and the presence of referrable wetlands (Category C ESA), existing EA conditions and EA definitions are placing restrictions on the development and continuing operation of the activity. The following sub-sections discuss proposed specific changes to the current environmental authority conditions of relating to limited petroleum activities and ESAs.

Limited Petroleum Activities

Facilities including well head facilities (SCADA, pumps etc), compressor stations and WTFs, are powered via high voltage transmission lines. Because powerlines are infrastructure essential to the functioning of the gas field, Arrow Energy is seeking the inclusion of powerlines as a limited petroleum activity. Whilst every attempt is made to co-locate powerlines with existing tracks and gathering line networks, this is not always a practicable or feasible option to supply power to the field, due to:

- Gas field configuration; and
- The presence of existing easements and infrastructure owned by third parties. For example infrastructure constructed and operated for projects conducted on overlapping tenure. Powerline easements must be selected to avoid these existing easements and infrastructure.

Wells, which are a limited petroleum activity, are authorised to be constructed in certain ESAs, where currently powerlines are not explicitly authorised to be located. This concession by the administering authority to enable appropriate field development in some ESAs is not supported by an allowance to provide the required power supply infrastructure.

Under current conditions, the construction of linear infrastructure through areas where ESAs are overlapping is not authorised. Whilst Arrow Energy seeks to avoid such areas when locating project infrastructure, this is not always possible.

As such it is important that where necessary, gas gathering lines, water lines, access tracks (including supporting structures) and powerlines can intersect a referrable wetland and cross without triggering a formal EA amendment for each individual crossing.

Arrow Energy is therefore seeking access to referrable wetlands for the construction and operation of linear infrastructure only. Arrow Energy will not locate dams, wells, compressor facilities or any other types of non-linear infrastructure in these areas, except where specific approval is sought from the administering authority and only in exceptional circumstances. Arrow Energy will only undertake works through the mapped wetland and waterways during dry periods to minimise impacts to the sensitive areas. All works will be subject to field ecological assessments and

clearances to ensure that high value habitats, vegetation communities and individual plant species are not impacted. The vegetation present is relatively open, which will enable Arrow Energy to maximise the use of open / previously disturbed areas and minimise the extent of clearing necessary as far as practicable. Licensed fauna spotter catchers will also be utilised during any clearing activities.

In some situations it may be practicable for Arrow Energy to use Horizontal Directional Drilling (HDD) to avoid impacts to the mapped areas. However, given the width of the mapped area, it is not anticipated that this option will be viable in most instances due to economic reasons.

Corridor Widths for Linear Infrastructure

Arrow Energy is seeking an increase in the widths of corridors for linear infrastructure within ESAs. Currently, the EA model conditions allow for the following widths:

- 18 m for dual carriageway roads
- 6 m for access tracks not associated with a gas or water line;
- 12 m for a single water or gas gathering line;
- 18 m for a trench with one water gathering line and one parallel gas gathering pipeline;
- 25 m width for multiple trenches where there are three parallel gas or water gathering lines; and
- 7 m width for any additional trench for a water or gas line.

Arrow Energy cannot construct the necessary infrastructure within the areas provided in the model EA conditions above in a safe manner to people or to the environment. Based on actual operational needs and environment, health and safety aspects, Arrow Energy require the following widths for access through ESAs and other remnant vegetation:

Tracks only

- 21 metres for dual carriage access tracks not associated with pipelines or overhead power lines;
- 18 metres for single carriage access tracks not associated with pipelines or overhead power lines;

Tracks, Pipelines and Powerlines

- 27 metres for dual carriage access tracks with a single pipeline trench;
- 24 metres for single carriage access tracks with single pipeline trench;
- 32 metres for dual carriage access tracks associated with a single pipeline trench and/or overhead power lines;
- 29 metres for single carriage access tracks associated with an overhead power line and/or a single pipeline trench; and
- 23 metres in width for overhead power lines not associated with access tracks or pipelines;

Pipelines

- for pipelines, including provision for a utility corridor and access track:
  - 21 metres for a single water or gas gathering line; or
  - 25 metres for a trench containing one gas or water gathering line and one parallel gas or water gathering pipeline; and
  - 7 metres for any additional parallel trench for gas or water gathering lines.

Takeoff Drains, Powerline Stays & Vegetation Storage

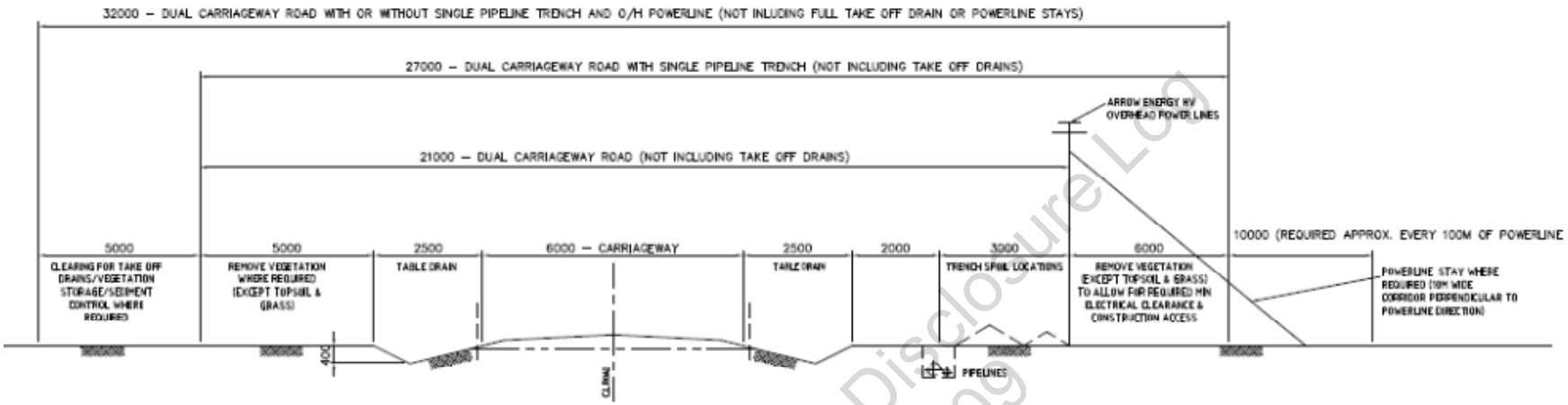
- 10 metres for take-off drains – required approximately every 100m of track. The drain is approximately 10m wide by 20m in length; and
- 10 metres for powerline stays – required approximately every 100m of track 10m wide by 14m from power poles.

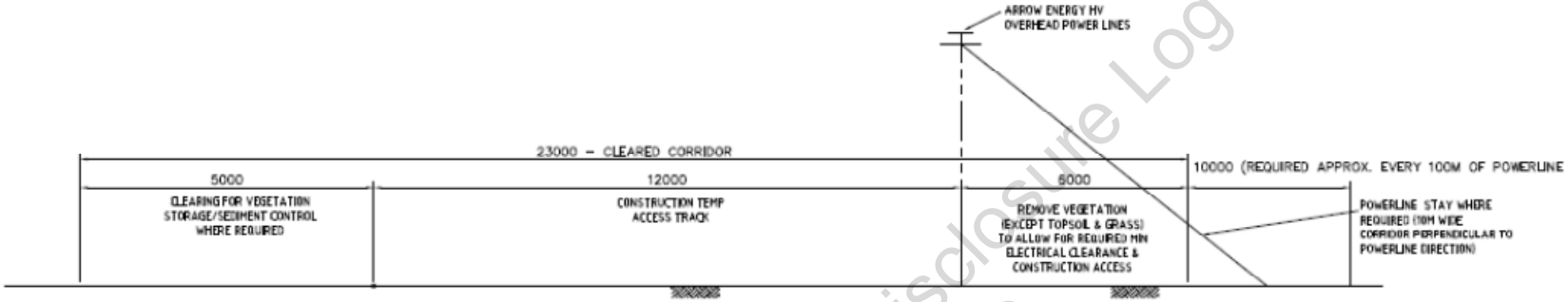
These widths are necessary to provide safe working conditions for construction teams and operators. The removal of spoil through trenching operations in narrow corridors can create very dangerous working conditions for construction teams – a situation that Arrow Energy is obligated to prevent. Reducing the corridor width does not allow for the required benching to ensure the trench walls provided a safe working environment, particular to low lying areas and creek crossings. The additional benching would utilise the area that would have been used for vegetation storage or takeoff drains on non low lying areas.

Dual carriage access tracks are typically constructed within a 32 m cleared corridor. This cleared width allows for the construction of table drains. Table drains are viewed by Arrow Energy as an essential erosion control measure which greatly assists in maintaining the integrity of the tracks and reduces the potential for erosion related issues (EP Act and International Erosion Control Association – Best Practise Erosion and Sediment Control) and minimises road maintenance works. Appropriate drainage on access tracks also allows for prolonged access to infrastructure during wet weather conditions and reduces the potential for the formation of unsafe road conditions. The below diagrams illustrate the requirements for the 32 m corridor widths.

Access tracks are also constructed with take-off drains. These are derived from the table drains and are designed to divert the water collected in the table drains away from the access tracks. These are constructed intermittently along the track length. The frequency and length of take-off drains is dependent on the topography present along the route, but are typically constructed every 100 m. Vegetation is selectively cleared outside the main 32 m corridor to construct the individual take-off drains, as seen in the above diagrams.

A 23 m cleared corridor is necessary for the powerline operation. Vegetation must be maintained at a sufficient distance from the powerlines, to maintain required electrical clearance. The powerlines also have stays (i.e. supports / tie-downs) associated with them and will require an additional 10m of vegetation clearing approximately every 100 m. The powerline stays come off the main powerlines to the ground at a 45°angle. Cleared easements must be maintained for the operational life of the powerline. The below diagram illustrates the corridor requirements for the construction of powerlines.





8.2 ENVIRONMENTAL VALUES

8.2.1 Terrestrial Flora and Fauna

Each terrestrial ecology environment identified within the DXP area contains unique attributes. The terrestrial ecology present within the DXP area can be described as containing 12 existing environments as a means of summarising the array of environmental values.

- EPBC Act Community: Natural grasslands on basalt and fine-textured alluvial plains of northern New South Wales and southern Queensland (REs 11.3.21, 11.3.24). It is considered likely that this community occurs within the DXP area.
- EPBC Act Community: White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland (RE 11.8.2a). It is possible that this community exists within the DXP area.
- Category A ESA, Lake Broadwater Conservation Park.
- Natural grassland road reserves (Dalby Kogan, Dalby Cecil Plains, and Dalby St George).
- EPBC Act Community: Brigalow (*Acacia harpophylla* dominant and co-dominant) (REs 11.3.1, 11.4.3, 11.4.10, 11.9.5, 11.9.6). This community is known to occur within the DXP area.
- EPBC Act Community: Weeping Myall Woodlands. It is considered likely that this community occurs within the DXP area.
- Category B ESAs: REs with an 'endangered' biodiversity status, not EPBC Act - listed: 11.3.17 and 11.4.12.
- Category C ESAs: REs with an 'of concern' biodiversity status: 11.3.2, 11.3.3, 11.3.4, 11.3.25, 11.3.27a, 11.3.27b and 11.3.27d.
- Stock routes and state or bioregional wildlife corridors.
- Essential habitat (supporting listed wildlife species).
- EPBC Act Community: Coolibah – Black Box Woodlands of the Darling Riverine Plains and Brigalow Belt South bioregions (RE 11.3.3).
- Other state forests and timber reserves.

8.3 POTENTIAL IMPACTS ON ENVIRONMENTAL VALUES

Direct impacts to flora species can be associated with clearing vegetation for project activities. Key potential impacts to intersected regional ecosystems include direct physical destruction from the clearing footprint and fragmenting viable habitat and loss of biodiversity. Indirect impacts to intersected and proximate regional ecosystems can include erosion and sedimentation from the construction processes and edge effects

(including weed invasion and fire). The introduction and proliferation of weed species can also have serious impacts on the ecological value of remnant vegetation.

Loss of habitat and foraging areas are generally the main potential impacts to fauna species associated with project activities, due to the clearing of vegetation or the proliferation of weed species. Fauna mortality may also result from entrapment in open trenches and in regulated dams and from collisions with project vehicles.

In summary, the key potential impacts to environmental values associated with flora and fauna include:

- Deterioration of the ecological value of land through disturbances resulting in fragmentation of vegetation, edge effects on vegetation, loss of vegetation and loss of habitat, that is associated with exploration and appraisal activities;
- Disturbance of soil and associated siltation in surface runoff or creation of erosion pathways;
- Weed and pathogen ingress due to vehicles and work crews entering areas; and
- Interaction with livestock and wildlife during operations resulting in mortality.

8.4 MANAGEMENT OF POTENTIAL IMPACTS

Impacts to ecologically significant vegetation communities and endangered, vulnerable and near threatened plants should be limited due to the relatively low presence of significant stands of remnant vegetation in the DXP area (Figure 13).

Direct impacts to flora and fauna can be readily avoided and managed, provided that the hierarchical approach of avoid, minimise, mitigate and offset is adhered to, activity specific mitigation measures are developed and implemented effectively and progressive rehabilitation is undertaken and maintained until such time that the disturbed area is stable and self-sustaining.

Before undertaking any construction activities that may impact vegetation, fauna or other habitat, Arrow undertakes a desktop site selection process followed by a detailed field based ecological assessment. Targeted field investigations take place to confirm species and/or habitat present, prior to undertaking petroleum activities. Key construction activities (such as clearing) are routinely supervised by ecologists to ensure that the activity is being conducted in a responsible manner and within the approved area in accordance with Arrow's Fauna Spotter/Catcher Procedure (99-H-PR-0048) and Land Clearing and Ground Disturbance Procedure (99-V-PR-0014). Where required, Arrow obtain the relevant permits from the QLD Parks and Wildlife Service for relocation or removal of species or for the tampering of an animal breeding place under the protection of the *Nature Conservation Act 1992*.

Provided that project activities are carefully planned, strict mitigation measures are implemented and adhered to, disturbances are kept to the minimum necessary and

rehabilitation works are carried out progressively and maintained effectively for the life of the project, the potential risks to flora and fauna will be minimised.

While the impacts described in Section 8.3 are possible, it is unlikely that they will be significant, given that:

- The nature of exploration and appraisal activities provide for flexibility in infrastructure locations, thereby allowing avoidance of sensitive areas with high ecological value.
- Infrastructure locations shall be planned and selected based on a range of environmental factors, but include avoidance of clearing vegetation wherever possible, (in particular vegetation classed as having significant values).
- Ecological assessments will be conducted prior to disturbances to ascertain the presence of site specific environmental sensitivities, such as protected species (and to avoid wherever practicable).
- The topography is predominantly flat throughout the DXP area such that soil and water impacts through clearing (e.g. erosion, slope failure, stormwater runoff and sedimentation) are less likely than on steeper terrain. Flat terrain is more conducive to containment of disturbance and the prevention of downstream impacts (e.g. sedimentation or pollution of proximate REs). Erosion and sediment control measures are detailed are in Section 7.
- In areas containing habitat areas, clearing activities will be undertaken in the presence of a suitably qualified spotter catcher to minimise any impacts to fauna.

Project activities will also be planned to avoid ESAs wherever possible and to maintain the value of their mandated protection zones. Activities shall only be conducted within ESAs or protection zones in accordance with the conditions of the EA or where required, with the appropriate authorisations of the administering authority.

8.4.1 Matters of National Environmental Significance

As described in Section 8.1, desktop assessments of the DXP identified the potential presence of a number of MNES (refer to Table 14) including threatened ecological communities (TECs), threatened plant species as well as a number of threatened animal species listed as vulnerable or endangered under the EPBC Act.

Proposed areas for field project activities will be preferentially located in pre-existing disturbed areas and in strict accordance with Arrow's land access assessment process. Part of this process involves the identification and assessment of ecological values present at any location where petroleum activities are proposed. This process restricts the types of petroleum activities that can be carried out in certain environments based on the values present. With the proper implementation of this assessment process, it is considered that the proposed activities within the DXP area will not significantly impact on MNES and therefore do not warrant approval under the EPBC Act at this time. In the event that Arrow identifies any MNES with the potential to be impacted when

conducting site specific investigations prior to proposed disturbances, Arrow will then submit the appropriate referral in accordance with the relevant provisions under the EPBC Act.

8.4.2 Protected Plants and animals

Arrow holds a class exemption under the *Nature Conservation (Protected Plants) Conservation Plan 2000* which allows Arrow to clear least concern protected plants as part of petroleum activities within DXP area. Clearing must occur in accordance with the conditions of the exemption which include:

- Undertaking on-ground ecological assessments prior to planned disturbances to identify the presence of endangered, vulnerable and near threatened plants;
- Employing a suitably qualified and experienced person to undertake the ecological assessments;
- Maintaining a record of clearing activities where whole plants are taken under the exemption; and
- Mitigating damage from taking whole least concern plants through revegetation or promoting natural regeneration through on-going maintenance.

To take or remove endangered, vulnerable or near threatened flora species, Arrow will apply for the appropriate permits in accordance with the provisions of the NC Act.

Arrow has a species management program for tampering with animal breeding places under Section 88 of the *Nature Conservation Act 1992* and Section 332 of the *Nature Conservation (Wildlife management) Regulation 2006, dated November 2010.* The generic species management plan will be followed by implementing relevant procedures: Wildlife and Stock management (99-H-PR-0075), Fauna Spotter/Catcher Procedure (99-H-PR-0048), Ecological impact assessment procedure (99-H-PR-0081), and rehabilitation procedure (99-V-PR-0015).

8.4.3 Control Strategies

Management of potential impacts to terrestrial flora and fauna under the project is activity based. For each of the core field activities a specific set of applicable environmental procedures will be applied. Key control strategies to address potential impacts to flora and fauna, as described in the relevant procedures, are presented in Table 20.

Table 20: Control Strategies for Potential Impacts to Flora and Fauna

Environmental Protection Objectives
• To minimise habitat loss and fauna mortality. • To avoid or minimize adverse effects on and to protect terrestrial ecosystems and associated biodiversity and habitat.

• To avoid or minimise adverse impacts on environmentally sensitive areas. • To control the introduction or spread of new or existing exotic terrestrial flora or fauna.	
Environmental Issue	**Control Strategies**
Access Tracks	**Construction** • Disturbances in environmentally sensitive areas, regrowth and remnant vegetation and water courses must be avoided wherever practicable. • Land clearing and vegetation removal will be minimised. • Constructing parallel or multiple access tracks will be avoided wherever practicable. • Existing fence lines or tracks should be utilised for access wherever practicable. • Watercourse crossings should be minimised and crossing should be avoided where there are unstable bed or banks. • Temporary access tracks shall be stabilised with crushed rock or similar materials to prevent or minimise erosion. • Regular inspections to monitor erosion and siltation will be undertaken. • Erosion and sediment controls will be maintained and replaced where necessary. **Operation** • Vehicles shall use existing designated access tracks only. • Fences and gates shall be left in the position they were originally found. • Vehicles shall be within the safe load and width limits. • Activities shall be conducted in compliance with the 99-V-PR-0016 Traffic and Transport - Environmental Aspects Procedure and 99-V-PR-0014 Land Clearing and Ground Disturbance Procedure.
Stock and Wildlife	**Stock** • Stock access to active work areas will be restricted, where possible. • Any restrictions placed on stock movements in the vicinity of work areas will be agreed with landholders so that disruption of stock is minimised. • Gates, holding yards and other areas used to move or contain stock will be identified and discussed with landholders prior to site works. **Wildlife** • An ecological assessment will be undertaken to determine any potential fauna habitat features, animal breeding places and the potential for threatened species, migratory species or special least concern animals. Prior to commencing vegetation clearing activities, a qualified spotter catcher shall assess the presence of any significant habitat features, that require:

	– Specific actions to minimize fauna injury. – Protection. – Clearance and relocation. • A qualified spotter catcher shall conduct a search of the area proposed to be cleared for the presence of fauna species. If fauna are detected, the spotter catcher shall assess the most appropriate method to avoid or minimize impacts to the individual. The following hierarchy of control shall be employed: – Avoid. – Minimise. – Mitigate. • Threatened Species Management Plans will be developed when project activities are identified as likely to impact on individuals or when works are undertaken within close proximity to threatened species. • Habitat corridors shall be created where possible to link 'islands' of habitats. • Habitat trees will be retained where possible. • Wide buffers of natural vegetation along creeks and rivers shall be retained to serve as corridors for species. • Suitable large, woody debris shall be retained where possible to provide cover and habitat. • Vehicles will be restricted to designated tracks and speed limits will be imposed. • Where activities may impose barriers to the movement of fauna for extended period of time, reasonable measures shall be implemented to facilitate fauna movement around or through the workplace. • Appropriate fauna exclusion and/or escape measures shall be implemented at regulated dams. • The time trenches are left open will be minimized. Exit points will be constructed using appropriate material and fauna refuges, such as sawdust-filled bags, will be placed regularly through areas of high faunal activity. • Activities shall be conducted in compliance with the 99-V-PR-0021 Wildlife and Stock Management Procedure and 99-H-PR-0048 Fauna Spotter Catcher Procedure. • Light spill from project activities will be minimised to reduce disturbance to nocturnal fauna. • Disturbance or harassment of wildlife and the unauthorized collection of flora and forest products is prohibited. • Foodscraps will be disposed of in a manner that prevents animal access. • During rehabilitation works, care will be taken when moving stockpiled logs and vegetation to avoid fauna mortality.

Vegetation Management	• Ecological assessments must be undertaken in areas subject to proposed disturbances by conducting a: – Desktop study to identify the species/communities and status of those species/communities inhabiting the study area. – Field investigation to describe the existing environment and to verify and delineate the identified flora and fauna species/communities. • Activities will not occur within a Category A, B or C ESAs, or their associated buffer zones, unless specifically authorized by the conditions of the EA. • Activities will aim to be undertaken within cleared areas, with the aim of avoiding remnant and high value regrowth vegetation. • Minimise the disturbance footprint and vegetation clearing. • Minimise the width of construction Right of Ways (ROWs) within areas of sensitivity to the greatest extent possible without compromising the safety of the workers. • Gathering lines and tracks will be located to avoid watercourses, drainage lines and riparian areas where practicable. • Vegetation will be cleared in accordance with the conditions of the Environmental Authority. • Cleared vegetation must be stockpiled in a manner that facilitates re-spreading or salvaging and does not impede vehicle, stock or wildlife movements. • Trees not identified for removal will be protected from damage. Construction activities will limit the scraping of standing tree trunks and breaking of limbs by equipment as far as practicable. • Trees will be felled away from existing stands where practicable. Where trees unavoidably fall into a stand, the tree will be left in situ to emulate natural tree fall and provide habitat for ground-dwelling species, where practicable. • Where ever possible, vegetation shall be removed at ground level by cutting / slashing (rather than removing root stock) and then stored for reuse as mulch during site rehabilitation, or sediment and erosion control. • Access of vehicles and personnel to areas outside the cleared work zone shall be restricted so as to prevent further disturbance.
Weeds and Pathogen Management	• Prior to, during and after conducting activities, the presence of weed infestations on-site shall be assessed and results recorded and communicated to staff. • Operational and maintenance activities shall be planned so that movement of plant and equipment between properties, corridors or areas with weed infestations or evidence of pathogen infection is minimised. • All vehicles and personnel shall only enter and exit the site from designated access tracks and roads.

	• Weed control methods such as chipping, spraying or employing a contractor to carry out weed control, shall be utilised. • To minimise the risk of weed spread where practicable, topsoil shall be stockpiled and reused in the area it came from. • Materials shall be accompanied by a Weed Hygiene Declaration Form stating that the material is free of weeds before being accepted at site. • Where necessary, portable washdown facilities will be located near designated work areas for the duration of works and / or government provided washdown facilities are to be used if available. • Washdown facilities shall be such that any run-off is contained and does not transfer weed seeds, spores or infected soils to adjacent areas. • After washdown, vehicles must obtain a Weed Hygiene Declaration Form and display a sticker/tag that indicates the vehicle is clean and can enter the relevant site. • Develop and implement a training program to minimise and control the use of herbicides on Arrow sites. • Activities shall be conducted in compliance with the 99-H-PR-0030 Weed and Pathogen Management Procedure.
Fire	• Fire-fighting equipment shall be installed where required and routinely inspected and tested. • Where there is a fire risk to a facility from the surrounding environment, through bush fires, burning flora, ash and/or smoke, the following fire prevention activities shall be considered and/or implemented: – Plant growth shall be prevented in controlled and cleared areas such as firebreaks; – Access ways maintained by regularly removing weeds and dead undergrowth; – Dead wood and other combustible fuels, grass and litter shall be removed in the facilities perimeter area. • Activities shall be conducted in accordance with the 99-H-PR-0020-Fire Prevention Procedure.
Rehabilitation	• Rehabilitation will be undertaken as soon as practicable upon completion of the works. • The pre-construction field investigation baseline characterisation will be utilised when rehabilitating project sites. • Significant species will be translocated or propagated where it is deemed necessary for use during rehabilitation or in offsets in accordance with relevant legislation. • Woody debris, logs and rocks where possible will be retained for use in rehabilitation and will be spread over part or all of the corridor or well pad, or as a minimum, pile along the edge of the

	corridor to provide refuge for crossing fauna. • Plant species selected for the purposes of rehabilitation will be specific to the original ecosystem and of local provenance wherever practicable. • Excavations will be backfilled and rehabilitated, particularly pipeline trenches and drilling sumps. Backfilling will be conducted in a manner that will promote successful rehabilitation and may include capping of exposed subsoil with topsoil and replacement of the land surface to pre-construction levels to reduce trench subsidence and concentration of flow.
Performance Indicators	
• Any complaints received resulting from Arrow's activities are appropriately investigated, actioned and closed out. • No evidence of vehicle deviation from designated access tracks resulting from Arrow's activities. • No clearing outside marked clearing boundaries resulting from Arrow's activities. • Minimise impacts to fauna or livestock resulting from Arrow's activities. • No proliferation of weeds on the project site or immediate surrounds resulting from Arrow's activities. • Evidence of appropriate vegetation stockpiling/mulching and respreading during, and following, construction relating to Arrow's activities. • All Arrow's onsite vehicles have certification of appropriate washdown / cleanliness. • Success of rehabilitation measures, via monitoring, relating to Arrow's activities.	

9. AQUATIC ECOLOGY

9.1 EXISTING ENVIRONMENT

Aquatic ecosystems within the DXP are diverse with permanent, semi-permanent and highly seasonal lotic (flowing water) and lentic (non-flowing water) environments present within the Condamine-Culgoa Drainage Basin.

Numerous watercourses were identified within the DXP, including the Condamine River. Permanent and semi permanent watercourses within the DXP are typically slow flowing and meandering during the dry season, with periods of higher flow during the wetter months. Ephemeral streams may experience short periods of high flow but also undergo long periods of low or zero flow during which time the streams become a series of waterholes or dry out completely.

9.1.1 Permanent and Semi-permanent Watercourses

Permanent and semi-permanent watercourses within the DXP include the Condamine River, Wilkie Creek, Oakey Creek and Braemar Creek. These systems contain water all year round, although in many cases are reduced to a series of isolated pools during the dry season.

Development and agricultural land use has resulted in the disturbance of the permanent and semi-permanent watercourses and their ecosystems. The disturbance ranges from minimal to highly altered. However, these ecosystems still provide good-quality aquatic habitats that are known to support a relatively diverse range of aquatic species including fish, turtles and invertebrates. In general the permanent and semi-permanent watercourses have uniform aquatic flora, fauna and macroinvertebrate communities across the DXP.

9.1.2 Ephemeral Watercourses

A high proportion of the ephemeral systems within the project area are unnamed systems that flow for very limited periods each year. These systems range from being moderately disturbed by existing land use activities to highly disturbed agricultural drainages.

In general, ephemeral watercourses within the DXP are not unique on a local or regional scale. These ecosystems contain no formal conservation status, no species, habitat or aquatic communities of special conservation significance, no fisheries values and no eco-tourism potential. They provide marginal aquatic habitat due to short periods during which they contain water, lack permanent connectivity to larger watercourses and minimal spawning/nursery habitat. However, they are critical for maintenance of water quality within the catchment.

Ephemeral watercourses are likely to be used opportunistically by aquatic fauna and flora that are tolerant of significant disturbance events and which can adapt to rapidly colonise and regenerate when conditions are suitable.

9.1.3 Environmentally Sensitive Areas

Environmentally Sensitive Areas (ESA's) within the DXP area were identified using the DERM ESA web mapping search tool (DERM, 2011d). The following ESA's were identified:

- Lake Broadwater Conservation Park is located within the DXP and is classified as a Category A ESA. This site is likely to be seasonally inhabited by some aquatic species for foraging or spawning. These species potentially include the EPBC Act listed Murray Cod (*Maccullochella peelii peelii*). This site is important in maintaining hydrological and ecological processes and filtering water, sediment and other pollutants.

- The Narran Lakes Nature Reserve (in northern New South Wales) is listed as a site of international importance under the Ramsar Convention. The site is the terminal wetland of the Narran River, which is fed by the Condamine River. The Condamine River drains a substantial part of the DXP. Narran Lake provides significant habitat for migratory species.

9.1.4 Endangered, Vulnerable or Near Threatened Species

The EPBC and Wildlife Online database searches identified one threatened aquatic species or potential habitat for threatened aquatic species recorded or likely to occur within the DXP and surrounding areas. The Murray Cod (*Maccullochella peelii peelii*), listed as vulnerable under the EPBC Act, was identified as 'species or species habitat may occur' within the DXP. Based on assessment of the habitat present within the DXP it is likely that this species is present.

The results of the database searches are indicative only. The complete DERM Wildlife online search results and EPBC results are located in Appendix C.

9.2 ENVIRONMENTAL VALUES

Aquatic ecosystems in the DXP area include ESA's, permanent and semi-permanent watercourses and ephemeral watercourses. The existing aquatic ecology environment identified within the DXP is comprised of unique characteristics. Table 21 lists the characteristics of the existing aquatic environment identified within the DXP.

Table 21: Characteristics of the existing aquatic environment

Existing Environment	Characteristics
Lake Broadwater Conservation Park	• High degree of ecological intactness. • Valuable aquatic habitat, in particular for: – National and state listed aquatic fauna species of significance, including the Murray Cod. – Locally significant species. • Provision of important ecological processes for maintaining and filtering water quality, sediment and other pollutants.
Permanent and semi-permanent watercourses	• Valuable aquatic habitat in particular for: – National and state listed aquatic fauna species of significance, including the Murray Cod. – Locally significant species such as Golden Perch (*Macquaria ambigua*) and Silver Perch (*Bidyanus bidyanus*). • Species diversification: aquatic ecosystems (unique at a local scale), ranging from minimally to highly disturbed, contain many areas of good quality aquatic habitat that are known to support a relatively diverse range of aquatic species, including fish, turtles and invertebrates. • Spawning habitat for aquatic species is present but does not represent critical spawning habitat. • Deeper pools and remnant waterholes providing refuge for a range of aquatic species, and these communities 'seed' populations when wet season flows provide connectivity between watercourses. • Habitat for longer-lived species (than those from ephemeral systems), which are less likely to recolonise following disturbance (hence there is a greater possibility of these species or communities becoming locally extinct).
Ephemeral Watercourses	• Marginal aquatic habitat.

9.3 POTENTIAL IMPACTS ON ENVIRONMENTAL VALUES

The primary activity that could impact on aquatic ecological values within the DXP is the construction of road and pipeline watercourse crossings. Watercourse crossings will involve:

- Removal of riparian vegetation thereby exposing the ground surface and increasing its susceptibility to increased sedimentation in watercourses and erosion. Disturbance to watercourse banks can also destroy turtle and frog habitat and may lead to weed encroachment.
- Earthworks and vehicle movement within the watercourse leading to potential scouring of the bed and banks and subsequent sedimentation (with the potential for sedimentation to smother benthic fauna).

- The installation of temporary watercourse diversions which could create an instream barrier and disrupt the hydrology and the flow of the watercourse.

Further construction activities that could adversely impact the aquatic ecology include accidental spills or release of construction waste near or in watercourses causing contamination. Terrestrial earthworks during well site, pipeline and production facility construction could also cause sedimentation and the spread of exotic disease.

During operation, the following activities could impact on ecological values:

- Use of herbicides during maintenance of wellheads, production facility sites and pipeline easements.
- Accidental spills or release of waste or sanitary wastewater near or in watercourses.
- Discharge of coal seam gas water into watercourses under emergency circumstances when the dams are approaching maximum capacity during periods of prolonged rainfall, potentially leading to streambed erosion and changes of water chemistry affecting aquatic flora and fauna.
- Use of vehicles for maintenance activities on access tracks potentially causing sedimentation and the spread of exotic species.
- The performance of culverts installed on production facility access tracks.

In summary, potential impacts to aquatic ecological values from project activities within the DXP include:

- Erosion and sediment transport;
- Decline in water quality and increase in algal blooms;
- Introduction and spread of exotic species;
- Reduced movement of aquatic biota; and
- Habitat loss, modification or fragmentation.

9.4 MANAGEMENT OF POTENTIAL IMPACTS

Direct impacts to flora and fauna can be readily avoided and managed, provided that the hierarchical approach of avoid, minimise, mitigate and offset is adhered to, activity specific mitigation measures are developed and implemented effectively and progressive rehabilitation is undertaken and maintained until such time that the disturbed area is stable and self-sustaining.

9.4.1 Control Strategies

Management of potential impacts to aquatic flora and fauna under the project is activity based. For each of the core field activities a specific set of applicable environmental procedures will be applied. Key control strategies to address potential impacts to flora and fauna, as described in the relevant procedures, are presented in Table 22.

Table 22: Control Strategies for Potential Impacts to Aquatic Flora and Fauna

Environmental Protection Objectives	
• To minimise habitat loss and fauna mortality. • To avoid or minimize adverse effects on aquatic ecosystems and associated biodiversity and habitat. • To avoid or minimise adverse impacts on environmentally sensitive areas. • To control the introduction or spread of new or existing exotic aquatic flora or fauna.	
Environmental Issue	**Control Strategies**
Access Tracks	**Construction** • Disturbances in environmentally sensitive areas and water courses will be avoided wherever practicable. • Land clearing and vegetation removal will be minimised within watercourses and their associated buffer zones. • Constructing parallel or multiple access tracks across watercourses will be avoided. • Watercourse crossings should be minimised and crossing should be avoided where there are unstable bed or banks. • Temporary access tracks shall be stabilised with crushed rock or similar materials to prevent or minimise erosion. • Culverts will be installed at water crossings, where required, in accordance with DERM's Guideline – Activities in a watercourse, lake or spring associated within mining operations (DERM, 2010c). • Regular inspections to monitor erosion and siltation will be undertaken. • Erosion and sediment controls will be maintained and replaced where necessary. **Operation** • Vehicles will use existing designated access tracks only.
Vegetation Management	• Ecological assessments will be undertaken in areas subject to proposed disturbances by conducting a: – Desktop study to identify the species/communities and status of those species/communities inhabiting the study area. – Field investigation to describe the existing environment and to verify and delineate the identified flora and fauna species/communities. • Activities will not occur within a Category A, B or C ESAs, or their associated buffer zones, unless specifically authorized by the conditions of the EA. • Gathering lines and tracks will be located to avoid watercourses, drainage lines and riparian areas where practicable. • Vegetation will not be cleared, where possible:

	– In or within 200m from any referable wetland; and – In or within 100m of the high bank of any other watercourse.
Aquatic Flora and Fauna	• Potential impacts to Lake Broadwater Conservation Park will be managed through the implementation of the appropriate buffer identified in the EA. • Watercourse crossings will be minimised, where practicable, during route selection. Crossings will be at locations that avoid or minimise disturbance to aquatic flora, waterholes, watercourse junctions and watercourses with steep banks. • Transport of equipment across watercourses will be avoided unless an appropriate crossing that minimises disturbance to the bed and banks and riparian vegetation is available. • The width of ROWs will be narrower at watercourse crossings where practicable. • Watercourse crossings will be constructed in manner that minimises sediment release to watercourses, stream bed scouring, obstruction of water flows and disturbance of stream banks and riparian vegetation (i.e. the crossing will be located at a point of low velocity, and straight sections will be targeted, with the pipeline or road orientated as near to perpendicular to water flow as practicable). • Flumes used to construct watercourse crossings will be suitably sized to maintain flows and fish passage. The bed will be protected from scouring at the site of downstream discharge of any flumes or pipes. • If diversion of watercourse flows using pumps is required the pump intakes will be screened with mesh to protect aquatic fauna. • Where practicable, pipelines will be co-located into one watercourse crossing corridor. • Stockpiled material will be stored away from watercourses or drainage lines, maintaining a 100m buffer from the high bank of the watercourse.
Weeds and Pathogen Management	• Prior to, during and after conducting activities, the presence of weed infestations on-site shall be assessed and monitored, and the results recorded and communicated to relevant staff. • Operational and maintenance activities shall be planned so that movement of plant and equipment between properties, corridors or areas with weed infestations or evidence of pathogen infection is minimised. • Develop and implement a training program to minimise and control the use of herbicides on Arrow sites. • All vehicles and personnel shall only enter and exit sites from designated access tracks and roads. • Washdown facilities shall be designed to contain run-off and not transfer weed seeds, spores or infected soils to adjacent areas.

	• Activities shall be conducted in compliance with the 99-H-PR-0030 Weed and Pathogen Management Procedure.
Rehabilitation	• Rehabilitation will be undertaken as soon as practicable and within 12 months of completion of the works. • Rehabilitation will be undertaken in accordance with Arrow's Rehabilitation Procedure. • The pre-construction field investigation baseline characterisation will be utilised when rehabilitating project sites. • Woody debris, logs and rocks retained for use in rehabilitation will be spread over part or all of the corridor, or as a minimum, pile along the edge of the corridor to provide refuge for crossing fauna. • Plant species selected for the purposes of rehabilitation will be specific to the original ecosystem and of local provenance wherever practicable. • Excavations will be backfilled and rehabilitated, particularly pipeline trenches and drilling sumps. Backfilling will be conducted in a manner that will promote successful rehabilitation and may include capping of exposed subsoil with topsoil and replacement of the land surface to pre-construction levels to reduce trench subsidence and concentration of flow.
Performance Indicators	
• Any complaints received resulting from Arrow's activities are appropriately investigated, actioned and closed out. • Minimise impacts to aquatic fauna resulting from Arrow's activities. • No proliferation of weeds on the project site or immediate surrounds resulting from Arrow's activities. • Minimise the potential for increase in algal blooms or nutrient levels resulting from Arrow's activities.	

10. NOISE

This section provides a summary of the acoustic environment values within the DXP area and an assessment of the potential for these values to be affected by direct and indirect impacts associated with the DXP. Control strategies for the management of these impacts have been developed.

10.1 EXISTING ENVIRONMENT

The DXP is situated in a regional location, with the predominant land uses in the area being related to agriculture and the energy sector. Accordingly, the DXP is expected to have an acoustic environment characterised by natural sounds such as wind in trees and man-made sounds associated with urban and agricultural areas. Background noise levels are likely to be relatively low, particularly during the night, when some activities contributing to ambient noise levels cease operating. There are, however, some areas where existing facilities associated with the coal seam gas, power generation or mining industries may have an influence on the existing acoustic environment. The location of sensitive receptors throughout the DXP area reflects the typically low population density of agricultural areas.

10.2 ENVIRONMENTAL VALUES

The EP Act provides for the *Environmental Protection (Noise) Policy 2008* (EPP Noise) to deal specifically with environmental values relating to noise quality and levels. The environmental values to be protected from noise and vibration are the qualities of the acoustic environment conducive to the following:

- Protecting the health and biodiversity of ecosystems.
- Protecting human health and wellbeing by ensuring a suitable acoustic environment for individuals to do any of the following:
  - Sleep.
  - Study or learn.
  - Be involved in recreation, including relaxation and conversation.
- Protecting the amenity of the community.
- In relation to vibration only, protecting the structural and cosmetic integrity of cultural heritage sites and dwellings.

10.2.1 Sensitive Receptors within the DXP

As detailed in Section 2.4 a survey conducted in 2009 identified approximately 400 potential sensitive receptors (buildings) within the DXP area, excluding the townships of Dalby and Cecil Plains. Sensitive places ground-truthed and mapped within the DXP area are shown in Figure 4.

Arrow Energy have contracted Coffey Environments to update the identification, ground-truthing and mapping of sensitive receptors in the DXP area and this work is due for completion late-2012. Potential sensitive receptors are located throughout the DXP area and will consequently be integral to the assessment of potential noise and air quality impacts.

10.2.2 Baseline Monitoring

Baseline noise monitoring was carried out for the Surat Gas Project Curtis Island EIS (Arrow Energy, 2012) at four representative locations in the DXP area and confirmed low ambient (LAeq) and background (LA_{90}) noise levels in the absence of existing coal seam gas industry activities. Elevated levels were recorded at sensitive receptors in proximity to existing production facilities.

Using this baseline data, each monitoring location's rating background level was calculated and is summarised in Table 23. These background levels are considered to be representative of all seasons.

Table 23 : Calculated rating background levels

Monitoring Location	Industrial Noise Influence	Rating Background Level (dB(A))*		
		Day	Evening	Night
ML 1	Yes	26	29	26
ML 2	No	29	22	19
ML 3	No	25	22	19
ML 4	Yes	32	34	34

*The rating background level is the median of the daily lowest tenth percentile (lowest 10th percent) of background noise levels, giving an overall background noise level for an assessment period (day, evening or night) over a monitoring period of three to seven days.

No appreciable vibration sources could be detected during inspection of the four representative measurement locations.

10.3 Potential Impacts on Environmental Values

Potential impacts to the acoustic environment from project activities include:

- Environmental noise disturbance. This includes nuisance noise and background noise creep, which is when noise levels progressively creep higher over time.
- Vibration-induced human discomfort and structural damage.

Activities with the potential to cause these adverse impacts on the values of the acoustic environment during the construction, operations and decommissioning phases of the project include the following:

- Construction of the exploration, appraisal and production wells, which includes site preparation, drilling and well construction.
- Construction of the associated gas and water gathering pipelines.
- Construction of high-pressure gas pipelines that connect production facilities to one another and with the sales gas pipeline.
- Construction of the CGPFs and power generation facilities.
- Blasting during construction. Blasting is not anticipated during construction of the project, but it was considered in the assessment should the need arise.
- Operation of the production wells and the CGPFs.
- Operation of the power generators.
- Decommissioning of the production wells.
- Decommissioning of the production facilities.

10.3.1 Transient Noise Sources

Transient noise sources on the DXP will mostly relate to construction of infrastructure and consequently will be transient or of a short duration.

Noise levels were modelled based upon known sound levels of typical construction equipment.

For construction of production facilities, modelling predictions indicate that, under worst-case meteorological conditions where noise propagation is pronounced, the daytime long-term noise criterion of 40 dB(A) will be met at sites located 3 km or more from the facility site.

For construction of production wells and pipelines, modelling predictions indicate that noise criteria will be met at sensitive receptors 1 km or more from the construction activity.

10.3.2 Fixed and Operational Noise Sources

Sound propagation from a potential noise source was modelled to several reference

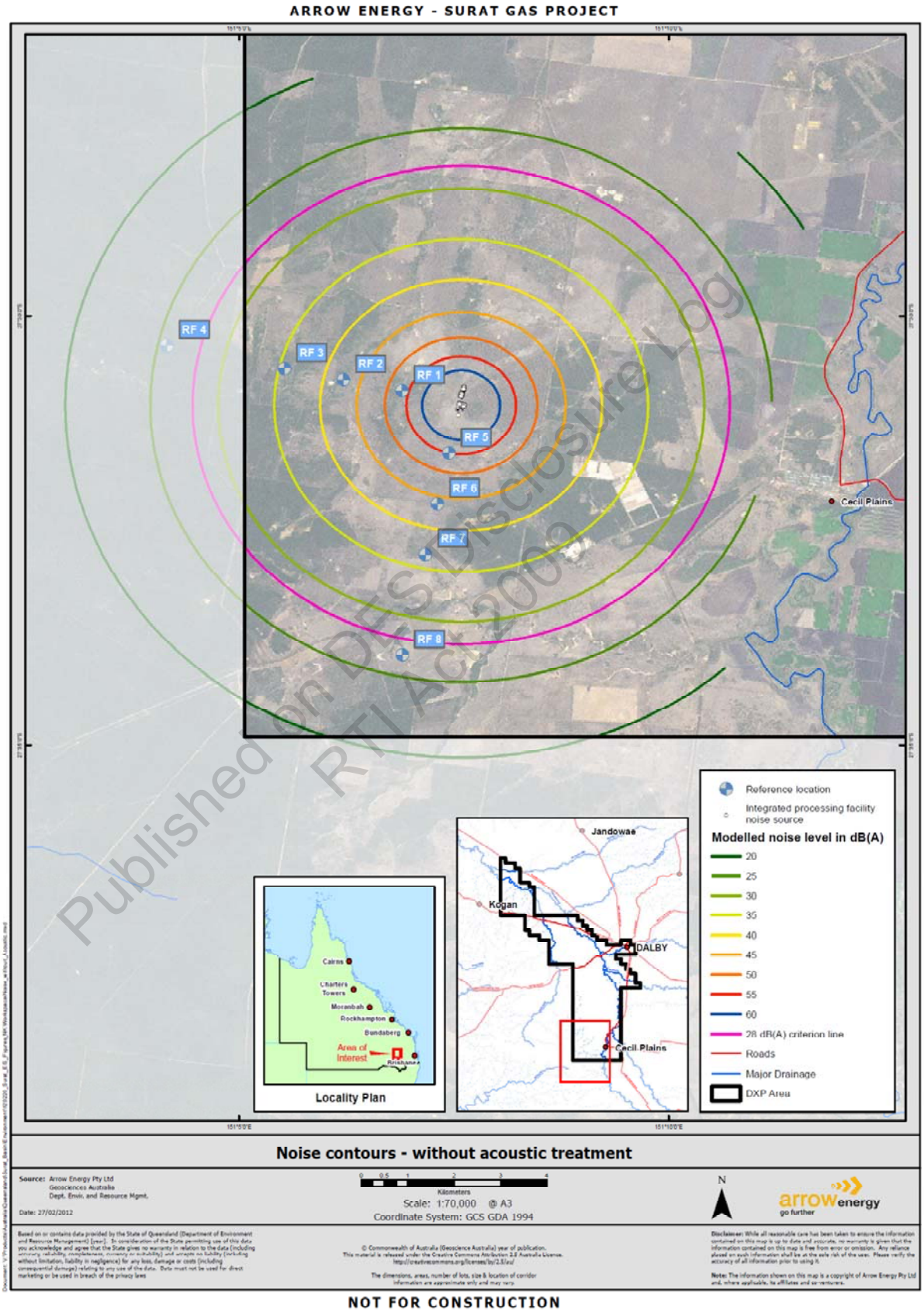


Figure 15) that were considered to be representative of possible locations of the closest sensitive receptors.

Production facility operational noise was modelled at each of the reference locations under the assumption of a worst-case noise scenario where all equipment is operating simultaneously and continuously. Further to this the modelling represents a worst-case scenario as the scenario uses an integrated processing facility whereby the production facilities (CGPFs and WTFs) were located within the same footprint. However, the production facilities on the DXP consisting of CGPFs and WTFs are located separately resulting in lower operational noise levels than that predicted by the modelling.

There will be no significant noise sources associated with the operation of water and gas pipelines as they will be located underground.

Vibration levels throughout the construction and operation of the project are expected to be below the threshold of human detection and not cause structural damage at sensitive receptors that are located at distances greater than 100 m from the activity.

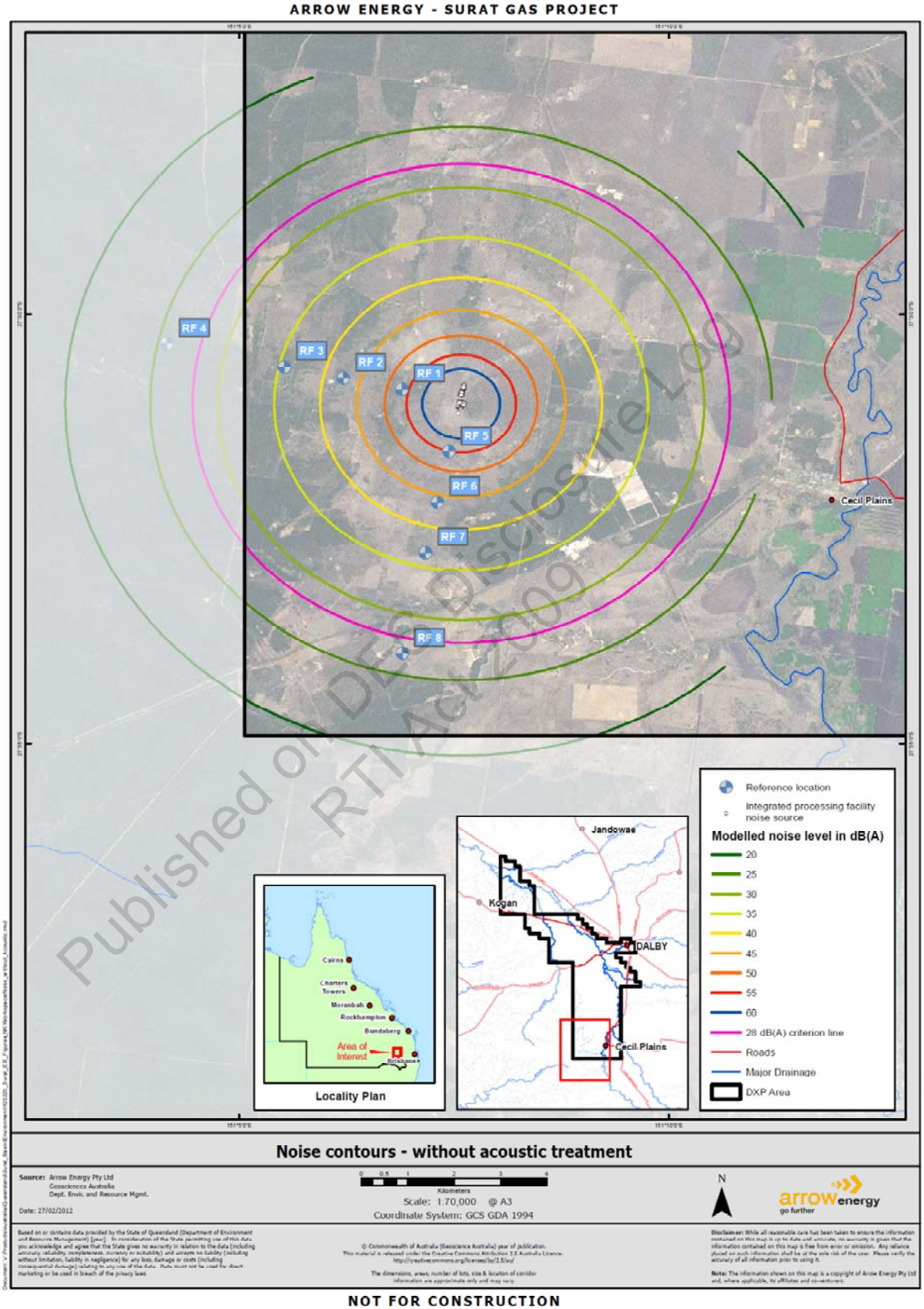


Figure 15 : Noise contours – without acoustic treatment

10.4 MANAGEMENT OF POTENTIAL IMPACTS

A management hierarchy of avoid, minimise and manage impacts was applied when developing noise and vibration management measures.

Therefore, the primary mitigation measure will be the exploration of opportunities to maximise the distance of project development sites from the nearest sensitive receptors. The relatively sparse pattern of occupation throughout the DXP area provides opportunities to site the infrastructure to provide adequate separation and avoid cumulative noise impacts from existing infrastructure.

Equipment selection and facility design will consider best-practice noise attenuation technology to control and prevent background creep, contain and minimise variable noise, and avoid sleep disturbance.

Residual impacts are expected to be negligible as the impact assessment determined that relevant noise and vibration criteria can be achieved at sensitive receptors through the selection, design and siting of facilities.

10.4.1 Control Strategies

Control strategies for noise and vibration for all project-related activities from planning and design through to decommissioning are found in Table 24.

Table 24: Control Strategies Relating to the Management of Noise

Environmental Protection Objective	
• To ensure that noise emissions from project activities comply with applicable noise and vibration criteria. • To protect the amenity of sensitive receptors by reducing noise and vibration impacts from production facilities and associated workforce and infrastructure.	
Environmental Issue	**Control Strategies**
Environmental noise disturbance.	• Ensure all engines, machinery equipment and pollution control mechanisms are operated and efficiently maintained. • Operate equipment and handle materials in a manner that does not cause unnecessary noise (e.g., excessive revving or dropping materials). • Consider control or abatement measures such as relocation of the activity, hours of operation, alternative arrangements with potentially affected persons to reduce identified intrusive noise sources. • Manage noise in accordance with the relevant environmental authority conditions. Where night-time activities are planned (10 p.m. to 6 a.m.) and are likely to exceed the prescribed noise criteria,

	conduct prior consultation with affected parties. • Consult with those who may be affected by increased noise levels due to construction activities with particular reference to the type and timing of works. • Maintain a complaints management system that captures noise complaints and records actions taken in response. If advised by the administering authority noise monitoring to investigate a noise complaint will be undertaken. • Selection of sites to consider the location of sensitive receptors. • Where Site-specific detailed noise modelling of production facilities is likely to exceed the established noise criteria at one or more sensitive receptors intrinsically quieter equipment or acoustic treatments will be considered in the design phase. • Where possible, locate facilities and equipment at a suitable distance to comply with noise limits at sensitive receptors.
Vibration-induced human discomfort and structural damage.	• Ensure all engines, machinery equipment and pollution control mechanisms are operated and maintained in accordance with manufacturers' recommendations. • Selection of sites to consider the location of sensitive receptors. • Locate equipment associated with production wells and associated wellhead infrastructure at a distance of 200 m or more from a sensitive receptor. • Consider the following factors prior to any blasting operations being conducted: – The type of rock and stratigraphy being blasted and any associated faulting. – The distance of the blast site from sensitive receptors. – The type, size and number of charges used. – The depth and manner in which the charge is installed. – Methods of controlling blast noise and vibration, such as mats or smaller blasts.
Monitoring Requirements	
• Implement monitoring, inspection and maintenance of avoidance, mitigation and management measures to ensure the residual impacts of noise continue to be negligible throughout the lifetime of the project. • If directed by the administering authority in response to a valid noise complaint, undertake noise monitoring in accordance with the DERM (2000) Noise Measurement Manual or a later version of that document.	
Performance Indicators	
• All complaints are registered, addressed and closed out. • Applicable noise and vibration levels are met at the sensitive receptor.	

11. WASTE

This section provides a summary of identified waste streams expected to be generated by project activities and an assessment of the potential for identified environmental values to be affected by impacts associated with waste generated in each phase of the project.

Environmental protection objectives related to the management of waste have been developed and the mitigation and management measures to achieve these objectives identified. More specific details on waste stream generation and management measures are provided in the following sections:

- Section 5, Air
- Section 6, Dams
- Section 7, Geology, Land and Soils
- Sections 8 and 9, Flora and Fauna
- Section 12, Water
- Section 13, Social Environment
- Section 14, Rehabilitation

11.1 WASTE GENERATION

The EP Act defines a waste as any gas, liquid, solid or energy (or a combination of wastes) that is surplus to, or unwanted from, any industrial, commercial, domestic or other activity, whether or not of value.

With respect to the DXP activities, relatively small amounts of domestic and industrial wastes will be generated during the construction and operation of project related facilities. The volume of each waste type will depend on the scale of each activity being carried out at any one time. The types of wastes that could be generated from DXP construction and operational activities will likely involve a mix of regulated and non-regulated wastes including:

- General waste.
- Sewage.
- Putrescible waste.
- Solid inert wastes such as building rubble, concrete, bricks, timber, plastic, glass, metals and tyres.
- Hazardous wastes such as cleaning chemicals, waste oils, spill clean-up materials and batteries.
- Drill cuttings and cement returns.

- Drilling fluids not suitable for re-use.
- Oily water.
- Cleared vegetation.
- Waste cut/fill materials generated during dam construction.
- Coal seam gas water.
- Brine.

Examples of waste types and approximate volumes generated as part of Arrow's exploration and production activities are shown in Table 25.

Table 25: Examples of Wastes Generated by DXP Activities

Activity	Waste Material	Approximate Quantities	Disposal
Construction of Exploration, Appraisals & Production Wells.	Drill cuttings	11m³ per well	Re-used in onsite rehabilitation or disposed off-site as Regulated Waste via licensed waste disposal contractor.
	Residual Muds, including clay stabilisers & additives.	75m³ per well	Drill fluids recycled where possible, otherwise disposed of as a regulated waste via licensed waste disposal contractor.
	Hard Waste	0.5m³ per well – wood pallets, scrap metal and general waste	Recycle where practicable, or removed by licensed waste disposal contractor.
Pipeline Installation	Scrap – welding rods / grinding discs	4 m^3 per week	Recycle where practicable, or removed by licensed waste disposal contractor
	Cleared vegetation	100 m^3 per 400 m drill string	Recycled where practicable or disposed off-site, or removed by licensed waste disposal contractor.
Operation and Maintenance	TEG	Partial internal change out 1 every 4 years (10m^3)	Licensed waste disposal contractor
	Activated carbon: spent activated carbon containing heavy organics, inorganic vanadium, boron compounds, elemental sulphur	2 per year per water treatment facility	Licensed waste disposal contractor
	Filter cartridges: cellulose based cartridges containing inorganic vanadium and boron compounds, elemental sulphur, potassium carbonate	25 per year per water treatment facility	Licensed waste disposal contractor

	and iron oxides		
	Membrane modules: polyamide membranes containing heavy organics	1 every 3 years per water treatment facility	Licensed waste disposal contractor
Facility Construction	Cleared Vegetation	50m3 per well	Re used otherwise disposed of as organic waste via Licensed waste disposal contractor.
	Used Oil, Filters & Lubricants.	2m3 per year.	Recycle where practicable, or removed by licensed waste disposal contractor.

11.1.1 General and Hazardous Wastes

Various streams of solid and liquid domestic and industrial wastes will be generated during each phase of the project and produced at various locations across the DXP area at any one time. A variety of storage facilities will be provided at each waste generating location to allow consolidation of wastes into specific waste streams. The contents of each storage facility can then be easily removed from each work area and the waste disposed of appropriately (i.e. to landfill, to recycling etc). All regulated wastes will be transported for off-site disposal by an appropriately licensed waste disposal contractor. The relevant waste tracking paperwork will be completed and copies retained on-site.

The accommodation of the workforce for the DXP will result in the generation of putrescible waste (food scraps, etc). Putrescible waste will require adequate storage (e.g. fully enclosed containers) and disposal in order to prevent the attraction of fauna (both native and introduced) and to prevent the generation of odours. All putrescible, recyclable and other general waste types will be taken off-site for recycling and disposal at an appropriately licensed facility.

Small volumes of hazardous wastes may be generated as part of project activities and include chemicals used for cleaning, waste oils and used spill clean-up materials. Hazardous wastes require careful storage, handling, transport and disposal. All hazardous and chemical waste will be suitably stored and handled in accordance with the relevant Australian Standards (e.g. AS 1940), fire safety regulations and relevant Arrow waste and chemical management procedures. Hazardous and/or regulated wastes will be taken off site by an appropriately licensed waste contractor for disposal at a regulated waste disposal facility authorised to accept such waste.

11.1.2 Vegetation

Some green waste will be generated as a result of any clearing of vegetation conducted as part of infrastructure sighting or clearing that is necessary to ensure the activities can be conducted safely (i.e. pipeline easement maintenance). Stockpiled vegetation will be re-spread wherever practicable to provide shelter for fauna, or mulched to assist in erosion and sediment control or rehabilitation.

11.1.3 Sewage

As discussed in Section 4.1.6, there are currently no permanent camps located on the DXP, but temporary drilling camps may be established to support seismic, exploration or appraisal activities. It is anticipated that the sewage waste stream associated with these small temporary camps will be stored and trucked off-site and therefore will not be released to land.

Treated waste generated by the two Aqua Nova Aerated Wastewater Treatment Systems, at the Daandine and Tipton CGPF sites are both less than 21 equivalent persons (EP). The effluent from each system is pumped to fenced-off subsurface irrigation areas (13 m x 5 m in area). As this system is enclosed, fugitive emissions are unlikely, and the system is serviced routinely. The systems are located in isolated areas where the nearest inhabitants are in excess of 2 km away from either facility. Surface water receptors for Daandine and Tipton are 800 m and 1200 m, respectively, away from the system and there are no Environmental Sensitive Areas within 2 km.

In the event that Arrow proceeds with construction of the two Sewage Treatment Plants (<450 EP) currently approved under the current EA PEN100449509, the treated effluent will be handled in a manner that will not result in environmental harm, and in accordance with EA conditions. These sewage treatment plants would be only be constructed if deemed necessary based on predicted workforce numbers and to manage volumes of sewage larger than current capacity.

11.1.4 Drilling Fluids and Solids

Arrow utilises water based drilling fluids in drilling operations that are comprised predominantly of fresh water with 2-3% salts. Salts are used to increase the mud weight and prevent natural clay in the formation from swelling. Some fluids may also contain small amounts of bentonite clay which is added to stabilise the formation and prevent the loss of any fluids. There may be other additives used such as polymers for stabilization, corrosion inhibitors, or biocides.

During drilling operations the drilling fluids are returned to the surface along with drill cuttings. The solids, comprising of mostly pulverised rock, are removed from the fluid either by settling pits or solids control equipment (shakers, de-sanders and de-silters, centrifuges and flocculation tanks) and the fluid re-used.

Where no solids control equipment is used, or where the solids control equipment does not adequately remove solids from the fluid, the fluid may become overloaded with solids and no longer be suitable for drilling. Once this occurs the fluid is either 'diluted' with fresh water and additives added, or removed from site for disposal or treatment for re-use and a new batch of drilling fluid mixed. The frequency of this depends on a number of factors including, well type and depth, geology and the type of solids control equipment used. Typically solids build up in the drilling fluid more frequently where settling pits and no solids control equipment are used, and less frequently when solids control equipment and surface tanks are used.

Arrow Energy is currently transitioning to drilling systems with improved solids control equipment and surface tanks rather than pits. This will provide greater opportunity to minimise the amount of fresh water and additives used for each well through the direct re-use of drilling fluid, thereby minimising the amount of liquid waste generated.

Where concurrent drilling activities are sufficiently close in proximity, centralised fluid processing facilities may be used to 'regenerate' fluids when they no longer become suitable for re-use.

Other than cement returns, the solids generated as by-products of the drilling process mainly comprise of drill cuttings with a component of drilling fluid (water plus additives). As such, the composition and consistency of the solids vary depending on a number of factors including, geology, drilling method (core or chip), drilling system and the drilling fluid used. A number of re-use, recycling and treatment options for the solids are currently being investigated. Options will be evaluated in the context of the waste and resource management hierarchy contained within the *Waste Reduction and Recycling Act 2011*.

11.1.5 Low Point Drain Condensation

Condensation from low point drains is collected in intermediate bulk containers stored at the surface. The condensation is then transported to aggregate dams for storage and subsequent treatment.

11.2 COAL SEAM GAS WATER

11.2.1 Coal Seam Gas Water Quality

Coal seam gas water is water extracted from coal seams in order to release gas from the coal. The volume and quality of the coal seam water resulting from a CSG appraisal well will vary from well to well and from tenure to tenure. Coal seam gas water production across the DXP area is variable but is estimated to average 2.2 gigalitres (GL) per annum.

The coal seam gas water quality from the Walloon Coal Measures can vary from fresh water to saline or highly turbid water. The quality of the coal seam gas water may also depend on the depth of the coal seam, but generally has the following characteristics:

- pH range between 7 and 11.
- Salinity generally ranging from 3,000 to 8,000 milligrams per litre (mg/L) (i.e., brackish) and total dissolved solids including sodium salts, bicarbonate salts, chlorides and others.
- Suspended solids from the well that will usually settle out over time.
- Ions including calcium, magnesium, potassium, fluoride, bromine, silicon and sulfate (as SO_4).
- Trace metals and low levels of nutrients.

Table 26 presents concentrations for a range of coal seam gas water quality parameters reported for samples collected from 67 existing production wells currently drawing coal seam gas water from the Walloon Coal Measures.

Table 26: Coal seam gas water quality in the Walloon Coal Measures

Water Quality Parameter	Unit	Minimum	Maximum	Mean
pH		7.1	11.4	8.1
Conductivity (a measure of salinity)	µS/cm	830	31,000	7,223
Total dissolved solids	mg/L	534	20,150	4,694
Calcium (Ca)	mg/L	4	1,160	136
Magnesium (Mg)	mg/L	2	850	113
Sodium (Na)	mg/L	135	6,950	1,420
Chloride (Cl)	mg/L	65	12,770	2,280
Bicarbonate (HCO_3)	mg/L	5.2	1,980	561
Sulfate (SO4)	mg/L	0	355	43

The design of water treatment and storage facilities will consider Queensland's Coal Seam Gas Water Management Policy (DERM, 2010a) and the Manual for Assessing Hazard Categories and Hydraulic Performance of Dams prepared by DERM (2011).

11.2.2 Coal Seam Gas Water Management Strategy

The Coal Seam Gas Water Management Plan – Surat Basin (refer to Appendix E) seeks to manage coal seam gas water during the life of the project in a way that maximises beneficial use and minimises the environmental impacts associated with water use and disposal.

Arrow's Coal Seam Gas Water Management Strategy (Appendix F) seeks to maximise beneficial use of coal seam gas water in accordance with identified environmental values and minimise the environmental impacts associated with water use and disposal.

The strategy identifies the preferred and potential management options for coal seam gas water and associated brine or salt, including treatment, storage, beneficial use and disposal. The distribution of coal seam gas water to the different management options will be continually reviewed as planning for field development evolves and opportunities for beneficial use arise as outlined below.

11.2.3 Coal Seam Gas Water Management Options

Although coal seam gas water is considered a waste under the EP Act, the government may approve its use as a 'resource' on a case-by-case basis if the water has a beneficial use. When used beneficially, coal seam gas water ceases to be defined as a waste.

Under the *Environmental Protection Regulation 2008*, Section 64D, for activities involving the use or disposal of coal seam gas water, the administering authority must consider the coal seam gas water management policy.

The Coal Seam Gas Water Management Strategy and Coal Seam Water Management Plan – Surat Basin (refer to Appendix E) detail Arrow's preferred management options. In summary, these options include:

- Substitution of allocations, and subsequent beneficial uses, including:
    - Agriculture – Irrigation and stock;
    - Industrial uses (construction and processing);
    - Urban uses (town water supply).
- New Uses;
- Injection;
- Water to watercourses;
- Ocean outfall.

11.2.4 Brine Management Options

Brine is a significant by-product of the water treatment process and also requires specific measures to manage its storage, use or disposal.

Assuming an average salt concentration of 4,500 mg/L, Arrow expects that treatment of coal seam gas water will generate in the order of 4.5 t of salt per megalitre of coal seam gas water. Arrow will continue to monitor coal seam gas water quality as the development progresses.

The Coal Seam Gas Water Management Strategy and Coal Seam Management Plan – Surat Basin (refer to Appendix E) further detail Arrow's preferred management options for brine. In summary, these options include:

- Selective salt precipitation.
- Brine injection (suitable formation).
- Disposal to a suitably licensed landfill.
- Ocean outfall.

11.3 ENVIRONMENTAL VALUES

The key environmental values to be protected from waste streams are:

- **Soils and Land.** Land use capability, having regard to economic consideration, habitat for flora and fauna and quality of land, to guarantee environmental sustainability.

- **Air Quality.** Air quality that is suitable for sustaining human and environmental health and amenity.
- **Ecology**. The diversity of ecological process and associated ecosystems and suitability of flora and fauna habitats.
- **Water Resources.** Water quality that is suitable for sustaining human health, agriculture, visual amenity and suitability of aquatic ecosystems.
- **Visual Amenity.** Features of the existing environment that are important for visual amenity.
- **Health and Safety.** The life, health and wellbeing of people, including the project workers.

11.4 POTENTIAL IMPACTS ON ENVIRONMENTAL VALUES

11.4.1 Potential Beneficial Uses of Waste Generation

Waste and resource management is based on the *Waste Reduction and Recycling Act 2011* hierarchy beginning with waste avoidance, minimisation, reuse, recycling, recover, treat and finally, disposal. The opportunity exists for reuse or recycling of certain construction materials, compounds, and constituents that may otherwise become wastes and be disposed of without obtaining maximum benefit from reuse or recycling the resource. Examples include scrap metal, use of waste oil as fuel, the recycling of plastics, glass, reuse of treated coal seam gas water, drill fluids and cuttings, paper and related materials.

When assessing options within the waste and resource management hierarchy, incidental factors such as the efficiency of treatment processes, nature of any by-products produced and the impacts of any transportation requirements will also be considered.

11.4.2 Potential Adverse Impacts of Waste

Adverse waste management issues associated with project activities include:

- **Uncontrolled Releases of Waste.** Failure to properly manage waste storage and containment systems could potentially result in soil and water contamination and impacts to agricultural land and on visual amenity.
- **Controlled Releases of Waste or Emissions.** Discharge of waste water and air emissions could potentially lead to adverse health and ecological impacts, e.g., discharge of sewage and generation of air pollutants, such as nitrogen dioxide (NO_2).

Potential impacts related to the management of coal seam gas water throughout all phases of the project include:

- Diminished surface water and groundwater quality and subsequent impacts on ecosystems and third-party users (including users downstream).
- Altered physical form and changes to hydrology within watercourses.

11.5 Management of Potential Impacts

Avoidance, mitigation and management measures have been proposed to achieve the identified environmental protection objectives. Avoidance, mitigation and management of potential waste impacts will be achieved primarily through implementation of a waste management hierarchy. Waste will be managed in accordance with the objectives of the *Waste Reduction and Recycling Act 2011*. Arrow will apply the following hierarchy of management options to all waste generated during the project activities:

- Avoid unnecessary resource consumption where possible.
- Source reduction. Reduce waste generation and disposal: avoid, eliminate, change or reduce practices that result in the generation of wastes.
- Re-use. Reuse waste materials that are in their original form.
- Recycle waste resources to make the same or different products.
- Recover waste resources where possible.
- Treat waste before disposal: render wastes safe by neutralisation or other treatment methods.
- Dispose of waste only if there is no viable alternative: dispose of waste products that can no longer be reused or recycled either through landfilling or incineration.

11.5.1 Control Strategies

Control strategies for the management of potential impacts related to wastes generated from DXP activities are presented in Table 27 below.

Table 27: Control Strategies Relating to the Management of Waste and Coal Seam Gas Water

Environmental Protection and Waste Management Objectives
In accordance with the *Waste Reduction and Recycling Act 2011*: • To use a waste management hierarchy and principles based on waste avoidance, reuse, recycling, recovery, treatment and disposal. • To minimise resource utilisation by re-use and recycling of waste. • To minimise impacts to the environment from the management of waste.

- To reduce the quantity of waste that is sent to landfills by recycling and reuse of waste.

In accordance with Arrow's Coal Seam Gas Water Management Strategy and Management Plan for the Surat Basin:

- To maximise beneficial use of coal seam gas water and brine.
- To minimise impacts to the receiving environment associated with coal seam gas water use and disposal.

Environmental Issue	Control Strategies
Management of regulated and non-regulated wastes generated by project activities.	**Planning and design:** • Develop and implement emergency response and spill response procedures to minimise any impacts that could occur as a result of releases of hazardous materials or any loss of containment of storage equipment. • Apply appropriate Australian and industry standards and codes of practice for the design and installation of infrastructure associated with the storage of hazardous materials (such as chemicals, fuels and lubricants). • Design water dams in accordance with relevant legislation and Queensland standards and DERM guidelines. • Develop onsite waste storage areas in accordance with industry practice and relevant waste management regulations. • Procure materials in bulk where practicable to minimise containers and movement of material. • Design the storage capacity of coal seam gas water and brine dams to be sufficient to manage waste liquids until such time that permanent beneficial use or disposal options are approved and operational. • Develop and implement training programs in the principles of the waste hierarchy to personnel handling wastes on a regular basis. **Construction, operations and decommissioning:** • Allocate bins for different waste streams to achieve solid waste segregation to maximise recycling and reuse opportunities. Provide appropriate domestic waste disposal facilities at designated work sites to assist in segregation of waste. • Manage contaminated soil or groundwater that cannot be avoided through physical investigation; manage quantification of the type, severity and extent of contamination; and remediate or manage in accordance with the Queensland Government's Draft Guidelines for the Assessment and Management of Contaminated Land (DE, 1998) and any other relevant legislation. • Contain coal seam gas water in dams for treatment. • Arrow will implement a waste auditing and reporting system

	for waste generating activities to: – Capture waste data to enable continuous improvement of waste avoidance, reduction and management measures throughout the project life. – Assess whether action is required to fulfil set waste objectives and management. – Assess the adequacy of proposed disposal and management measures and identify where these measures need improvement. – Monitor potential environmental impacts to enable positive action to be implemented in case of incidents or accidents related to waste activities. • Store liquid waste generated (other than coal seam gas water and sewage) and periodically remove it for disposal or recycling. • Dispose of waste that cannot be reused or recycled at appropriately licensed facilities. • Store putrescible solid waste in covered containers to prevent odours, public health hazards and access by fauna. • Contain all waste fluids and solids resulting from drilling activities in appropriate containment structures prior to re-use, recycling, treatment or disposal. • Re-use wastes wherever practicable. Opportunities for re-use will be maximised by undertaking the following: – Reuse of cleared vegetation for mulch and soil erosion control. – Reuse of brine for production of potentially saleable salt products and implementing salt crystallisation (see Section 11.2 and Appendix E) – Segregation of wastewater streams, i.e., contaminated stormwater, waste waters and coal seam gas water. – Reuse of treated waste water for dust suppression, construction activities or irrigation. – Reuse of treated coal seam gas water for town water supply, where of appropriate quality. – Reuse of hydrotest water. – Reuse of treated water for agricultural use, industrial use, potable water supply or injection into aquifers. – Treatment and reuse of solid wastes, such as drilling cuttings, as soil conditioners, road base, other uses or construction material where practicable. • Use onsite waste treatment for waste streams such as sewage, coal seam gas water and other specified wastes. Sewage will be treated in package sewage treatment plants. Sewage treatment plants will be located at production and

	water treatment facilities and include settlement, digestion, aeration, clarification and disinfection equipment. • Handle, store and dispose of regulated wastes in accordance with relevant standards and the *Environmental Protection (Waste Management) Regulation 2000*. • Comply with Queensland Government waste tracking requirements. • Segregated general waste will be treated if necessary and stored onsite prior to disposal. Segregation will include the separation of liquid from solid waste, separation of regulated from non-regulated waste, and separation of reusable and recyclable from non-reusable and non-recyclable waste.
Management of coal seam gas water to control: • Diminished surface water quality. • Diminished groundwater quality. • Diminished soil quality. • Altered physical form and changes to hydrology within watercourses due to discharge of coal seam gas water to watercourses. • Altered surface water supply and quality to downstream users due to discharge of coal seam gas water to watercourses. • Altered aquatic and terrestrial ecological processes.	• Maintain water balance models for long-term planning and management of coal seam gas water. Review and update modelling in alignment with the production-forecasting schedule. • Identify strategies to minimise coal seam gas water surface storage and to promote increased efficiency. • Ensure coal seam gas water used for dust suppression on roads or for construction and operation activities is treated if required. **Planning and design:** • Develop and continually maintain the coal seam gas water management strategy throughout the project life to optimise the investigation and implementation of the potential coal seam gas water management options in alignment with the overall project development. **Operations:** • Discharge water from project activities at a rate and location that will not result in erosion. Install additional erosion protection measures, including energy dissipation structures, at discharge outlets. • Incorporate into a discharge response plan or water management plan procedures for the controlled discharge of coal seam gas water. Procedures will include conditions for discharge, stream flow data, notification and reporting. • Demonstrate the requirement for disposal when beneficial uses are unavailable, including details of the control measures that will be implemented.
Monitoring Requirements	
Waste management: • Inspect waste storage locations to ensure waste management measures are being adhered to. • Maintain a waste tracking system for regulated waste. • Maintain and update a water balance model that includes but is not limited to:	

  - Monitoring of volume and quality of coal seam gas water produced and treated.
  - Monitoring of disposition volumes of treated and untreated coal seam gas water.

Coal seam gas water management:

- In accordance with the EA a visual inspection will be conducted of physical form integrity and monitor hydrology, turbidity, total suspended solids, pH, dissolved metals and total petroleum hydrocarbons upstream and downstream of authorised locations where water is to be discharged directly to a watercourse.
- Measure the volume and quality of treated coal seam gas water released to surface waters on a routine basis in accordance with regulatory requirements and approved release limits.
- Maintain and update a water balance model that includes but is not limited to:
  - Monitoring of volume and quality of coal seam gas water produced and treated.
  - Implementation of end point metering to monitor disposition volumes of treated and untreated coal seam gas water.
  - Monitoring of the volume of brine and its by-products used beneficially or disposed to landfill.
- Ensure that the quality of coal seam gas water used for dust suppression meets the prescribed limits.

Performance Indicators

Waste management:

- Evidence of appropriate handling and treatment of contaminated land resulting from Arrow's activities is maintained.
- Wastes resulting from Arrow's activities are appropriately segregated and stored on site.
- Regulated waste transport records relating to Arrow's activities are kept on site.
- Any contamination or spill incidents resulting from Arrow's activities are effectively contained, documented and closed out.

Coal seam gas water management:

- Beneficially use the majority of coal seam gas water.
- No releases of coal seam gas water or brine to watercourses or land except under authorised and controlled situations.
- Compliance with water quality objectives and no permanent impact to the physical form or hydrology of watercourses as a result of project activities.

12. WATER

12.1 EXISTING ENVIRONMENT

12.1.1 Surface waters – General Characteristics

The DXP is located within the Condamine-Culgoa Drainage Basin, which forms the northern headwaters of the Murray-Darling river system. The DXP lies within the sub-catchments of the Condamine River as listed below and shown in Figure 16.

- Condamine River.
- Cooranga Creek.
- Braemar Creek.
- Back Creek.
- Jingi Jingi Creek.
- Jimbour Creek.
- Wilkie Creek.
- Moramby Creek.
- Clayhole Creek.
- Myall Creek.
- Oakey Creek.
- Crawlers Creek.
- Ashall Creek.
- Including all tributaries and associated waterways.

Present and potential water uses for the catchments in the DXP area include agricultural (crop production and stock watering), pastoral, urban, mining and recreational use. Water is also drawn for drinking water supplies from a number of watercourses within the DXP area, including the Condamine River and adjoining streams.

Other water uses in the DXP area include recreation (e.g., swimming, fishing) and aesthetics. Lake Broadwater was recognised for its cultural value, and the Condamine River is likely to have cultural and spiritual values associated with it.

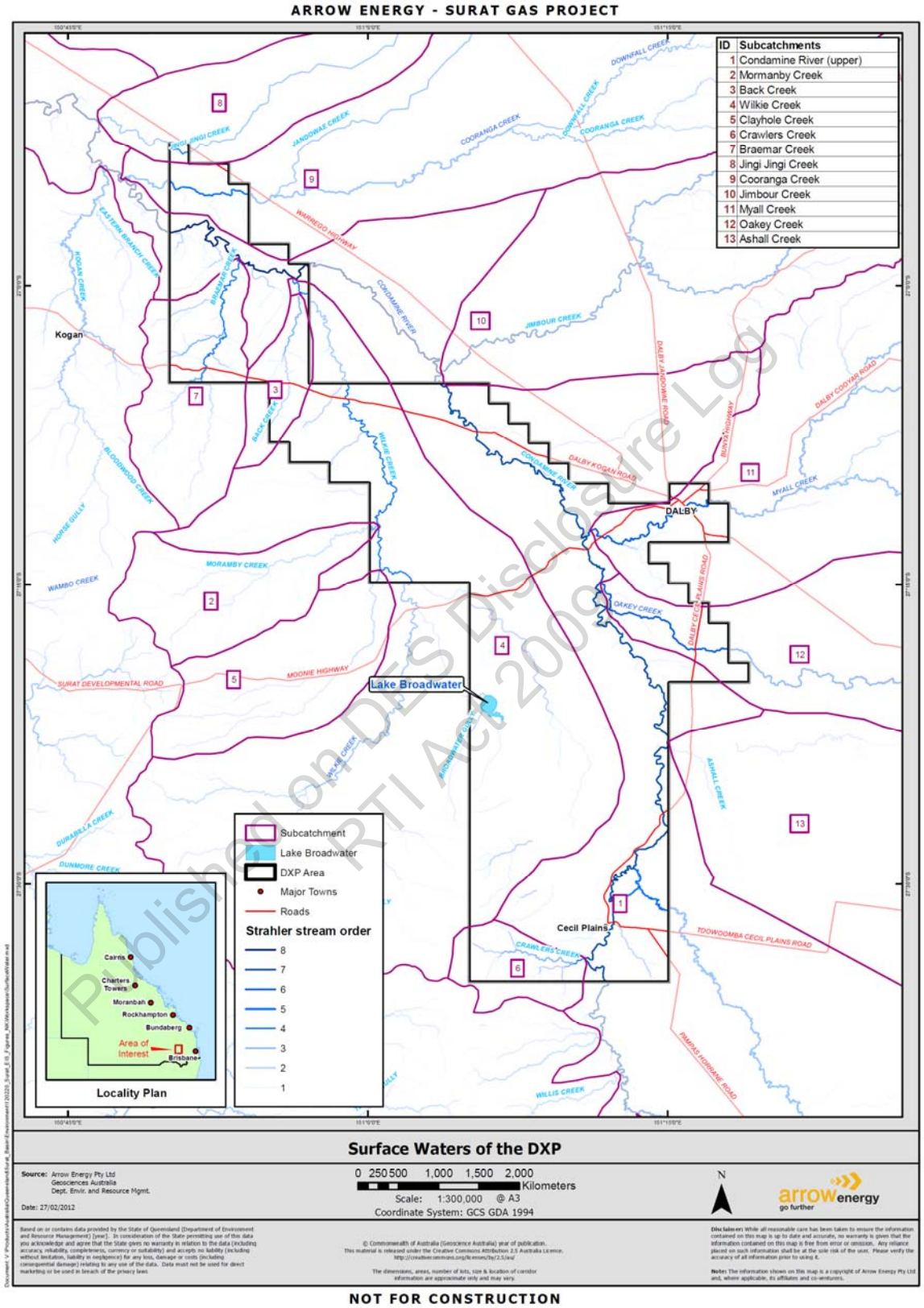


Figure 16: Surface Waters of the DXP

Watercourses within the DXP area exhibit a range of conditions, but are generally slightly to moderately disturbed. Disturbance of watercourses has resulted in bed and bank erosion to varying levels. The changes to water flows throughout the year are likely to result in shifts in water quality across the seasons, with water quality during storm events differing from that of drying pools (e.g., reductions in dissolved oxygen in drying pools (DERM, 2009).

Key characteristics of available water quality data for the watercourses in the DXP area are summarised below.

- DERM (2009) identified several catchments flowing from the east into the Condamine River as being among the most saline areas of Queensland. Electrical conductivity concentrations vary with stream flow: highly variable concentrations were recorded in the Condamine River and in the Oakey Creek subcatchment at low stream levels, and generally low electrical conductivity concentrations were recorded at high stream levels. Across the DXP area, the pH and electrical conductivity levels were generally suitable for the protection of slightly to moderately disturbed ecosystems.

- Overall water quality indicators were variable and generally not consistent with guideline values developed for the protection of slightly to moderately disturbed ecosystems (ANZECC, 2000); however, the quality was generally comparable to reference data provided by DERM (2009) for relevant catchments in the vicinity of the DXP area.

- According to the mapped Queensland salinity zones, surface water within the Condamine-Culgoa Basin is of moderate to very high salinity.

- Turbidity was generally low during periods of low stream flow in the Condamine River and in the Oakey Creek subcatchment. During periods of high flow, turbidity was more variable but generally higher than low-flow periods.

- Dissolved oxygen concentrations across the area were below the guideline values established for the protection of slightly to moderately disturbed ecosystems and for human consumption. Dissolved oxygen was generally low in surface waters, and this is likely to reflect the non-permanent nature of many streams in the area.

- The nutrients recorded in the rivers within the DXP area were generally above guideline values nominated to protect surface waters from eutrophication. Total nitrogen, total phosphorus, fluoride and sulfate showed generally high variability during periods of low flow, with concentrations stabilising during high flows. Heavy metals (including copper, boron and zinc) in the Condamine River and the Oakey Creek subcatchment were highly variable during periods of low flow, but concentrations were generally low and more stable during periods of high flow.

- Some petroleum hydrocarbon compounds and phenols were detected in selected samples taken from the Condamine-Culgoa Basin during field survey events. In

addition, some petroleum hydrocarbon compounds were detected in selected samples taken from the Border Rivers Basin (at Muri Muri Creek).

- Silty substrates and poorly vegetated, unstable banks were observed in some watercourses; and this may contribute to the high suspended solids and elevated turbidity found in the watercourses. The high suspended solids and turbidity may also contribute to reduced dissolved oxygen concentrations. Elevated total metal concentrations relative to the dissolved metals fraction may also result from high suspended solids.

12.1.2 Surface waters – Wetlands

Three types of wetlands – riverine, lacustrine and palustrine – contribute to habitat diversity in the DXP area. Riverine wetlands are all deepwater habitats within a channel. The channels are naturally or artificially created; they periodically or continuously contain moving water or form a connecting link between two bodies of standing water. Lacustrine wetlands are large, open, water-dominated systems larger than 8 ha. The open lake part of Lake Broadwater is classified as lacustrine. This definition also applies to modified systems (e.g., dams), which possess characteristics similar to lacustrine systems (e.g., deep, standing or slow-moving waters). Palustrine wetlands are primarily vegetated non-channel environments of less than 8 ha. They include billabongs, swamps, bogs, springs and soaks and have more than 30% emergent vegetation. The vegetated swamp surrounding the open water lake at Lake Broadwater is classified as palustrine.

Palustrine and lacustrine wetlands have been identified as forming part of the Condamine River floodplain. Two wetland areas (Lake Broadwater and Long Swamp) are known to support a high number of listed flora species in addition to migratory species and additional listed fauna identified under the China-Australia Migratory Bird Agreement, Japan-Australia Migratory Bird Agreement and Republic of Korea–Australia Migratory Bird Agreement.

One wetland of national significance is located in the DXP area. Lake Broadwater, west of Dalby, is a semi-permanent freshwater lake used for recreational purposes (e.g., skiing, swimming, boating) and is classified as a conservation park. It is located in the Condamine River catchment and is classified as a Category A environmentally sensitive area (ESA). The lake is situated at the edge of the broad valley of the Condamine River and is connected to Wilkie Creek via the Broadwater Overflow and also connected to the Condamine River when in the river is in flood. The site is important in maintaining ecological processes and filtering water, sediment and other pollutants.

12.1.3 Surface waters – Hydrology

The Condamine River flows northwest through the DXP area before flowing east and joining the Balonne River. Watercourses of the DXP area within the Condamine-Culgoa Drainage Basin are dominated by low gradients and hence generally low-energy conditions.

Within the Condamine-Culgoa Basin, average rainfalls in excess of 25 mm in 24 hours may result in stream rises, minor flooding and local traffic disruptions extending downstream. Average catchment rainfalls in excess of 50 mm in 24 hours may cause significant stream rises, with the possibility of moderate to major flooding developing with local traffic disruption. Major floods occur regularly, on an average of every two years, and generally in the months of late spring, summer and autumn.

The Condamine River, which forms the northern headwaters of the Murray-Darling river system, is largely a continuous flowing river that distributes flood flows into such watercourses as Wilkie Creek during large flood events. Most other watercourses in the area are ephemeral, only flowing after rainfall events. Vegetation clearance, construction of weirs and dams, and extraction of water for irrigation has greatly altered the hydrology of the Condamine River. The Condamine River, being the largest watercourse in the region and in a major irrigation area, is monitored extensively with 12 gauging stations located within or near the DXP area. Flows in the Condamine River have been gauged for 63 years and have ranged from 0 m^3 per second (October 1981) to 4,817 m^3 per second (December 2010). Flows in its tributaries have ranged from 0 m^3 per second (multiple dates) to 883 m^3 per second (January 1956).

Flow data from two of DERM's stream flow gauging stations was reviewed and is considered indicative of the hydrology of the Condamine River within the DXP area. Details of the two gauging stations are provided below:

- Brigalow Gauging Station number 422336A, (latitude:-26.90428, longitute:150.783), located downstream of the confluence with Wilkie Creek, at the township of Brigalow (near Wara)

- Loudoun's Bridge Gauging Station number 422332A, (latitude:-27.2251, longitute: 151.8573), located at Loudoun's Bridge, upstream of the confluence with Wilkie Creek.

Figure 17 presents all flow data (excluding data with error codes) from the commencement of flow gauging in 1972 to January 2012 at the Brigalow gauging station (Station ID: 422336A). The figure also presents a near four decade analysis of the river flow (with the exception that the first two years of data in the 1970 to 1980 decade are missing and the last two years of flow data in the latest decade are included in the 2000 to 2012 period shown). The data shows that median flow (50% of samples) in the Condamine River has reduced significantly from over 100 ML/day in the 1970s to 0 ML/day in the 2000 to 2012 period.

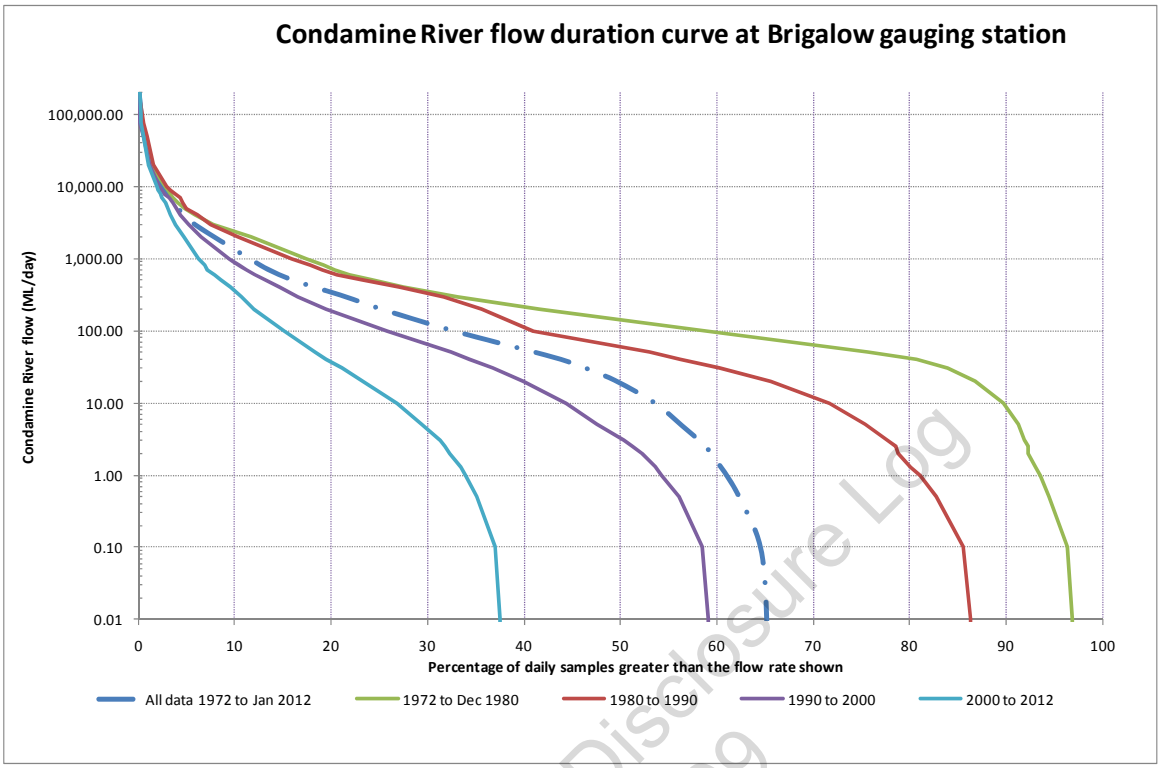


Figure 17: Condamine River flow duration curve at Brigalow gauging station

Figure 18 shows the flow duration curves for each decade (or part of the decade) taken at the Loudoun's bridge stream flow station (Station ID: 422332A). By separating the 2010 – 2012 data from the previous decade (2000 – 2010), the impact of the major drought is evident in this period. The flow in the Condamine River from January 2010 to January 2012 has been greater than the earlier and pre-development flows (indicated by 1969 to 1980 data). A reduction in magnitude and duration of recession flow (lower flows) compared to earlier decades is also evident in the 2010 to 2012 data.

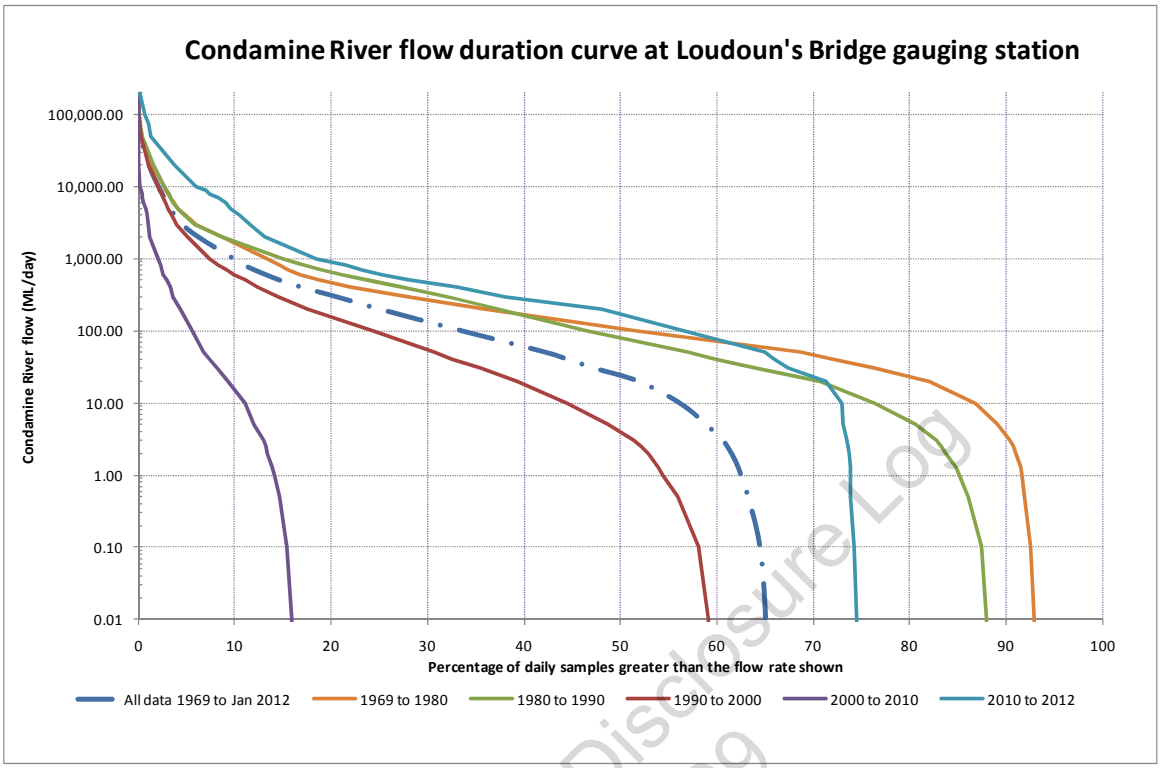


Figure 18: Condamine River flow duration curves at Loudoun's Bridge gauging station

There are no DERM flow gauging stations within the Wilkie Creek catchment, so historical data is not available. To establish representative flow patterns in Wilkie Creek, the Oakey Creek gauging station was used, as the two catchments are of similar size, located within close proximity of each other and contain similar land uses. Oakey Creek catchment has a surface area of 1970km^2, and Wilkie Creek catchment has a surface area of 1410 km^2. The stream flow gauging station used was the Oakey Creek station identification number 422350A at Fairview (latitude:-27.30339444, longitude: 151.27797222). Figure 19 shows that the earliest recorded (1980 to 1990) median flows were about 12 ML/day (in over 70% of samples collected). Flows were notably low in the period from 2000 to 2010, which coincides with a period of major drought, with recovery to a median flow of about 11 ML/day in the latest period of data shown (2010 to 2012).

Additional detail on existing surface water conditions at Wilkie Creek are included in Appendix G.

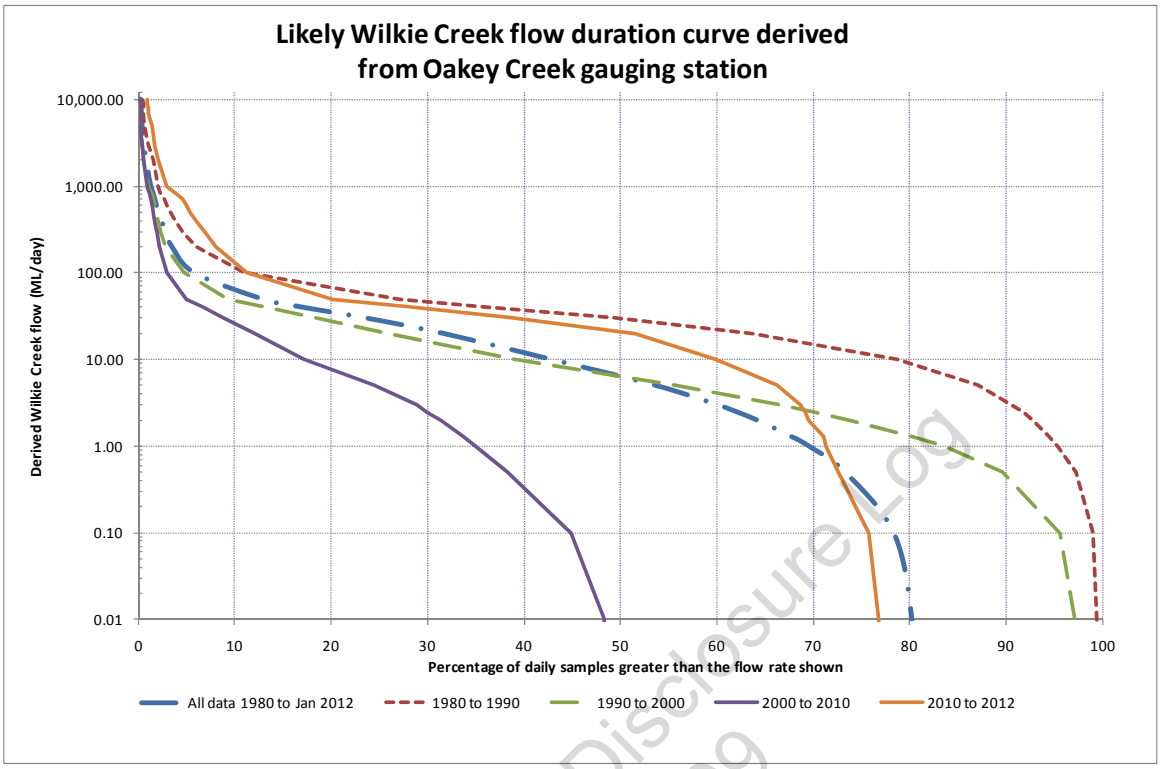


Figure 19: Wilkie Creek flow duration curves from Oakey Creek gauging station

12.1.4 Groundwater

The properties and distribution of groundwater systems within the study area are a reflection of the geological evolution of the region. Sedimentation into the Surat Basin commenced approximately 200 million years ago, resulting in a sedimentary sequence with a maximum thickness of around 2,500 m. The geological sequence contains a series of interbedded groundwater-bearing formations (aquifers) and low-permeability, generally fine-grained formations (aquitards). The DXP area is also located on the eastern margin of the Great Artesian Basin (GAB), which is Australia's largest contiguous groundwater resource. The GAB is made up of a multilayered confined aquifer system and is up to 3,000 m thick.

Each aquifer is characterised by a set of intrinsic hydrogeological parameters, such as porosity, hydraulic conductivity and specific storage. These parameters control how the aquifers behave in the subsurface environment. Four groundwater systems have been identified within the DXP area on the basis of common aquifer characteristics and values, listed below and shown in Figure 20.

- Shallow groundwater system (Condamine Alluvium).
- Intermediate groundwater system (Mooga Sandstone, Gubberamunda Sandstone and Springbok Sandstone).
- Coal seam gas groundwater system (Walloon Coal Measures).
- Deep groundwater system (Hutton Sandstone and Precipice Sandstone)

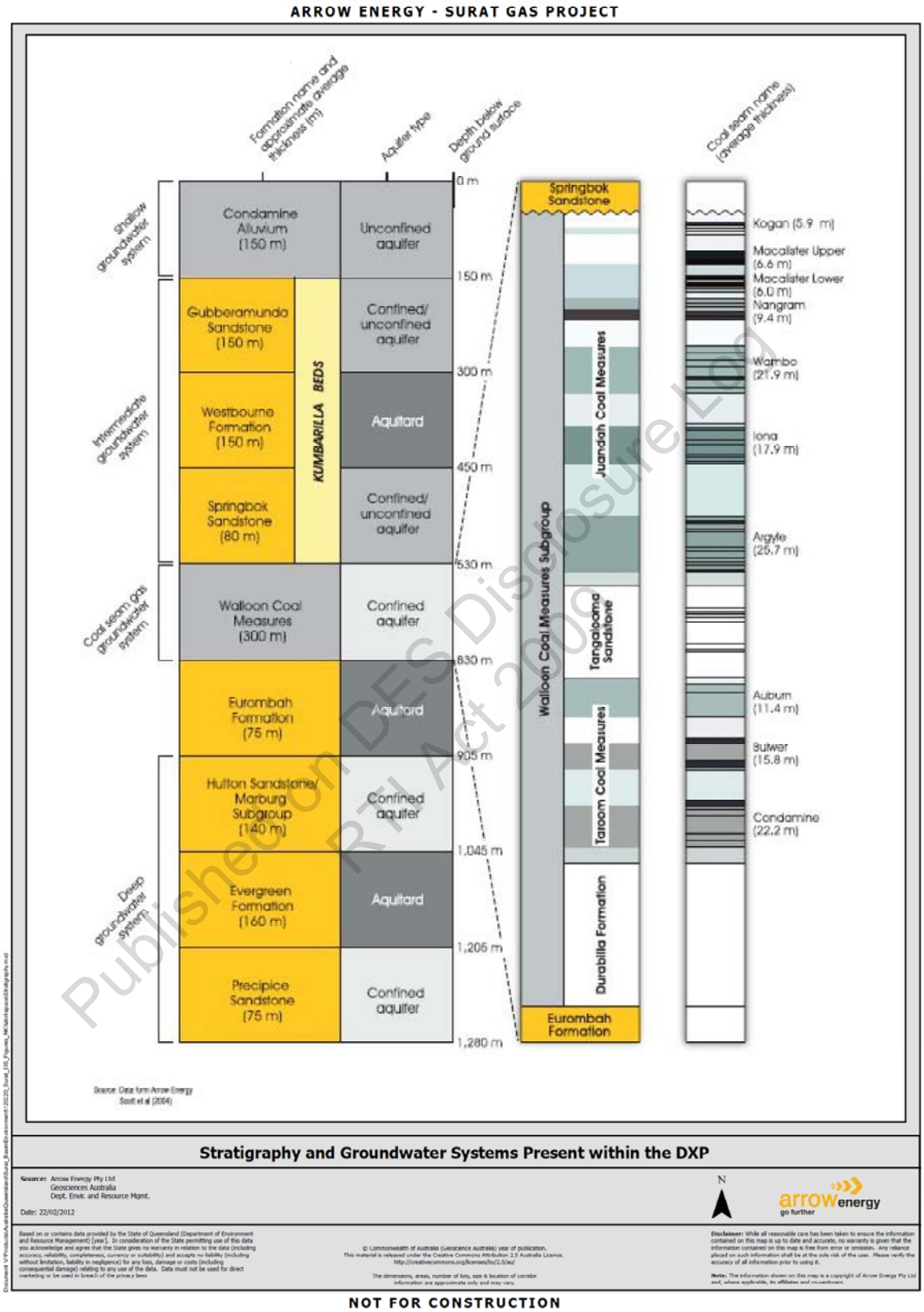


Figure 20: Stratigraphy and Groundwater Systems Present within the DXP

Groundwater-dependent ecosystems rely on groundwater for survival and can potentially include but are not limited to wetlands, vegetation, springs, river baseflows (where groundwater flows from aquifers to watercourses) and cave ecosystems. Ecosystems of the Condamine River are considered to be groundwater-dependent in areas where the Condamine Alluvium aquifer discharges to the Condamine River. While this process is interpreted to be limited (Barnett & Muller, 2008; Hillier, 2010), it is an important interaction between groundwater and surface water within the DXP area.

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

A summary of the groundwater systems within the DXP is presented in Table 28.

Table 28: Summary of Aquifer Characteristics, Groundwater Levels and Quality for Groundwater Users within the DXP

Groundwater System and associated aquifers	General characteristics
Shallow groundwater system: • Condamine Alluvium • Other unconfined aquifers	Groundwater is found extensively DXP area in these unconfined aquifers, with the Condamine Alluvium forming the main unconfined resource aquifer. The Condamine Alluvium overlies the sediments that form the Surat Basin and is predominantly associated with the Condamine River valley. The Condamine Alluvium is up to 150 m thick and comprises unconsolidated clay, silt, sand and gravel deposited through processes associated with the Condamine River and its tributaries. In places, it is interpreted that the Condamine Alluvium is incised into the Walloon Coal Measures (Hillier, 2010). Deposition of a 'hydraulic separation layer' (comprising clay and other low-permeability material) at the base of the Condamine Alluvium may restrict the movement of water between the Condamine Alluvium and Walloon Coal Measures. Current conceptual modelling implies that groundwater movement between the Walloon Coal Measures and overlying aquifers is low where these confining layers are present. These confining layers may be absent beneath some parts of the Condamine Alluvium where the alluvium is incised into the Walloon Coal Measures and the 'hydraulic separation layer' is not present. Shallow aquifers in the DXP area recharge predominantly from surface drainage, in particular from the main branch of the Condamine River (Huxley, 1982; SKM, 1999). The quality of the groundwater within the shallow groundwater system is generally variable and is influenced by surface recharge processes and interactions with deeper groundwater systems. The groundwater is slightly alkaline (average pH of 7.9) and ranges from fresh to very saline. Metal concentrations in the shallow groundwater system also vary, with elevated concentrations of iron and manganese limiting potable use of the water. The variability of the groundwater quality in this system allows a wide variety of uses but can also have limited uses in localised areas. The system is also more prone to modification due to the infiltration of pollutants, nutrients and agricultural chemicals, such as fertilisers, herbicides and pesticides, into the shallow subsurface profile due to land development, settlement and urbanisation. Groundwater in the Condamine Alluvium generally flows to the northwest, and available data indicates that groundwater elevations have declined from 1995 onwards. This decline is likely to relate to historical extraction of groundwater for irrigation, combined with long-term low recharge rates due to low rainfall. The estimated overall

	decline ranges from a few centimetres to 10 m.
Intermediate groundwater system: • Gubberamunda Sandstone • Springbok Sandstone	The Gubberamunda Sandstone is medium to coarse grained, with minor components of siltstone and conglomerate, forming a permeable freshwater aquifer varying in thickness from less than 100 m to greater than 200 m in the central areas of the Surat Basin. The Springbok Sandstone is an aquifer that can produce substantial quantities of groundwater from highly permeable beds, particularly specific coarse-grained units that are informally called the 'Proud Sandstone'. It predominantly contains sandstone beds with some siltstone, mudstone and thin coal seams. This aquifer can often be gas charged due to leakage of coal seam gas from the underlying Walloon Coal Measures. There is limited discrete groundwater quality data available for the Gubberamunda and Springbok Sandstones; however, data is available for the Kumbarilla Beds, a formation that includes these units. For discussion and comparison purposes, data available for the Kumbarilla Beds is used to characterise the quality of the intermediate groundwater system. The available data indicates that groundwater within this system has variable quality, likely to reflect chemical evolution and mineral dissolution within the aquifer units (Herczeg et al., 1991). The groundwater is slightly alkaline (average pH of 8.2) and ranges from fresh to moderately saline. The variability of the groundwater quality in this system allows a wide variety of uses. Discrete groundwater elevation data for the aquifers within the intermediate groundwater system is limited; however, the data available for the Kumbarilla Beds indicates relatively uniform groundwater elevations prior to 1995 and a groundwater flow direction predominantly to the southwest. Limited discrete data for the Gubberamunda Sandstone indicates an overall groundwater flow direction from north to south. Groundwater elevation data available for the Springbok Sandstone shows a general flow direction from northwest to southeast. The dataset available for 1995 to 2009 shows relatively little change in the groundwater elevations over time; however, based on limited data, groundwater elevations have generally declined in the Springbok Sandstone since 1995.
Coal seam gas groundwater system: • Walloon Coal Measures	Groundwater within this system is contained within confined aquifers of the Walloon Coal Measures. Within the DXP area, the Walloon Coal Measures range in thickness from 100 to 500 m and are formally subdivided into the following formations: • Juandah Coal Measures • Tangalooma Sandstone. • Taroom Coal Measures. • Durabilla Formation.

	The Juandah and Taroom Coal Measures consist of coal seams separated by a complex sequence of interbedded siltstones, mudstones and sandstones. The coal tends to occur as discontinuous thin stringers that can have limited lateral extent. Within the DXP area, the Tangalooma Sandstone is very discontinuous and consists of individual sand lenses rather than a consistent sheet, and therefore mapping is limited. The Durabilla Formation is predominantly interbedded mudstone, siltstone and sandstone. In places, this formation is described in conjunction with the Eurombah Formation, forming an aquitard between the Walloon Coal Measures and the underlying Hutton Sandstone/Marburg Subgroup. Groundwater quality information available for the Walloon Coal Measures indicates variable groundwater quality. It is interpreted that this variability is related to chemical evolution and mineral dissolution within the aquifer, together with the assorted rock types within this formation (Herczeg et al., 1991). Groundwater within the Walloon Coal Measures is generally slightly alkaline (average pH of 8.1) and saline. Individual measurements for total dissolved solids, however, range widely from fresh to very saline, with some concentrations approaching seawater salinity. This wide range indicates a corresponding wide range of uses, with limited uses in localised areas. Groundwater levels available for the Walloon Coal Measures show a dominant flow direction to the west, with a secondary flow direction to the east. More extensive data in the Dalby and Millmerran areas is available for the Walloon Coal Measures. These datasets show a variety of responses, with some bores having little variation in groundwater elevations since 1995 and others having more significant reductions. In particular, a monitoring bore installed in the Daandine area provides data from 2005 to 2007, reflecting the effects of initial Arrow coal seam gas activities. Groundwater levels recorded in this bore show a drawdown in the Walloon Coal Measures of nearly 30 m, with the rate of drawdown increasing from 2.5 m/a between 2005 and 2006 to 12.5 m/a between 2006 and 2007.
Deep groundwater system: • Hutton Sandstone • Precipice Sandstone	The deep groundwater system contains confined aquifers characterised as porous, permeable medium- to coarse-grained quartzose sandstones that generate significant groundwater resources in the region. Within the DXP area, the deep groundwater system contains the Hutton Sandstone/Marburg Subgroup and the Precipice Sandstone, separated by the Evergreen Formation, which acts as an aquitard. The Hutton Sandstone/Marburg Subgroup is commonly 120 to 180 m thick and consists of fine- to medium-grained sandstone with some mudstone and siltstone. In the Surat Basin, the Hutton Sandstone grades into the Marburg Subgroup where it transitions into the Clarence-Moreton Basin. The Precipice Sandstone is generally coarse grained at the base, with a finer-grained upper section. It can vary in thickness from 50 m to over 100 m and is an aquifer that can produce significant quantities of high-quality groundwater. Based on limited data, groundwater quality within the Hutton Sandstone is variable but is generally fresh to brackish

	and alkaline (average pH of 8.4). A larger dataset is available for the Marburg Subgroup, which also indicates fresh to moderately saline and alkaline (average pH of 7.8) groundwater with overall variable quality, interpreted to reflect chemical evolution and mineral dissolution within the aquifers (Herczeg et al., 1991). The aquifers that make up the deep groundwater system within the DXP area form part of the GAB. The groundwater quality characteristics available for these aquifers are similar to the overall GAB groundwater quality, and the variability is related to chemical processes that occur as the groundwater migrates away from recharge areas. No specific sites of cultural and spiritual importance related to this groundwater system were identified within the DXP area. However, aquifers in the deep groundwater system have historical cultural significance as artesian groundwater resources. Groundwater from the deep system can also support spiritually important springs, especially in more regional GAB discharge areas outside DXP area. Groundwater from this system is of moderate to high biological importance due to higher water quality than other groundwater systems. Aquifers in the deep groundwater system have the potential to naturally discharge to surface features. They are of high biological importance due to the identified connection between them and mound springs in more regional GAB groundwater discharge areas. Groundwater elevation data available for the Hutton Sandstone shows flow directions from north to south and northwest to northeast. Groundwater flow within the Precipice Sandstone generally originates from exposed recharge areas in the northeast, and subsequent groundwater flow is towards the Dawson River catchment to the southwest. Limited groundwater elevation data is available for the period after 1995, and four bores within the Hutton Sandstone and Marburg Subgroup do not show any significant reduction in groundwater elevations. In summary, the variability in the available baseline groundwater-level data reflects general groundwater variability across the DXP area.

Extraction of groundwater in the Surat Basin commenced prior to the 1900s, resulting in a large-scale decline in groundwater levels within key aquifer units. The distribution of registered bores across the region (including areas outside of the DXP) is shown in Figure 21: Groundwater Resources Accessed by Registered Bores within the region. Data from water bores registered with DERM shows that the majority of registered bores within the DXP area access groundwater within the Condamine Alluvium. The Queensland water entitlements registration database shows that the majority of bores within the DXP area are licensed for use as irrigation water supplies. The approximate location of registered bores and Arrow production wells located within the DXP area is shown in Figure 22.

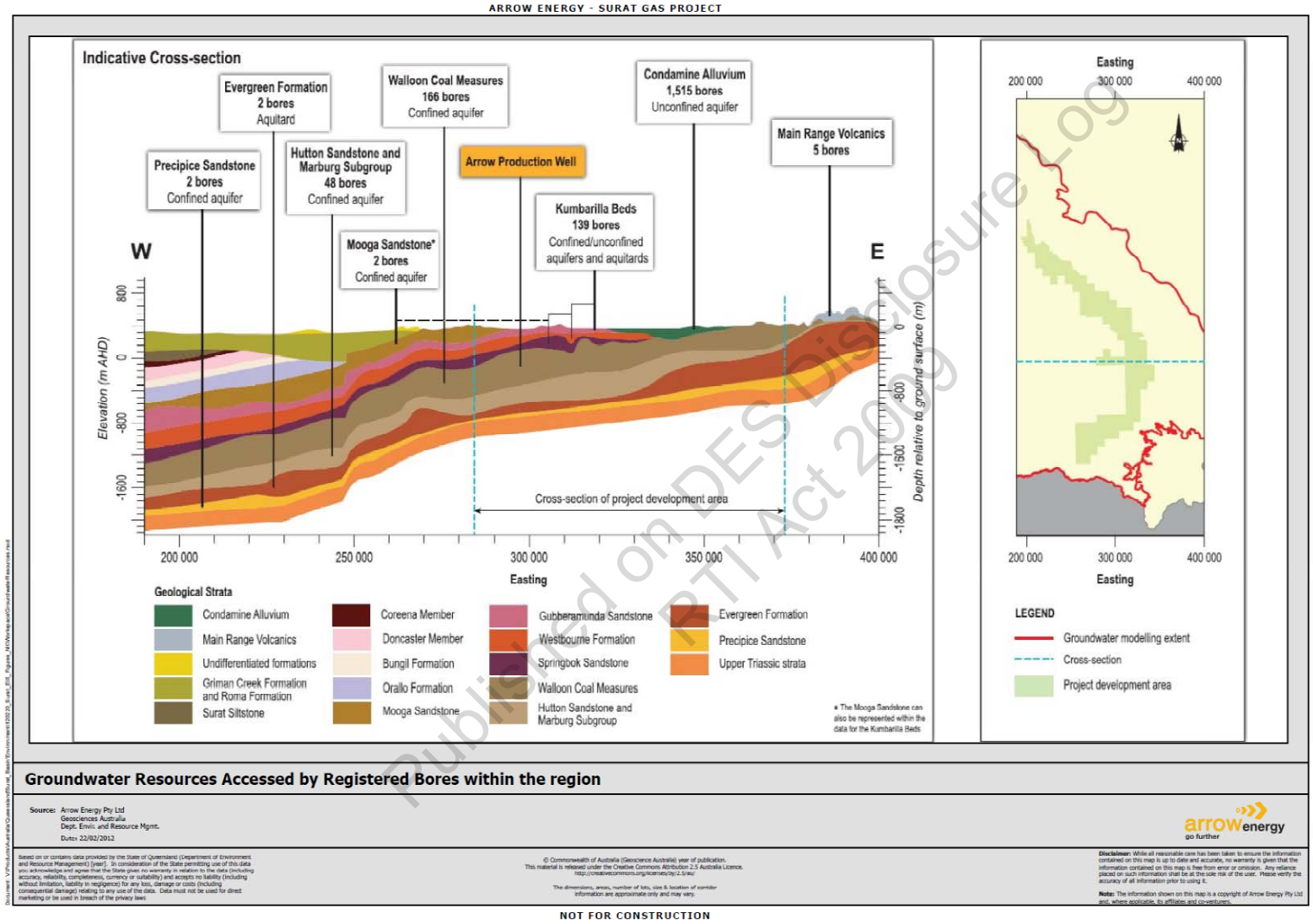


Figure 21: Groundwater Resources Accessed by Registered Bores within the region

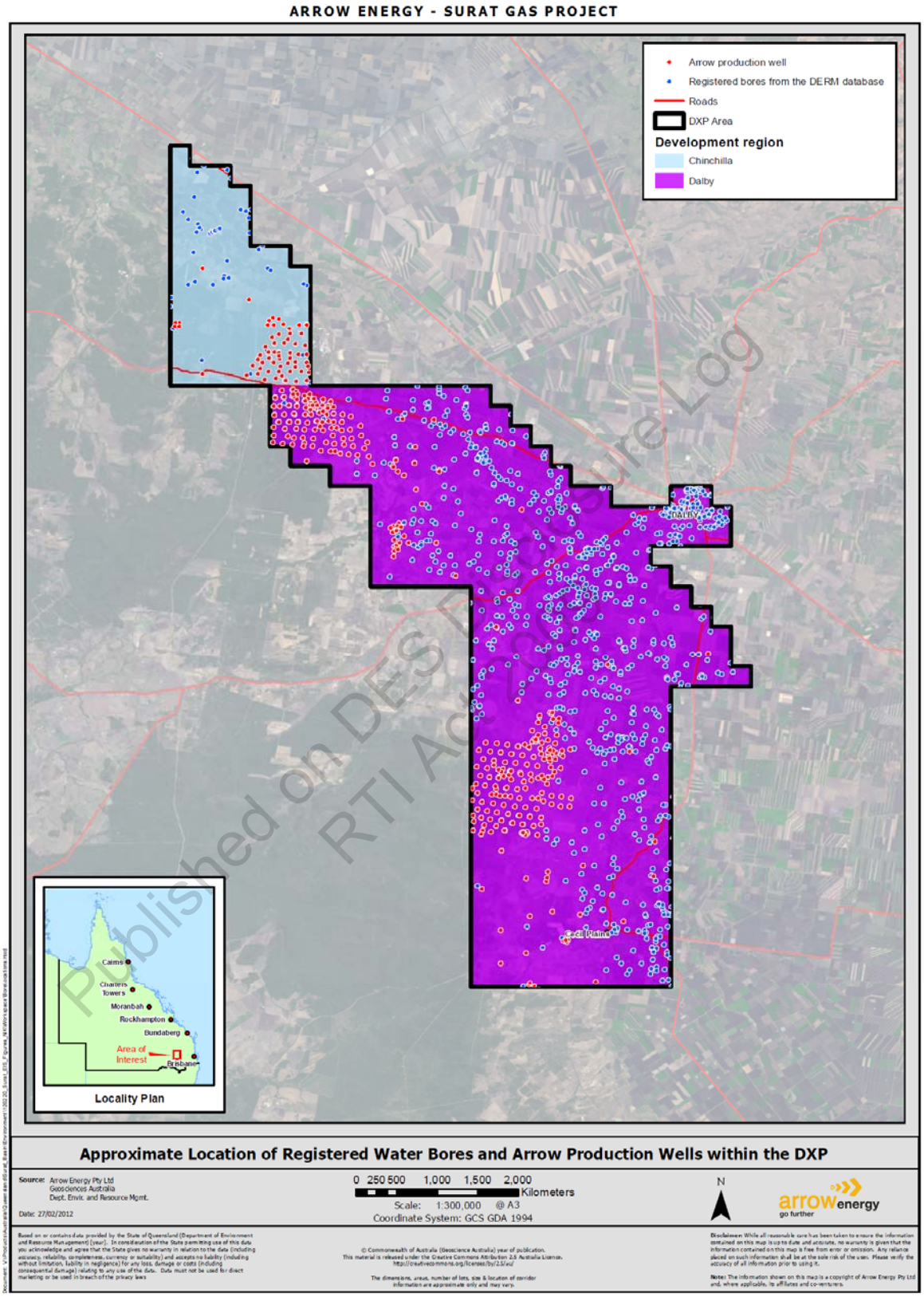


Figure 22: Approximate Location of Registered Water Bores and Arrow Production Wells within the DXP

12.2 ENVIRONMENTAL VALUES

The EP Act provides for the *Environmental Protection (Water) Policy 1997* (EPP Water) to deal specifically with environmental values relating to the quality of the water environment, including groundwater. It provides a framework for identifying the environmental values for waters, and establishing water quality guidelines and objectives to enhance or protect the environmental values. The environmental values as defined in the EPP Water can be grouped as follows:

- Waters are able to support biological environmental values, including:
  - High ecological value waters—the biological integrity of an aquatic ecosystem that is effectively unmodified or highly valued.
  - Slightly disturbed waters—the biological integrity of an aquatic ecosystem that has effectively unmodified biological indicators, but slightly modified physical, chemical or other indicators.
  - Moderately disturbed waters—the biological integrity of an aquatic ecosystem that is adversely affected by human activity to a relatively small but measurable degree.
  - Highly disturbed waters—the biological integrity of an aquatic ecosystem that is measurably degraded and of lower ecological value than waters mentioned above.
- Waters are able to support aesthetic and human interaction values, including:
  - Primary recreational use (i.e. full body contact, e.g. swimming, skiing)
  - Secondary recreational use (i.e. contact other than full body contact, e.g. boating, fishing).
- Waters are able to support consumptive or productive use values, including:
  - Primary industry or agricultural purposes;
  - Agricultural use;
  - Aquaculture use;
  - Producing aquatic foods for human consumption;
  - Drinking water; and
  - Industrial purposes.
- Waters are able to support anthropomorphic values, including:
  - Cultural and spiritual values.

Based on this, and the description of the existing environment above, the surface water environmental values to be enhanced or protected are summarised in Table 29.

Table 29: Values of the existing environment: surface water

Existing Environment	Characteristics Contributing to the Value
Wetlands (Lake Broadwater)	• High degree of ecological intactness. • Valuable aquatic habitat, in particular for: – National and state listed aquatic fauna species of significance, including the Murray cod. – Locally significant species. • Provides important ecological processes for maintaining water quality and filtering sediment and other pollutants.
Wetlands (other)	• Generally high degree of ecological intactness; however, site-specific variation occurs. • Support terrestrial and aquatic species. • Contribute to habitat diversity. • Provide aquatic habitat. • Provide ecological processes for maintaining water quality and filtering sediment and other pollutants.
High-order streams (permanent and semi-permanent watercourses)	• Moderate degree of ecological intactness with clear evidence of disturbance. • Continuous flow that supports benefits of downstream use. • Contribution to habitat diversity. • Drinking water • Sensitivity to disturbance. • Support of recreational activities. • Reduction of flood peaks and extending base flows.
Low-order streams (ephemeral watercourses)	• Provide marginal habitat. • Provide marginal ecological processes.

Each groundwater system identified within the DXP area has a variety of characteristics that define the sustainability of the groundwater resource in terms of quantity and quality. A combination of characteristics that define a groundwater system allow the groundwater to be relied upon in a number of ways, with groundwater values summarised in Table 30.

Table 30: Summary of groundwater values

Groundwater System	Ecological Value	Biological Integrity Able to be Maintained	Potential Consumptive and Productive uses	Cultural and Spiritual Values
Shallow: Condamine Alluvium	The system is more prone to modification due to the infiltration of pollutants, nutrients, and agricultural chemicals, such as fertilisers, herbicides and pesticides, into the shallow subsurface due to land development, settlement, and urbanisation. There are physical connections between this groundwater system and such surface features as the Condamine River.	Where physical connection between this groundwater system and surface features occurs, the groundwater quality is predominantly able to maintain slightly to moderately disturbed ecological systems.	Groundwater from this system has generally low to moderate total dissolved solids concentrations (average of approximately 1,300 mg/L), allowing a wide range of beneficial uses; however, it is predominantly suitable for agricultural use within the DXP area.	No specific sites are identified within the DXP area; however, where baseflow discharge to the Condamine River occurs, the Condamine Alluvium aquifer may indirectly support cultural values associated with the Condamine River.
Intermediate: Mooga Sandstone Gubberamunda Sandstone Springbok Sandstone	The ecological value of the intermediate groundwater system increases with depth, as this generally reflects increased isolation from potentially impacting human processes. There are no known areas of physical connection between this groundwater system and surface features within the DXP area; however, they may exist within the groundwater model extent.	If a physical connection between this groundwater system and surface features exists, the groundwater quality is predominantly able to maintain effectively undisturbed ecological systems and some slightly to moderately disturbed ecological systems.	Based on variable total dissolved solids concentrations (average of approximately 1,400 mg/L), groundwater from this system has a range of uses; however, it is predominantly suitable for agricultural use within the DXP area.	No specific sites are identified within the DXP area.

Summary of groundwater values (cont'd)

Groundwater System	Ecological Value	Biological Integrity Able to be Maintained	Potential Consumptive and Productive uses	Cultural and Spiritual Values
Coal Seam Gas: Walloon Coal Measures	Groundwater from this system is generally considered to be of lower ecological value due to higher salinity, high sodium absorption ratio, and coal formation chemistry. There are no known areas of physical connection between this groundwater system and surface features within the DXP area; however, they may exist within the groundwater model extent.	If a physical connection between this groundwater system and surface features exists, the generally poor groundwater chemistry and salinity would likely fail to support ecological systems.	The aquifers within the coal seam groundwater system are generally considered to be of lower quality due to higher salinity (average total dissolved solids values of approximately 4,600 mg/L) and high sodium absorption ratios. The groundwater is generally suitable for stock watering and production of aquatic food for human consumption.	No specific sites are identified within the DXP area.
Deep: Hutton Sandstone/ Marburg Subgroup Precipice Sandstone	The deep groundwater system is generally considered to be of high ecological value due to lower salinity, isolation from potentially impacting human processes and the identified natural connection between the deep groundwater system and mound spring complexes in more regional Great Artesian Basin groundwater discharge areas. There no known areas of physical connection between this groundwater system and surface features within the DXP area, however, they may exist within the groundwater model extent.	If a physical connection between this groundwater system and surface features exists, groundwater quality from this system is predominantly able to maintain effectively undisturbed ecological systems and some slightly to moderately disturbed ecological systems.	Lower total dissolved solids concentrations (average of approximately 1,900 mg/L for the Hutton Sandstone) allow a wide range of uses; however, groundwater from this system is predominantly suitable for agricultural uses within the DXP area.	No specific sites are identified within the DXP area; however, aquifers in the deep groundwater system have historical cultural significance as artesian supply.

12.3 POTENTIAL IMPACTS ON ENVIRONMENTAL VALUES

12.3.1 Surface Water

Potential impacts to surface water values from associated project activities are described for each project phase.

12.3.1.1 Construction

During construction of wells (exploration and production), gathering lines and production facilities, the following impacts could occur:

- Changes to physical form and diminished water quality from the removal of riparian vegetation and subsequent reduced bank stability and increased erosion and sediment mobilisation.
- Diminished water quality from the removal of terrestrial vegetation leading to increased runoff and sedimentation in the watercourses.
- Changes to hydrology, diminished water quality and changes to physical form from controlled and uncontrolled releases of hydrotest fluids.
- Diminished water quality from spills of hazardous materials or drilling muds.
- Damage to property from placement of infrastructure in floodplains.
- Diminished water quality from earthmoving and soil stockpiling leading to increased sedimentation in watercourses.
- Flooding, changes to physical form and changes to hydrology by placing infrastructure in surface water flow paths.
- Changes in physical form and water quality from pipeline or vehicle watercourse crossings causing bed and bank erosion and subsequent mobilisation of sediment.
- Changes in hydrology due to blockages in streams from pipeline watercourse crossings (open-cut crossings).
- Surface water quality degradation due to contaminated runoff from activities.

12.3.1.2 Operation

During operation of the wells and production facilities, the following impacts could occur:

- Changes to hydrology, diminished water quality and changes to physical form from controlled and uncontrolled releases of coal seam gas water and hydrotest fluids.
- Diminished water quality from increased runoff from compacted areas leading to sedimentation in the watercourses.
- Surface water degradation and injury to people or property from a catastrophic release of a water storage dam.
- Diminished water quality from spills of hazardous materials.
- Damage to property from placement of infrastructure in floodplains.

- Flooding, changes to physical form and changes to hydrology by placing infrastructure in surface water flow paths.
- Changes to hydrology caused by changed surface flow paths.
- Changes to physical form due to scour and generation of sediment at watercourse crossings caused by use and maintenance of access tracks.
- Surface water quality degradation due to contaminated runoff from activities.

12.3.1.3 **Decommissioning**

During decommissioning of wells, gathering lines and production facilities, the following impacts could occur:

- Diminished water quality from spills of hazardous materials.
- Diminished water quality from earthmoving and soil stockpiling leading to increased sedimentation in watercourses.
- Diminished water quality from increased runoff in cleared areas leading to sedimentation in the watercourses.
- Changes to physical form from activities causing sediment movement into watercourses due to the proximity of works to watercourses and wetlands.

12.3.2 Groundwater

Potential impacts to the groundwater values from associated project activities are described for each project phase.

Potential impacts to groundwater that are related to land contamination as a result of disturbance of existing contaminated land or project activities are discussed in Section 7.3.

12.3.2.1 **Construction**

The primary activities that could impact groundwater values are the construction of exploration and production wells and monitoring bores, gathering lines, production facilities and associated infrastructure (e.g., construction camps). These activities have the potential to impact on groundwater values in the following ways:

- Reduced rainwater infiltration and subsequent reductions in aquifer recharge from the surface due to the following:
  - Construction of impervious surface coverings associated with integrated production facilities.
  - Land disturbance activities resulting in reduced porosity and permeability of surface profiles.
- Incomplete or incorrect well installation resulting in interconnection of aquifers and consequential cross-contamination.
- Use of lubricants and drilling fluids during the drilling process resulting in localised contamination of aquifers.

- Leaks and spills at the wellhead during drilling draining and infiltrating into the boreholes leading to contamination of the intersected aquifers.

12.3.2.2 **Operation**

Coal seam gas water will be extracted from the Walloon Coal Measures, so direct impacts to the groundwater levels in this aquifer cannot be avoided. There also are potential indirect impacts to groundwater levels and quality in surrounding groundwater systems as a result of coal seam gas water extraction. This is discussed further below.

In addition to coal seam gas water extraction, other operations activities to be conducted by Arrow have the potential to affect groundwater, such as drilling wells and storing saline water, chemicals and fuels.

12.3.2.3 **Coal Seam Gas Water Extraction**

Depressurisation of the Walloon Coal Measures will lower aquifer pressures, potentially resulting in the following direct impacts:

- Reduced groundwater flow to groundwater-dependent ecosystems or areas of cultural and spiritual importance fed by the Walloon Coal Measures.

- Reduced groundwater supply to existing or future groundwater users accessing groundwater from the Walloon Coal Measures.

The extraction of coal seam gas water from the Walloon Coal Measures has the potential to indirectly impact upon other groundwater systems present within the DXP area. Subsequent depressurisation of adjacent aquifers has the potential to cause indirect aquifer interflow and groundwater drawdown, resulting in the following indirect impacts:

- Diminished groundwater quality in aquifers above and below the Walloon Coal Measures. This relates to groundwater mixing as drawdown in the Walloon Coal Measures induces flow across deeper and shallower aquifers, especially the Springbok and Hutton sandstones.

- Reduced groundwater flow to discharge features or areas of cultural and spiritual importance fed by the adjacent aquifers.

- Reduced groundwater supply to existing or future groundwater users accessing groundwater from the adjacent aquifers.

- Land subsidence and changes to surface water flow regimes and landforms.

Coal seam gas water production across the DXP area will be approximately 2.2 GL/a. These extraction rates are significantly less than the average (22 GL/a) used as the basis for modelling of unmitigated groundwater drawdown impacts as presented in the Surat Gas Project EIS (submitted to DERM in February 2012). The numerical model prepared for the Surat Gas Project EIS takes into account the expected coal seam gas water extracted as part of the DXP. Therefore, the groundwater drawdown predicted in the Surat Gas Project EIS represents an over estimate of what is likely to occur as a result of DXP activities, based on greater extraction over a broader area, and over a longer time period. Groundwater drawdown as a result of coal seam gas water extraction in the DXP area is expected to be an order of magnitude lower than the results of the numerical

model prepared for the Surat Gas Project EIS, with more localised drawdowns together with localised recharge mechanisms aiding recovery in the Walloon Coal Measures and the overlying and underling aquifers.

12.3.2.4 Other Operational Activities

Surface activities during the operations phase of the project that can impact groundwater values are as follows:

- Leaks and spills of chemicals, fuels and oils stored at the surface in association with integrated production facilities may result in contamination of the intersected aquifers.
- Discharges of liquid domestic wastes and effluent to land have the potential to contaminate groundwater systems.

Activities related to the storage, treatment and transfer of coal seam gas water and its by-products during the operations phase of the project have the potential to impact on groundwater values as listed below:

- Seepage or leaks of untreated coal seam gas water and brine from storage facilities have the potential to contaminate the shallow groundwater system.
- Coal seam gas water discharged to streams has the potential to infiltrate the subsurface profile and contaminate the shallow groundwater system.
- Leaks and spills from subsurface infrastructure, e.g., gathering lines, could result in contamination of intersected aquifers.
- Seepage or leaks of coal seam gas water and its by-products from storage facilities (e.g., dam failure) have the potential to alter the shallow groundwater flow direction and associated recharge or discharge patterns.

12.3.2.5 Decommissioning

Potential impacts to groundwater values during decommissioning include incomplete or incorrect well decommissioning that may result in interconnection of aquifers and consequential cross-contamination.

12.4 Management of Potential Impacts to Waters

Arrow's Coal Seam Gas Water Management Strategy (Appendix F) seeks to manage coal seam gas water during the life of the project to minimise the environmental impacts associated with water use and disposal. The conceptual coal seam gas water management strategy identifies the preferred and potential management options for coal seam gas water and associated brine or salt, including treatment, storage, beneficial use and disposal. The distribution of coal seam gas water to the different management options will be continually reviewed as planning for field development evolves and opportunities for beneficial use are further assessed.

12.4.1 Surface Waters

Avoidance, mitigation and management measures have been proposed to achieve the identified environmental and social protection objectives. The primary means by which avoidance is achieved is through design and site selection.

12.4.1.1 Release to Wilkie Creek

As discussed in Section 4.2.2 a preferred water management option is to undertake a controlled release of treated water into Wilkie Creek. The release of treated water as an emergency discharge is currently approved under EA PEN100449509. Arrow has assessed potential impacts associated with controlled releases of treated coal seam gas water to Wilkie Creek. This assessment has informed the management measures and the circumstances under which Arrow will discharge treated coal seam gas water to Wilkie Creek. Further details of the assessment are presented in Appendix G –Daandine Water Release Studies.

12.4.2 Groundwater

The primary mitigation measure for groundwater will involve the application of a hierarchy of management options that form the basis for an adaptive management framework. The adaptive management framework is structured to allow management decisions to be made based on an increased knowledge base developed over time. Groundwater management is also linked to Arrow's coal seam gas water management strategy by way of substitution of groundwater allocations and injection into suitable shallow and deep aquifers.

Currently, Arrow implement a groundwater monitoring program within the DXP area, with regular assessment of physical groundwater parameters (temperature, electrical conductivity, total dissolved solids, dissolved oxygen, pH and salinity) having been conducted since 2006.

Arrow is implementing a groundwater monitoring program for the larger Surat Gas Project, which encompasses the DXP area. This groundwater monitoring program will be used to increase the understanding of the hydrogeology of the Surat Basin, to identify potential impacts of coal seam gas groundwater-related activities, and to provide data for decision making and groundwater modelling. This groundwater monitoring program will include developing a network of groundwater monitoring sites using existing bores (Government and private) and installing additional groundwater monitoring bores in the shallow, intermediate, deep and Walloon Coal Measure groundwater systems. This groundwater monitoring network will consist of sites identified in the Underground Water Impact Report for the Surat Cumulative Management Area and additional sites determined by Arrow. The groundwater monitoring program will be used to fulfil Arrow's obligations under the *Water Act (2000)* and identify Project-related impacts including groundwater abstraction, water storage and water disposal or reuse.

The management of potential impacts to groundwater that are related to land contamination as a result of disturbance of existing contaminated land or the potential to cause land contamination through project activities are discussed in Section 7.

12.4.2.1 Injection Trial

A preferred water management option is the injection of coal seam gas water into aquifers. In order to address the viability of injection as a coal seam gas water management option, two stages of aquifer injection feasibility studies (Arrow 2010, Schlumberger 2009) of deep injection have been undertaken.

Arrow has planned to undertake a 6 month injection trial in the Tipton area. The trial will include the construction and installation of an injection well, water treatment infrastructure and monitoring wells. Details of the Injection Trial Program are provided in Appendix H Injection Trial Program.

If the trial proves injection to be feasible, the design of a full-scale injection system will be conducted, as one component of a portfolio of CSG-water management options for the Surat Gas Project.

12.4.3 Control Strategies

Control strategies for the management of potential impacts on the water environment are presented in Table 31 below.

Table 31: Control Strategies for Potential Impacts to Waters

Environmental Protection Objectives	
Surface Water: • To protect Lake Broadwater Conservation Park. • To avoid or minimise degradation in water quality, impedance of flow and changes to the physical characteristics of watercourses and wetlands. Groundwater: • To minimise impacts due to altered groundwater levels. • To minimise impacts to groundwater quality.	
Environmental Issue	**Control Strategies**
Surface Water	
General	**Planning and design:** • Manage potential impacts on Lake Broadwater Conservation Park (Category A ESA) through implementation of the relevant buffer proposed. • Avoid permanent pools, chains of ponds, and alluvial islands, where practicable, when selecting watercourse crossing points. • Stormwater contact with disturbed areas will be limited by diverting flows away from unsealed ground surfaces to minimise the transport of sediment via stormwater runoff. • When siting facilities, avoid wetlands and consider the following: – Stream processes that may result in channel migration (either over time or as a result of project activities) and areas that are highly

	susceptible to erosion (i.e., dispersive soils). – Downstream values of nearby watercourses or wetlands. – Minimising changes to natural drainage lines and flow paths. – Flooding regimes and areas subject to inundation. • Implement a 100-m buffer zone from the high bank of all watercourses to ensure that no development or clearance occurs within these buffers (other than construction of watercourse crossings for roads, pipelines and discharge infrastructure and associated stream monitoring equipment. • Minimise watercourse crossings, where practicable, during route selection. Where required, select crossing locations to avoid or minimise disturbance to aquatic flora, waterholes, watercourse junctions and watercourses with steep banks. • Develop site-specific management plans for permanent and semi-permanent watercourse crossings detailing construction and environmental management requirements, including consideration of the scour potential of the watercourse. • Implement a protocol for the discharge of coal seam gas water to watercourses in a controlled manner under relevant operational situations, taking the sensitivity of the receiving watercourse into consideration. Conduct discharge events in accordance with specific parameters, including release volumes, flows and duration, and water quality. **Construction:** • Construct watercourse crossings in a manner that minimises sediment release to watercourses, stream bed scouring (e.g., the crossing location will be at low-velocity, straight sections, with the pipeline or road orientated as near to perpendicular to water flow as practicable), obstruction of water flows and disturbance of stream banks and riparian vegetation (i.e., the crossing location will be at a point of low velocity, and straight sections will be targeted, with the pipeline or road orientated as near to perpendicular to water flow as practicable). Avoid, where practicable, the use of rock gabions, as they are unsuited to watercourses of the region. • Develop an erosion and sediment control plan and install and maintain appropriate site-specific controls. • Runoff will be directed through sedimentation basins, straw bales or a constructed wetland to reduce erosion and sediment contamination to waters. • Minimise the disturbance footprint and vegetation clearing. • Clear areas progressively and implement rehabilitation as soon as practicable following construction and decommissioning activities. • Control sediment runoff from stockpiles. • Grade soil away from watercourses. • Design water dams in accordance with relevant legislation and Queensland standards and DERM guidelines. **Operations:** • Maximise beneficial use of coal seam gas water. • Apply appropriate Australian and industry standards and codes of

	practice for the handling of hazardous materials (such as chemicals, fuels and lubricants). • Apply appropriate Australian and industry standards and codes of practice for the design and installation of infrastructure associated with the storage of hazardous materials (such as chemicals, fuels and lubricants).
Changes to physical form.	• Design culverts and drains to maintain flow and prevent headward erosion. • Consider the bank and stream bed stability when siting watercourse crossings and, where practicable, utilise existing stable crossings or locations where bedrock control exists to minimise the risk of erosion and generation of sediment. • Minimise potential impacts on surface waters through implementation of the following measures during construction of watercourse crossings: – Delay clearance of stream banks until the watercourse crossing is due to be constructed, to the greatest extent practicable. Implement appropriate erosion and sediment control measures (e.g., silt fences, sediment basins and erosion berms) on watercourse approaches and banks and ensure prompt completion of construction. – Stockpile watercourse bed material in the watercourse channel adjacent to the construction ROW only when the watercourse is dry, and site the stockpile to avoid impacts on riparian vegetation and in-stream features. – Retain coarse alluvial material from watercourse crossings for backfill armouring over the finer unconsolidated material. – Stabilise and maintain stream banks following watercourse crossings. • Discharge water from project activities at a rate and location that will not result in erosion. Install additional erosion protection measures, including energy dissipation structures, at discharge outlets. • Inspect rehabilitated watercourse channels and banks following significant flow events and undertake remedial works as required.
Changes to hydrology.	• Check for flood warnings or subscribe to flood warning services where relevant during construction of watercourse crossings. • Plan construction of watercourse crossings to occur during periods of low rainfall and low flow, when practicable. • Decommission infrastructure in such a manner that it will not adversely affect overland or flood flows and in accordance with relevant legislation and regulations
Surface water quality degradation.	• Identify strategies to minimise coal seam gas water surface storage and to promote increased efficiency. • Avoid disrupting overland natural flow paths and, where avoidance is not practicable, maintain connectivity of flow in watercourses. • Develop and implement a hydrostatic testing procedure prior to commencement of hydrotest activities that includes but is not limited to the following measures: – Conduct consultation with landowners and relevant regulatory

	authorities prior to sourcing and disposing of hydrotest water. – Avoid or minimise harmful chemical additives and reuse hydrotest water on adjacent pipeline sections where practicable. – Ensure hydrotest water that is discharged or recycled for secondary uses meets relevant statutory water quality guidelines. • Ensure the use of coal seam gas water meets beneficial-use licence conditions. • Minimise potential impacts to surface waters caused by erosion and sedimentation through implementation of the following measures: – Locate soil stockpiles away from watercourses and wetlands to minimise potential for sediment runoff to enter the watercourse or wetland. • Install and maintain diversion drains to divert clean surface runoff water around production facilities and away from construction areas. • Develop and implement incident reporting, emergency response and corrective action systems or procedures. Include systems for reporting, investigation and communications of lessons learned. • Incorporate into an emergency response plan or water management plan procedures for the controlled discharge of coal seam gas water under emergency conditions. Procedures will include water balance modelling, weather monitoring and forecasting, stream flow data, notification and reporting. • Segregate stormwater discharge from potential contaminant process areas. • Establish water quality monitoring stations upstream and downstream of discharge points to watercourses as part of a monitoring program to ensure compliance with environmental authority conditions and relevant standards. • Use coal seam gas water for dust suppression on roads or for construction and operation activities authorised in the environmental authority in accordance with the water quality parameters described in the environmental authority. • Minimise the inventory of hazardous materials stored on site.
Groundwater	
• Reduced flows to groundwater-dependent ecosystems and areas of cultural and spiritual importance. • Reduced groundwater supply to existing or future groundwater users.	**Planning and design:** • Prepare a baseline assessment plan to establish benchmark data in registered third-party bores (where possible) prior to the commencement of Arrow extraction activities in accordance with the Water Act, including the preparation and implementation of a groundwater monitoring and investigation strategy. • Undertake bore assessments of third-party bores (where possible) in accordance with the Water Act, including: – Having the Queensland Water Commission for the Surat Cumulative Management Area identify bores requiring assessment. – Developing make-good agreements that include the outcome of bore assessments and implementation of make-good measures in the event that impaired capacity occurs. • Continue an investigative program that will help quantify the

	connectivity between the Condamine Alluvium and the Walloon Coal Measures. The program will involve: – Monitoring the effects of groundwater extraction in the Walloon Coal Measures on the Condamine Alluvium to estimate horizontal and vertical hydraulic conductivity between the alluvium and the Walloon Coal Measures. – An investigative drilling program that will provide greater definition of the interface between the two units and will evaluate the geological and hydrogeological properties of the material at the interface of the units. – Groundwater chemistry studies to characterise mixing and migration between the units. – Groundwater modelling, utilising the connectivity data obtained through investigative components of the program, to understand important processes in the system and predict potential impacts. • Continue a program of aquifer testing in dedicated groundwater monitoring bores to increase the predictability of aquifer properties and groundwater movement. • Collect relevant geological and hydrogeological data from existing and future production wells, monitoring bores and registered third-party bores (where possible) together with information collated collaboratively with other proponents and regulatory authorities. • Update and calibrate the geological model and the numerical groundwater model with relevant data on an ongoing basis, including: – Aquifer thicknesses and interfaces between formations. – Aquifer properties, e.g., porosity, permeability. – The location of sensitive areas, e.g., groundwater discharge springs. – Observed responses in monitoring bores that reflect aquifer behaviour during coal seam gas extraction. • Utilise the updated geological and numerical groundwater models to: – Make ongoing predictions regarding changes to groundwater levels and groundwater quality as the project develops. – Improve confidence in the understanding of the sensitivity and resilience of the aquifers within the identified groundwater systems. • Perform groundwater modelling simulations to predict impacts on groundwater resources in overlying and underlying aquifers. This information will subsequently be used to evaluate the suitability of these resources for use in make-good measures. • Verify the preferred water management strategy by modelling the effectiveness of substitution and injection (where conducted) in offsetting depressurisation impacts in aquifers. **Construction:** • Construct all coal seam gas production infrastructure in accordance with the standards described in the P&G Act and regulations to that act. • Construct all monitoring bores in accordance with the minimum construction requirements for water bores in Australia (LWBC &

	NMBSC, 2003) and the minimum standards for the construction and reconditioning of water bores that intersect the sediments of artesian basins in Queensland (DERM, 2004). • Ensure well drilling is monitored by a suitably qualified geologist to ensure aquifers are accurately identified for correct well construction. Operations: • Consider injection of coal seam gas water or brine of a suitable quality (if proven technically feasible) into shallow or deep aquifers to offset depressurisation impacts in aquifers. • Manage potential impacts on identified spring complexes by: – Supporting the identification of specific aquifers that serve as a groundwater source for discharge springs. – Assessing springs that are predicted to be subject to unacceptable impacts through the source aquifer. – Developing monitoring and mitigation strategies to avoid or minimise unacceptable impacts. • Implement a well integrity management system during commissioning and operation of production wells. • Minimise impacts of groundwater depressurisation on sensitive areas (e.g., groundwater-dependent ecosystems). • Develop a procedure for investigating the impaired capacity of third-party bores. The investigation will be comprised (but not limited to) the following phased investigation response: – Verify groundwater levels in the nominated bores and investigate groundwater levels and groundwater quality in compliance monitoring bores against established trigger thresholds. – Request bore information and groundwater data from affected parties. – Review and assess data. – Advise bore owners in writing of findings. • If impaired capacity is confirmed (bore can no longer produce quality or quantity of groundwater for the authorised purpose, and the impact is due to coal seam gas activities), implement make-good measures in accordance with the Water Act. • Include where possible make-good measures such as substitution of groundwater allocations of equal or better quality to maintain user supply, deepening of bores, modification of pumps, or supply of groundwater from an alternative source. **Decommissioning:** • Decommission or repair all production wells and monitoring bores, either at the end of their operating life span or in the event of a failed integrity test in accordance with the minimum construction requirements for water bores in Australia (LWBC & NMBSC, 2003) and the P&G Act and regulations to that act. Should production wells be converted into monitoring bores, do so in accordance with relevant regulations

Diminished groundwater quality.	**Planning and design:** • Inspect and observe site locations for the presence of contamination prior to commencement of intrusive activities. • Apply appropriate Australian and industry standards and codes of practice for the handling of hazardous materials (such as chemicals, fuels and lubricants). • Apply appropriate Australian and industry standards and codes of practice for the design and installation of infrastructure associated with the storage of hazardous materials (such as chemicals, fuels and lubricants). • Avoid development on contaminated land through the completion of appropriate register searches and desktop investigations (i.e., avoid land or the contaminated portion of a parcel of land that is listed on the Contaminated Land Register or the Environmental Management Register, where practicable). • Conduct physical investigations on selected parcels of land to influence facility siting decisions on a localised scale (i.e., target the portion of land that is not contaminated by understanding the extent of contamination). • Arrow will enforce a no hydraulic fracturing (fraccing) policy in the DXP area. • Prepare a baseline assessment plan to establish benchmark data in registered third-party bores (where possible) prior to the commencement of Arrow extraction activities in accordance with the Water Act, including the preparation and implementation of a groundwater monitoring and investigation strategy. • Consider local biological, groundwater and surface water conditions when identifying sites for coal seam gas water dams and brine dams. • Consider local groundwater conditions when identifying sites for the installation of buried infrastructure (e.g., gathering lines). **Construction:** • Avoid disturbance of contaminated soil and groundwater when it is identified or observed during intrusive works. • Manage contaminated soil or groundwater that cannot be avoided through physical investigation; manage quantification of the type, severity and extent of contamination; and remediate or manage in accordance with the Queensland Government's Draft Guidelines for the Assessment and Management of Contaminated Land (DE, 1998). • Construct all coal seam gas production infrastructure in accordance with the standards described in the P&G Act 2004 and regulations to that act. • Construct all monitoring bores in accordance with the minimum construction requirements for water bores in Australia (LWBC & NMBSC, 2003) and the minimum standards for the construction and reconditioning of water bores that intersect the sediments of artesian basins in Queensland (DERM, 2004). • Select drilling fluids to minimise potential groundwater impacts. Do not use oil-based drilling fluids. • Ensure well drilling is monitored by a suitably qualified geologist to ensure aquifers are accurately identified for correct well construction.

	• Develop the construction, design and monitoring requirements for new dams (either raw water, treated water or brine dams) and determine the hazard category of the dam, in accordance with the requirements of the most recent version of the Manual for Assessing Hazard Categories and Hydraulic Performance of Dams (DERM, 2011b). Construct the dams under the supervision of a suitably qualified and experienced person in accordance with the relevant DERM schedule of conditions relating to dam design, construction, inspection and mandatory reporting requirements. • Install groundwater monitoring bores near dams as a leak detection measure: – The number of monitoring bores and their location will take into account site-specific hydrogeology, preferential pathways and potential receptors of impacts. – Monitor bores installed near dams will have groundwater levels and relevant water quality parameters monitored on a routine basis. – The number of monitoring bores or associated monitoring frequencies will be increased and further investigation will be triggered where impacts are identified. **Operations:** • Develop and implement emergency response and spill response procedures to minimise any impacts that could occur as a result of releases of hazardous materials or any loss of containment of storage equipment. • Carry out corrective actions immediately upon the identification of any contamination of soil or groundwater that has occurred as a result of project activities. • Incorporate into an emergency response plan or water management plan procedures for the controlled discharge of coal seam gas water under emergency conditions. Procedures will include water balance modelling, weather monitoring and forecasting, stream flow data, notification and reporting. • Store onsite materials in suitable containment systems constructed to industry standards and Australian standards (AS 1940-2004, The Storage and Handling of Flammable and Combustible Liquids (Standards Australia, 2004a), and AS 3780, The Storage and Handling of Corrosive Substances (Standards Australia, 2008), at a minimum. Maintain quality control and quality assurance procedures to monitor volumes and quantities. Bund aboveground storage areas to contain spills. • Connect wastewater and sewerage systems to sewers where locally present. Alternatively, install wastewater treatment or reuse systems in accordance with AS/NZS 1547:2000, On-site Domestic Wastewater Management (Standards Australia, 2000); DERM guideline for managing sewerage infrastructure to reduce overflows and environmental impacts (DERM, 2010b); and Queensland water recycling guidelines (DERM, 2005). • Store and manage all waste materials (domestic and industrial) in accordance with industry regulations and DERM conditions. Use licensed waste management contractors. Conduct audits of disposal

	facilities, disposal permits and onsite operations to ensure adherence to regulations. **Decommissioning:** • Excavate any saline material during rehabilitation of coal seam water dams or brine dams and select an appropriate option for management for the material (e.g., treat for reuse, or dispose of in a registered landfill). • Implement a decommissioning and rehabilitation plan in accordance with the dam design plan. • Decommission or repair all production wells and monitoring bores, either at the end of their operating life span or in the event of a failed integrity test in accordance with the minimum construction requirements for water bores in Australia (LWBC & NMBSC, 2003) and the P&G Act and regulations to that act.
• Altered groundwater flow patterns impacting supply to third-party users, groundwater-dependent ecosystems and areas of cultural and spiritual importance. • Diminished rainwater infiltration and reduced aquifer recharge.	**Planning and design:** • Consider local biological, groundwater and surface water conditions when identifying sites for coal seam gas water dams and brine dams. • Consider local groundwater conditions when identifying sites for the installation of buried infrastructure (e.g., gathering lines). • Avoid unnecessary impervious surface coverings and minimise land footprint and vegetation clearing when designing facilities.
• Land subsidence affecting surface water systems and landforms.	• Address the potential for surface deformation through participation by Arrow in a collaborative study with other proponents using historical and baseline data from the Advanced Land Observation Satellite covering a time-lapse period from January 2007 until January 2011. This will allow a detailed analysis of the region and will enable the analysis of the evolution of measured surface deformation in space and time. The assessment will correlate and calibrate data deliverables (calibrated global map and vector files for measurement points) from the Advanced Land Observation Satellite to show the mean deformation rate, identify areas of large-scale deformation and compare patterns with other information (e.g., geology, basin structure, extraction wells and injection data).

Monitoring Requirements

Surface Water:

- Inspect erosion and sediment control measures following significant rainfall events to ensure effectiveness of measures is maintained.
- Visually inspect physical form and monitor hydrology, turbidity and pH upstream and downstream of crossings immediately prior to, during and after construction of watercourse crossings.
- Routine visual inspections undertaken while carrying out activities in the beds or banks of watercourse, wetland or spring.
- Routinely inspect spill containment controls and spill response kits.
- Measure the volume and quality of treated coal seam gas water released to surface waters on a routine basis in accordance with regulatory requirements and approved release limits.
- Routinely monitor water quality in dams.

Groundwater:

The groundwater monitoring and inspection program is an intrinsic part of the adaptive management framework and requires several aspects, associated with site-specific controls around project infrastructure and more regional monitoring of groundwater levels and groundwater quality associated with Arrow's activities, as listed below:

- Install groundwater monitoring bores near dams as a leak detection measure:
  - The number of monitoring bores and their location will take into account site-specific hydrogeology, preferential pathways and potential receptors of impacts.
  - Monitor bores installed near dams will have groundwater levels and relevant water quality parameters monitored on a routine basis.
  - The number of monitoring bores or associated monitoring frequencies will be increased and further investigation will be triggered where impacts are identified.
- Prepare groundwater monitoring reports in accordance with the EP Act.
- Provide chemical monitoring of contaminated soils and groundwater in relevant monitoring bores.
- Ensure methods used to monitor groundwater levels and quality, together with monitoring frequencies and parameters, are in accordance with approved regulatory standards.
- Develop a structured database to host groundwater data from the project (i.e., groundwater levels and groundwater quality).
- Install an appropriate regional groundwater monitoring network (that satisfies Arrow's obligations as described in the underground water impact reports) to:
  - Establish baseline groundwater level and groundwater quality conditions.
  - Assess natural variation (i.e., seasonal variations) in groundwater levels.
  - Monitor groundwater levels during the operations phase.
  - Monitor groundwater quality during the operations phase.
  - Establish suitable datum levels for each aquifer system.
  - Target sensitive areas where more frequent monitoring and investigation is required (e.g., groundwater-dependent ecosystems).
  - Monitor groundwater drawdown as a result of coal seam gas extraction.
  - Monitor impacts in accordance with the Water Act and regulations.
  - Provide an 'early warning system' that identifies areas potentially impacted by project activities to allow early intervention.
- Comply with inspection and monitoring requirements developed by the Queensland Water Commission in relation to groundwater drawdown and springs.

Performance Indicators

Surface Water:

- No permanent impact to the physical form or hydrology of watercourses as a result of project activities.
- No unauthorised release of contaminants directly or indirectly into watercourses.

Groundwater:

- Groundwater-dependent ecosystems and areas of cultural and spiritual importance are not adversely affected.
- Existing groundwater users are not adversely affected.
- Groundwater quality in aquifers above and below the Walloon Coal Measures is not adversely affected.
- Natural groundwater flow patterns are maintained through use of smallest practicable project footprints.
- No potential impacts related to land subsidence based on the results of any measured surface deformation and subsidence resulting from Arrow activities.

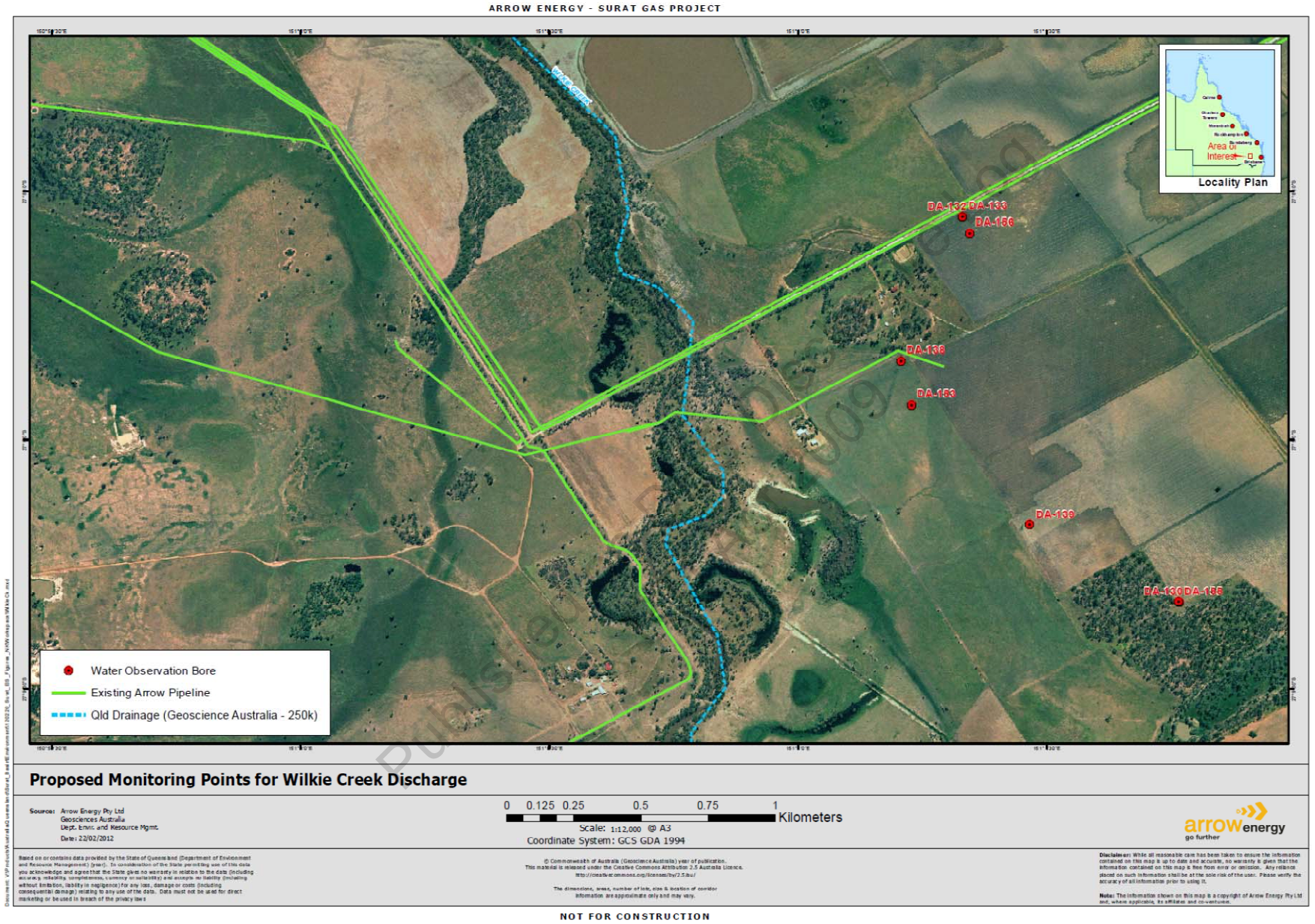


Figure 23: Proposed Monitoring Points for Wilkie Creek Discharge

13. SOCIAL AMENITY

13.1 EXISTING ENVIRONMENT

13.1.1 Land Tenure

The land use in the area is strongly related to the different soil types and topography. Soils within the DXP area are dominated by heavy clays, which form rich agricultural soils around the Condamine River. Agricultural land use within the DXP area ranges from concentrated agriculture on the Condamine River floodplain, where many paddocks have been laser-levelled to achieve effective flood irrigation, through to cattle grazing in more marginal areas located to the north and west. Limited agricultural activity exists in areas of higher elevation and within state forests.

Predominant land uses within the study area are cropping and grazing. The communities have displayed a high level of resilience through prolonged periods of drought, substantial floods and fluctuations in agricultural commodity prices. Detailed information regarding the types of agricultural production that exist is described in Section 7.

Land within the DXP area is predominantly freehold tenure. Crown land comprising conservation reserves and national parks is also present in the region.

13.1.1.1 **Resource Tenure**

The Darling Downs contains deposits of commercially viable coal seam gas, crude oil and coal, with a number of communities in the region benefiting from the development of these energy resources. The extent of petroleum and mining tenures in proximity to the DXP area are shown in Figure 24.

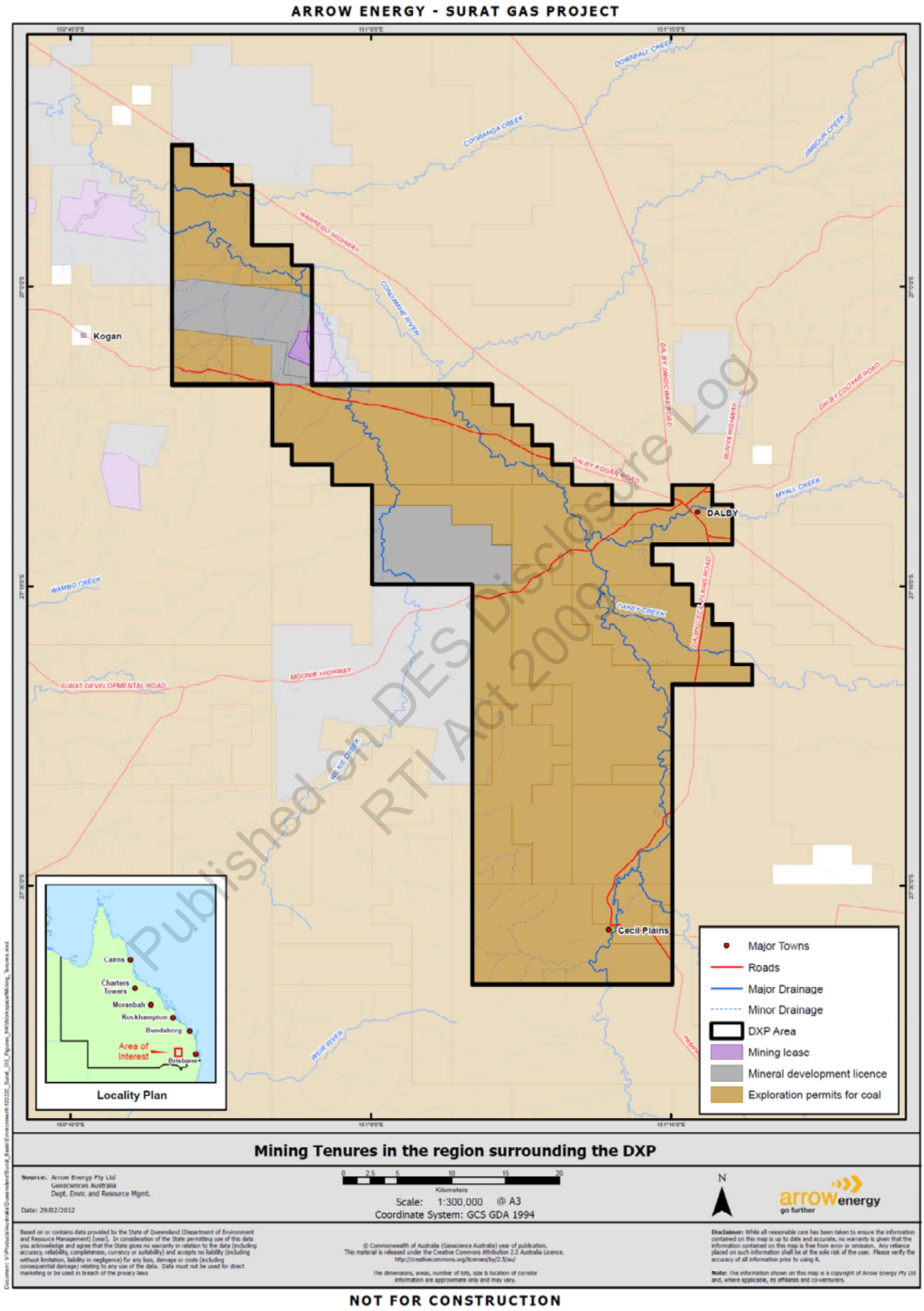


Figure 24: Mining Tenures in the region surrounding the DXP

13.1.2 Population Centres

Population data of towns and cities in and around the DXP area is presented in Table 32.

Table 32: Population of towns and cities in and around the DXP area (Source: CGQ (2010), ABS (2001), ABS (2007))

Community	1881 Population	1921 Population	2001 Population	2006 Population	2006 Population Density
Cecil Plains	-	-	281	235	76 per km^2
Chinchilla	-	3,095	3,376	3,682	265 per km^2
Dalby	1,300	2,395	9,731	9,776	204 per km^2
Miles	-	-	1,196	1,164	277 per km^2
Millmerran	-	1,679	1,250	1,223	260 per km^2
Darling Downs Statistical Division* (including persons living outside towns)	31,480	93,778	-	213,754	2 per km^2

* The Darling Downs Statistical Division comprises the Goondiwindi, Southern Downs, Toowoomba and Western Downs regional councils.

The average population density of two persons per square kilometre across the Darling Downs Statistical Division is indicative of the fact that over half the regional population live on rural properties outside of towns. The size of rural properties within and around the DXP area varies. The average size of land parcels in Chinchilla and Kogan is 40 ha and 95 ha respectively. Dalby and Millmerran have average land parcels of 133 ha and 230 ha respectively.

13.1.3 Nearby Residences

As detailed in Section 2.4 a survey conducted in 2009 identified approximately 400 potential sensitive receptors (buildings) within the DXP area, excluding the townships of Dalby and Cecil Plains.

The identification, ground-truthing and mapping of sensitive receptors within the DXP area is integral to the assessment of potential noise and air quality impacts. As part of environmental and social impact assessments conducted by Coffey Environments (Australia) Pty Ltd (contracted by Arrow Energy), topographic maps, aerial photographs, satellite imagery, local knowledge, and information from stakeholder consultation were all used to identify sensitive receptor locations. Sensitive receptor locations were then ground-truthed in the DXP area by Arrow Energy in October 2009. Sensitive places ground-truthed and mapped within the DXP area are shown in Figure 4.

As illustrated in Figure 4, the potential sensitive receptors are located throughout the DXP area and will consequently be an important consideration when planning project activities.

13.1.4 Landscape and Visual Amenity

The existing environment contains a variety of landscapes, including broad, open, arable plains; elevated native forest; and wooded river valleys. The landscapes have been shaped by variations in geology, soils, landform, vegetation and the settlement and use by people.

Ten landscape character types have been identified within the DXP area on the basis of common landscape elements, attributes and values:

- Landscape Type A: Wooded River Valley.
- Landscape Type B: Settled Arable Plains.
- Landscape Type C: Sodic Transitional Pastures.
- Landscape Type D: Lowland Native Forest.
- Landscape Type E: Elevated Native Forest.
- Landscape Type F: Foothill Plains and Valleys.
- Landscape Type G: Lowland Brigalow Plains.
- Landscape Type H: Terraced Brigalow Farmland.
- Landscape Type I: Forested Steep Hills.
- Landscape Type J: Chromosol Undulating Lowlands.

The visual baseline is described in terms of views from selected representative viewpoints, which correspond to the location of residences, settlements, work places, recreational features, recognised vantage points, tourist trails and roads.

13.1.5 Roads and Transport

Major road and rail networks link the Darling Downs communities with Brisbane and other regional centres. The main highways linking townships within and around the DXP area are the Warrego, Gore and Leichardt Highways. A number of lower order roads link rural areas and communities within the DXP area. A regular passenger rail service connects the region with Brisbane via the Western Line.

The functional road types present within the DXP area include highways, regional connecting roads, rural connecting roads and rural access roads:

- Highway. Highways are high-order roads of a high standard, facilitating connectivity between regional centres.
- Regional Connecting Road. Regional connecting roads are high-order roads of a high standard, facilitating connectivity between townships.
- Rural Connecting Road. Rural connecting roads are lower-order roads facilitating connectivity between higher-order roads.
- Rural Access Road. Rural access roads are low-order roads predominately facilitating access to local uses.

13.1.6 Cultural Heritage

13.1.6.1 Indigenous Cultural Heritage

The existence of Indigenous cultural heritage within an area is generally dependent on the extent of previous Indigenous activity in the area and the extent to which development of the area has disturbed or destroyed Indigenous cultural heritage. Landscape features, combined with knowledge of existing land use and level of disturbance, help to identify areas most likely to contain Indigenous cultural heritage. For example, there is strong potential for Indigenous cultural heritage to exist near watercourses and in forested areas that have not been cleared. It is, however, less likely that evidence of Indigenous cultural heritage remains in disturbed areas, such as cultivated areas, roads, residential communities and industrial developments.

Within the project development area, 372 sites are listed on the Queensland Indigenous Cultural Heritage database. Of these, approximately 60% are stone artefact scatters, with a further 25% being scarred trees. There are extensive ethnohistorical accounts of Indigenous activity in the project development area. Cultural heritage sites and places that are not yet known are likely to be found within the project development area.

One known Indigenous cultural heritage site listed on the Register of the National Estate is located wholly or partially within the DXP area (Table 33).

Table 33: Register of the National Estate listed sites with Indigenous heritage values located within the DXP area

Place Name	Description	Location	Within DXP Area	Register of the National Estate Place ID (Listing Status)
Lake Broadwater Conservation Park	Known to be a particularly important place for Indigenous people, having been used for both residential and ceremonial purposes. Associations with an important creator being (i.e., the Rainbow Serpent) have also been identified.	10 km southwest of Dalby	Yes	18052 (indicative place)

The Bigambul People have registered native title applications that cover part of the project development area.

13.1.6.2 Non-Indigenous Cultural Heritage

Non-Indigenous visitation in the region dates back to the mid-nineteenth century. Since this period, there has been a diverse range of settlement and land uses, resulting in scattered archaeological sites.

Many of the known heritage sites within the DXP area are associated with early settlement and include early pastoral stations, towns, railway camps, schools and churches. Additional sites are associated with transport routes, such as railways, and their associated camps. Pastoralism left its mark in the area with fences, scattered pastoral stations and varied collections of farm machinery.

There is potential for other historic sites and places to exist that have not been found before. Areas most likely to contain previously unknown sites are those associated with major transport routes (particularly the railway lines), along stock routes and old stagecoach routes, as well as river corridors and vermin fences. Areas on disturbed land used for agricultural activities have a very low likelihood of containing intact non-Indigenous cultural heritage sites or artefacts. Non-Indigenous cultural heritage sites that are as yet to be discovered within the DXP area are likely to include artefact sites from grazing and agricultural industries of local heritage value.

13.1.7 Relevant Stakeholders

The following are stakeholders that may have direct or indirect interests in the DXP and the associated petroleum activities:

- State regulatory agencies and relevant government departments including:
  - The Department of Environment and Heritage Protection (DEHP),
  - The Department of Natural Resources and Mines (DNRM);
  - the Department of State Development, Infrastructure and Planning (DSDIP); and
  - the Department of Transport and Main Roads (DTMR);
- Local government – Western Downs Regional Council and Toowoomba Regional Council;
- Operators of existing utilities and infrastructure;
- Landholders and interest groups; and
- Cultural Heritage / Native Title claimants.

Other interested parties may be identified through further assessments and ongoing consultation with existing stakeholders.

13.2 ENVIRONMENTAL VALUES

13.2.1 Land Use

The key industries in the wider region surrounding the project area include agriculture, forestry, fishing, manufacturing and oil and gas exploration and production, as discussed in the following sections.

Agriculture

The Dalby / Chinchilla region supports a wide variety of agricultural practices including grain (wheat, barley, sorghum, cereals, coarse grains, legumes etc) and cotton production. Cattle grazing is also undertaken and Dalby is currently Queensland's largest livestock selling centre.

Oil and Gas Exploration and Production

The Surat Basin holds vast hydrocarbon resources including coal and CSG which are continually being explored, assessed and extracted for energy users on both a local and international scale.

Surat Basin CSG was first used to supply gas to the Swanbank E gas-fired power station (DEEDI, 2012). Production testing of Surat Basin gas started in around 2004, with commercial coal seam gas production commencing in early 2006 from the Kogan North field.

The wider Dalby region is now associated with an expanding oil and gas industry (including exploration, production and gas transmission), and has recognised the potential of this expanding market with businesses in the region diversifying into the supply of components, parts and services for the energy sector (WDRC 2012).

Recreation and Tourism

Recreation and tourism in the broader region is mainly associated with Dalby and its surrounds, where attractions include the Pioneer Park Museum and Heritage Trail, the Warra Heritage Centre, historic Jimbour Station and Winery, and the Jondaryan Woolshed and Station. The surrounding natural areas (including Lake Broadwater Conservation Park and Bunya Mountains National Park) provide opportunities for camping, walking, bird watching and boating.

Forestry

A number of state forests are situated within the broader region surrounding the project area. These state forests are managed by the Queensland Parks and Wildlife Services under the Forestry Act 1959 and are considered biodiversity reservoirs. Activities currently being undertaken in these parks includes timber harvesting; grazing; bee-keeping; quarrying; flora and fauna conservation; cultural heritage; water conservation and recreational activities.

13.2.2 Landscape and Visual Amenity

The visual amenity assessment within the DXP area considered protection of viewpoints from location of residences, settlements, work places, recreational features, recognised vantage points, tourist trails and roads.

13.2.3 Roads and Transport

The road environmental values are the functional road types present within the DXP area. Three key aspects of each functional road type have been identified as important to various users, neighbours and road authorities of the road network:

- Efficiency. Efficiency relates to aspects of the road network that facilitate the efficient operation of the network, e.g., linkages between higher-order roads, overall volumes of traffic and types of intersection.

- Safety. Safety includes aspects of the physical road infrastructure that relate to safety, e.g., bridges, rail crossings, cattle grids, school bus infrastructure and standard of road construction.

- Amenity. Amenity relates to aspects of the experience afforded to the passive participants of the road network (users of adjacent land), e.g., light, dust and noise nuisance due to changes in traffic volumes or road function.

13.2.4 Cultural Heritage

13.2.4.1 Indigenous Cultural Heritage

The environmental values to be protected are associated with either archaeological significance (i.e., including physical evidence) or cultural significance (i.e., of significance to Indigenous peoples for cultural, spiritual or historical reasons). Assets and artefacts in the existing environment include the following:

- Places with identified Indigenous values that are EPBC Act–listed and also included on the Register of the National Estate.
- Places that are included in the Queensland Indigenous Cultural Heritage Database. This database contains only broad information on each site, such as its type, date recorded, general location and Aboriginal party details. The details of many of these sites have been collected during cultural heritage assessments for other projects in the region.
- Places, objects and areas of cultural heritage value identified during previous investigations conducted by Aboriginal parties on behalf of Arrow. Where Aboriginal parties have allowed it, the details of these sites are retained in Arrow's GIS database.
- Places, objects and areas of cultural heritage value that are currently not identified, including those that become known through studies conducted prior to the commencement of construction activities. It is essential that these places, objects and areas of cultural heritage significance that are not yet known be recognised as an environmental value, as there is extensive evidence of the activity of Indigenous peoples across the DXP area and surroundings in terms of archaeological evidence and ethnohistorical accounts.

The value of the assets and artefacts in the environment are determined and attributed by the Indigenous people. It is the link between custom and folklore and spirituality that creates the value in places and in the inanimate objects that remain in the landscape. Table 34 summarises the landscape types and the likelihood that they contain cultural assets and values (as established by Bonhomme Craib & Associates (2009)).

Table 34: Sensitivity of the landscapes in which Indigenous cultural heritage may occur

Landscape Type	Cultural Assets and Values	Likelihood of Cultural Heritage Being Present
Defined waterways (including lagoons) and their immediate tributary areas on sandy or sandy loam soils	• Scarred trees. • Stone and shell scatters. • Axe-grinding grooves. • Burials.	High to very high
Black soil gilgais	• Stone artefacts (high frequencies of 'tools'). • Hearths.	Moderate
Ridges and rocky uplands	• Stone arrangements. • Wells. • Stone artefacts.	Moderate to high

High terraces below 300 m above sea level on duplex or sandy loam soils	• Scarred trees. • Stone artefact scatters.	Moderate
Ridges and escarpments	• Wells. • Quarries. • Bora grounds or stone arrangements.	Moderate to high
High plains above 300 m above sea level away from hydrological features	• Isolated stone artefact or artefacts. • Scarred trees.	Low
Black soil plains (including open floodplain)	• Scarred trees. • Isolated stone artefact or artefacts. • Stone sources and associated flaking.	Low

13.2.4.2 Non-Indigenous Cultural Heritage

Within the DXP area, there are no sites of national significance; however, the Dalby war memorial was formerly registered on the Register of National Estate (until being transferred to the Queensland Heritage Register) and the Boonaraga Cactoblastis Memorial Hall is believed to display national listing qualities.

Six sites with state heritage significance have been identified in the DXP area (refer to Table 35; Figure 25), with one of these also registered with the National Trust of Queensland. All sites are located within the project's town exclusion areas.

Table 35: State listed heritage sites within the DXP area

Heritage Site	Description	Register
Dalby War Memorial and Memorial Park	A memorial to commemorate the contribution made by local residents to World War I. The soldier statue on the memorial is one of only two in Queensland that are cast in bronze.	• Queensland Heritage Register (formerly entered on the Register of National Estate) • National Trust of Queensland
Dalby swimming pool complex	The earliest Olympic-sized pool in Queensland outside Brisbane. Built in 1936.	Queensland Heritage Register
Dalby Town Council Chambers and offices (former)	The third council chambers to be built in the town. Built in 1936.	Queensland Heritage Register
St John's Anglican Church	A brick church built in 1922-1923.	Queensland Heritage Register
Dalby Fire Station	The central portion of the Dalby Fire Station dates from 1935 and includes extensions built in 1963 and 1957. It is the oldest and longest operating fire station in	Queensland Heritage Register

	regional Queensland.	
St Columba's Convent (former)	The convent is a substantial brick and timber building built in 1913 from donations made by parishioners. The convent was designed by local architect George Bernard Roskell. It illustrates the spread of the Catholic Church in regional Queensland and the contribution made by the Sisters of Mercy in its establishment of convents, schools and boarding accommodation. The order occupied St Columba's until 1990.	Queensland Heritage Register

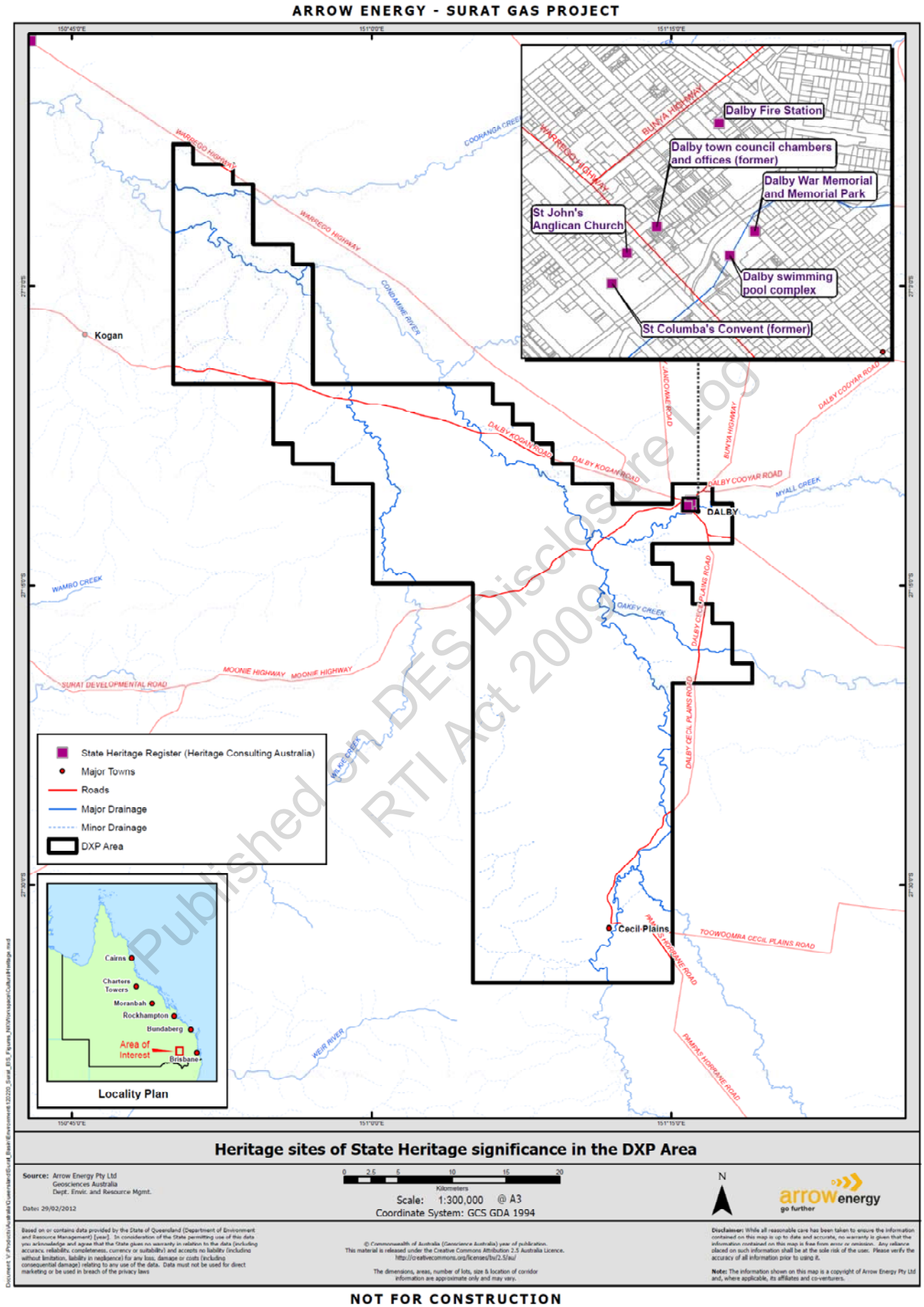


Figure 25: Heritage sites of State Heritage significance in the DXP Area

13.3 POTENTIAL IMPACTS ON ENVIRONMENTAL VALUES

13.3.1.1 Community Impacts

The stakeholder group most likely to be impacted by proposed project activities will be landholders within the DXP area and surrounding local communities who may be indirectly impacted through increased traffic and disruption to access routes. Arrow continues to undertake consultation with affected landowners as detailed project planning progresses, so as to consider all aspects of the property, including the landholder's business activities. Arrow is committed to working with landholders to establish voluntary access agreements and to reach agreement on compensation arrangements and to ensure that all potentially adverse project impacts are avoided or mitigated to the satisfaction of all parties.

The project may result in increased traffic volumes and increased proportions of heavy vehicle traffic (i.e. trucks) together with potential deterioration of road infrastructure not designed for regular industrial and heavy vehicle traffic. A cumulative effect on the local council roads, due to the expansion of the energy industry throughout the region, is also likely.

Two additional impacts may include:

- Heavy goods transport and other project related vehicles may be required to utilise school bus routes as a result of the dispersed nature of the rural development and the CSG infrastructure; and,
- Increased petroleum plant, vehicles and equipment may be required to travel through townships and residential areas as many of the roads in the region do not bypass the townships.

Arrow will develop Traffic Management Plans (TMP) where required in order to minimise the impact on local communities. The TMP will include arrangements for activities such as short-term lane closures caused by construction activities, restricted traffic routes, and preferred times for travel and will be completed in consultation with relevant regulatory authorities (including local council and the Department of Transport and Main Roads) and will be undertaken well in advance of any planned activities.

Aesthetic impacts to the community will generally be temporary and predominantly confined to the construction phase. Long-term above-ground infrastructure associated with exploration activities is typically small and unobtrusive. Large infrastructure such as dams, will be sighted in consultation with landholders and will be designed to maintain visual amenity as far as practicable. Arrow has also recently undertaken extensive consultation with the community throughout the Surat Basin in an effort to discuss and address landholder concerns in relation to Arrow's operations in the area.

Arrow is committed to protecting and promoting the social and environmental values of the communities in which it works. By engaging with community groups, landholders, Indigenous groups, local businesses and Governments at all levels, Arrow can successfully work towards a plan for a sustainable and shared future. Accordingly, Arrow is in the process of building resources for landholder, environmental and community teams and activities to achieve this goal. Specific fact

sheets have also been developed to further explain Arrow's activities and are available on the Arrow website (http://www.arrowenergy.com.au).

To assist in Arrow's goal of a shared future with communities, Arrow has developed the Brighter Futures Community Investment Program, designed to enhance to the quality of life in the communities in which Arrow operates. Arrow will provide financial support for projects and initiatives that will make a credible and long-term contribution to local communities in the focus areas of health and safety, education and the environment.

13.3.2 Landscape and Visual Amenity

The primary construction activity that could impact landscape and visual amenity values is the construction of exploration and production wells, gathering lines, production facilities and associated infrastructure (e.g., construction camps). This activity will involve:

- Excavation, trenching, drilling, earthmoving, vegetation clearance or trimming, construction of infrastructure and temporary lighting that will disrupt landscape character, views and visual amenity.
- The presence of a workforce, construction camps and associated transport (e.g., large trucks, four-wheel-drive vehicles, graders, excavators and tractors).

The impact of the activity will vary depending on the nature of the construction activity (e.g., construction of a production well versus construction of a production facility), type of landscape and location of visual receptors.

During operations, the following project activities could impact upon landscape and visual amenity values:

- The presence and operation of production wells, gathering lines, power reticulation, production facilities and associated infrastructure that will disrupt landscape character, views and visual amenity.
- The presence of operation and maintenance crews, and associated transport.

The nature of the impact will largely be determined by the size of the infrastructure and the type of landscape.

Impacts upon landscape and visual amenity values during decommissioning include:

- Decommissioning, disassembly and removal of production wells, gathering lines, power reticulation, production facilities and associated infrastructure that will disrupt landscape character, views and visual amenity.
- The presence of a workforce and associated accommodation and transport (e.g., large trucks, four-wheel-drive vehicles, graders, excavators and tractors).

Waste generated in each project phase could also potentially impact landscape and visual amenity if not appropriately managed.

13.3.3 Roads and Infrastructure

Increases in traffic volumes across the road network within the DXP area can potentially impact the efficiency, safety and amenity of roads. The key traffic-generating activities that will occur during each phase of the project are as follows:

- Construction. Haulage of materials and equipment to depots and distribution from depots to works sites within the DXP area, installation of production wells, gas and water gathering infrastructure, construction of production facilities, roads to production facilities, dams associated with production facilities and construction camps.
- Operations. Operation and maintenance of well sites, gathering infrastructure and production facilities.
- Decommissioning. Decommissioning and rehabilitation of well sites, gathering infrastructure and production facilities.

Due to the staged development approach, there will be points in time when the construction, operations and decommissioning phases will be occurring concurrently across the DXP area.

Highways in the DXP area are built and operated at a standard that is likely to accommodate changed traffic conditions. Lower-order roads (rural connecting roads and rural access roads) are constructed for and operate with lower traffic volumes than higher-order roads, and they exhibit higher sensitivity to increases in traffic volumes.

13.3.4 Cultural Heritage

13.3.4.1 Indigenous Cultural Heritage

Cultural Heritage will be managed in accordance with the relevant management tools and cultural heritage agreements with the Aboriginal Party. Potential impacts on Indigenous cultural heritage values are considered to be most significantly associated with construction activities and, to a lesser extent, operations and, to an even lesser extent, decommissioning activities. Clearing activities and ground disturbance associated with the construction of the project have the potential to impact on known and unknown Indigenous cultural heritage, places, objects and evidence. Without the implementation of appropriate management controls, project activities could:

- Destroy, damage or disturb objects of physical heritage (i.e., archaeological evidence) in the landscape.
- Encroach upon or disturb places of cultural significance to Indigenous persons.

Arrow will uphold a firm commitment to the protection of cultural heritage values throughout all project phases.

13.3.4.2 Non-Indigenous Cultural Heritage

Project development will potentially impact upon non-Indigenous cultural heritage sites through direct ground disturbance activities and indirect disturbance through encroachment on sites during construction, operations and decommissioning.

13.4 MANAGEMENT OF POTENTIAL IMPACTS

13.4.1 Control Strategies

Control strategies for the management of potential impacts on the social environment are presented in Table 36 below.

Table 36: Control Strategies Relating to the Management of Impacts to the Social Environment

Environmental Protection Objectives	
Indigenous and non-Indigenous Cultural Heritage: • To avoid or minimise and manage adverse impacts from project activities on known and unknown Indigenous cultural heritage sites and objects. • To retain a documented record of the Indigenous cultural heritage that is found through the course of the project so that the history of the area is preserved for future generations. • To avoid or minimise disturbance from project-related activities to non- Indigenous cultural heritage sites and artefacts. *Roads and Transport:* • To minimise potential impacts to road amenity, safety and efficiency from project-generated traffic and transport. *Landscape and Visual:* • To reduce short-term and long-term visual impacts on sensitive receptors.	
Environmental Issue	**Control Strategies**
Indigenous and non-Indigenous Cultural Heritage	
• Accidental destruction, damage or disturbance of objects of physical heritage in the landscape. • Encroachment upon or disturbance of places of cultural significance to Indigenous persons during the course of construction or routine operations.	• Prepare CHMPs or equivalent agreements in accordance with the provisions of the Aboriginal Cultural Heritage Act 2003. • Complete comprehensive initial cultural heritage assessments where disturbance is proposed (noting that this will be staged in line with proposed development schedules), with direct input from relevant Aboriginal parties. • Assess the results of the initial cultural heritage assessments in collaboration with the Aboriginal parties and develop a program for the management of all significant Aboriginal areas and objects to be affected by the project. Include management measures required prior to construction and those required throughout the life of the project. • Ensure places of Aboriginal cultural heritage significance are considered during detailed design. Ensure that operations gives effect to the avoidance principle as enunciated in the *Aboriginal Cultural Heritage Act 2003*. • Maintain a GIS database of sites of Indigenous cultural heritage that are known or found during the course of investigations and works (where Aboriginal parties allow the listing of the sites). • Obtain all necessary permits and approvals prior to the commencement of works. • Ensure site inductions provide cultural heritage awareness for places and objects (to avoid) and the appropriate procedures to follow should there be any new discoveries.
• Accidental destruction,	• Avoid known cultural heritage sites, where practicable, through site

damage or disturbance to non-Indigenous cultural heritage sites and artefacts. • Encroachment on non-Indigenous cultural sites during the course of routine operations.	selection. • Implement a 'chance finds' procedure for the discovery of unknown sites during construction as part of the cultural heritage management plan. This should include a stop work requirement on initial discovery, appropriate reporting and recording, and such management measures as avoidance, salvage or destruction. • Develop a cultural heritage management plan in consultation with the Queensland Heritage Office prior to commencement of ground disturbance works that will mitigate and manage potential impacts on non-Indigenous cultural heritage sites. • Conduct preconstruction clearance surveys of sites to identify the presence of heritage sites. • Develop site-specific cultural heritage management plans in consultation with the Queensland Heritage Office should construction be planned within 100 m of listed heritage sites. • Consult with the local community regarding the management of threatened historic sites and places. • Incorporate cultural heritage awareness into site induction procedures, including information on heritage values of the region, legal obligations and implementation of the 'chance finds' procedure. • Record and report unknown sites identified during construction as chance finds. The cultural heritage management plan will include all measures for managing the discovery of chance finds. • Notify the Queensland Heritage Office if any cultural heritage sites or items of significance are uncovered during construction. • Undertake archaeological assessment by a qualified heritage practitioner if cultural heritage sites or artefacts are uncovered during construction. • Maintain a database of all sites where non-Indigenous cultural heritage is known or found during the course of investigations and works. • Take particular care when working in those areas where significant heritage places are located within 500 m of proposed wells, pipelines or other infrastructure.
Roads and Transport	
Increases in traffic volumes across the road network within the DXP area can potentially impact the efficiency, safety and amenity of roads.	**Planning and design:** • Assess and identify works required to manage the increased traffic volumes and road safety issues associated with the project in road use management plans prepared and regularly reviewed in consultation with the relevant council or the Department of Transport and Main Roads. • Assess and identify the need to upgrade unsealed roads or widen sealed roads where project activities and traffic will create road safety issues. Such works will be done in consultation with the relevant council (if a local government road) or DTMR (if a state road). • Undertake threshold assessments to determine whether upgrading of rail crossings is warranted. • Implement driver training and fatigue awareness for employees and

	contractors. • Implement an in-vehicle monitoring system for project vehicles. • Schedule roster changes to avoid peak traffic times. • Develop project logistics plans to provide safe movement of people and materials, as well as to minimise traffic volumes. • Develop journey management plans in consideration of high-risk roads. • Use heavy-vehicle routes that avoid unsuitable bridges. **Construction, Operations and Decommissioning:** • Where assessed necessary, provide protected turning lanes for entry to permanent facilities to address road safety issues. • Ensure access driveways to project facilities and infrastructure have appropriate sight distances. • Implement traffic controls, including signage (e.g., reduced speed limits, warning signs) and restrictions of movements (e.g., no travel during school bus pick-up and drop-off times). • Maintain the integrity of private roads and tracks and minimise dust generation, where appropriate, in consultation with relevant landowners and council. • Confine project traffic to designated roads and access tracks, where practicable. • Implement traffic controls, including signage (e.g., reduced speed limits, warning signs) and restrictions of movements (e.g., no travel during school bus pick-up and drop-off times). • Limit project traffic on school bus routes during pick-up and drop-off times on school days or install appropriate school bus infrastructure, e.g., signage or pull-over areas where necessary. • Make workers aware of school bus routes, as well as typical pick-up and drop-off times in the vicinity of the work sites. • Coordinate with local law enforcement for movement of heavy or oversized loads. • Implement journey management plans. • Manage project-related activities in the vicinity of existing stock routes in accordance with the *Land Protection (Pest and Stock Route Management) Act 2002.*
Landscape and Visual	
Changes in landscape character.	• Site each production facility in the landscape of lowest sensitivity, where practicable, such as next to existing industrial developments or existing coal seam gas facilities. • Hide or screen production facilities using natural landscape features or planted native vegetation barriers, where appropriate. Avoid removal of mature trees and other woodland features that screen views to facilities. Establish screening barriers using endemic species in advance of construction of the facilities. • Where it is not practicable to screen or integrate a facility into the landscape, consider designing the facility to be a feature in the landscape, taking into consideration the form, texture and arrangement of buildings and structures.

	• When clearing vegetation, seek to avoid creating gaps in stands or patches and to avoid isolating parcels of remnant vegetation from more continuous tracts. • Minimise the disturbance footprint and vegetation clearing. • Maintain the integrity of private roads and tracks and minimise dust generation, where appropriate, in consultation with relevant landowners and council. • Use existing roads and tracks, where practicable. • Where feasible, target dry weather periods when undertaking construction in sensitive landscape areas (e.g., waterway crossings) to minimise visual impacts due to sedimentation and erosion. • Clear areas progressively and implement rehabilitation as soon as practicable following construction and decommissioning activities. • Utilise landscape features and contours, where practicable, to integrate linear infrastructure (access tracks, gathering lines) into the landscape. • Minimise the width of roads and tracks. • Develop an erosion and sediment control plan and install and maintain appropriate site-specific controls. • Remove surface infrastructure and rehabilitate disturbed areas as soon as practicable to predisturbance landscape characteristics or consult with landowners regarding reinstatement objectives.
Diminished visual amenity.	• Use shrouded, downcast lighting to minimise spill and restrict it to the minimum required for safety and security. Design lighting in accordance with AS 4282-1997, Control of the Obtrusive Effects of Outdoor Lighting (Standards Australia, 1997). • Co-locate facilities where practicable and design infrastructure layouts to minimise the footprint (taking into consideration the elements that contribute to landscape character) to reduce visibility of the facilities. • Avoid visually sensitive locations and landscapes when siting facilities, where practicable. Seek backdrops when siting facilities to protect the skyline in distant views. Avoid siting facilities within view of sensitive viewpoints, particularly the bird hide and camping area at Lake Broadwater, expansive views from the Cunningham Highway, towns, schools and private residences. • When siting production facilities, maintain the maximum distance practicable from, and minimise visual disturbance to, the most sensitive visual receptors. Seek to maintain at least 500 m separation from sensitive viewpoints, particularly tourist trails, major roads, residences and built-up areas. • Consult with potentially impacted visual receptors (landowners and neighbours) in locating facilities. Seek to reduce the form and shape of facilities visible by landowners and residents. • Conduct planned maintenance flaring during daylight hours to minimise light spill, where practicable. • Where practicable, plan the movement of equipment and materials during times of least visual impact (i.e., work day start and end). • Locate topsoil and spoil mounds in visually unobtrusive locations, where practicable.

	• Minimise construction time near sensitive visual receptors. • Implement dust suppression measures for roads and construction sites to ensure that dust does not cause a nuisance. • Maintain visual amenity controls used to reduce landscape and visual impacts. Replace lost trees or shrubs in screening barriers to ensure they establish and maintain an effective barrier.

Monitoring Requirements

Indigenous and non-Indigenous Cultural Heritage:

- Inspect known Indigenous sites identified as having the potential for being impacted by the project and subsequently acknowledged for avoidance, in accordance with the relevant approval and permit conditions including the cultural heritage management plan.
- Inspect known non-Indigenous sites identified as having the potential for being impacted by the project and subsequently acknowledged for avoidance, in accordance with the relevant approval and permit conditions including the cultural heritage management plan.

Roads and Transport:

- Routinely monitor integrity and amenity on project-related roads.
- Monitor compliance with the project's road safety requirements through regular review of reports generated by the in-vehicle monitoring system.
- Conduct regular safety inspections of project vehicles.

Landscape and Visual:

- Inspect erosion and sediment control measures following rainfall events to ensure effectiveness of measures is maintained.

Performance Indicators

Indigenous and non-Indigenous Cultural Heritage:

- Compliance with the cultural heritage management plans developed for the project.

Roads and Transport:

- No permanent disruption to road efficiency.
- No third-party traffic-related incidents associated with the project.
- No net loss to road amenity.

Landscape and Visual:

- Compliance with design specifications (which will aim to integrate facilities and associated infrastructure into the landscape setting).

14. REHABILITATION

The timing and works undertaken as part of rehabilitation activities will be dependent on the activity type and the stage of the project. Some project activities such as seismic surveys and drilling are temporary in nature, enabling preliminary rehabilitation to be undertaken once the activity is completed. Longer term infrastructure that is present for the duration of the project will be subject to site specific decommissioning and rehabilitation plans developed in accordance with any regulatory requirements of the day and in discussion with the landholder.

Rehabilitation objectives can be specific to each individual site, however as a minimum Arrow shall ensure that each disturbance is rehabilitated to be:

- Safe to humans, wildlife and domestic animals.
- Non-polluting.
- Stable (landforms).
- Able to sustain an agreed land use.

Rehabilitation objectives are achieved by addressing potential environmental impacts that may arise from the future site use by containing and mitigating any contaminants or pollutants. Rehabilitated sites will require ongoing maintenance until such time that land stabilisation has occurred and the area is self-sustaining and/or is suitable for its intended use (e.g. cropping or grazing), and meeting criteria with environmental authority conditions

Management of site rehabilitation for areas disturbed from petroleum activities including dams, well sites, pipelines, seismic survey lines, tracks, roads and associated infrastructure is detailed in the Arrow 99-V-PR-0015 Rehabilitation Procedure, located in Appendix D. In addition to this procedure, Table 37 provides an overview of key rehabilitation activities for different types of infrastructure and activities proposed to be undertaken in the DXP area.

Table 37: Overview of Typical Rehabilitation Methods for Common Site Infrastructure

Environmental Protection Objectives	
• Ensure the site is safe for humans and animals. • Prevent impact to soils, surface water and groundwater. • Provide a stable landform. • Create a final state that can support an agreed land use and is compatible with surrounding land use.	
Petroleum Activity Feature	**Control Strategies**
Production wells and monitoring bores	• Infrastructure decommissioned in accordance with the relevant regulatory standards to prevent gas and water leakage. • Rehabilitation of Arrow sites conducted in accordance with the Arrow Rehabilitation Procedure (99-V-PR-0015). • For active production well sites, initial landform reconstruction, topsoil replacement, and revegetation, completed outside the wellhead fence enclosure.

	• Petroleum-related infrastructure isolated, drained, purged and removed from site. • Non-petroleum related infrastructure may remain on site if agreed with landowner and DEHP. • Statutory signposts installed to mark the location of decommissioned wells. • A stable landform with a self-sustaining vegetation cover of appropriate species composition established to enable natural vegetation progression and minimal weed invasion.
Gas and water gathering systems	• Wells decommissioned in accordance with the relevant regulatory standards to prevent groundwater mixing and future leakage to groundwater systems. • Gathering lines decommissioned in accordance with the relevant regulatory standards to prevent gas and water leakage into the ground. • Contents of gathering lines collected to prevent discharge to receiving environment. • Solid or liquid wastes associated with facilities collected and removed to licensed waste facilities. • Any contaminated land remediated to appropriate human health and environmental standards.
High pressure gas pipelines	• Former wellheads reduced to as small as practicable, with ground surface shaped to promote natural drainage patterns and limit pooling of surface water. • Any underground infrastructure filled with an inert substance to prevent subsidence, where required. • Soil ripped or scarified in highly trafficked areas using suitable techniques to promote free drainage. • A stable landform with a self-sustaining vegetation cover of appropriate species composition established to enable natural vegetation progression and minimal weed invasion.
Production facilities and power generation facilities	• Ground conditions established that are conducive to natural regeneration. • A stable landform with a self-sustaining vegetation cover of appropriate species composition established to enable natural vegetation progression and minimal weed invasion.
Water treatment and storage facilities	• Dams and associated reticulation system may be left in situ if agreed with landowner and DEHP. • Where dams are removed, their contents will be drained and disposed of to appropriate waste facilities. • Brine residue will be removed as waste and disposed of at an appropriately licensed facility. • Any contaminated land will be remediated to appropriate human health and environmental standards. • Dam backfilled and ground surface shaped to promote natural drainage patterns and limit pooling of surface water. • Any underground infrastructure filled with an inert substance to prevent subsidence, where applicable. • Ground conditions conducive to natural regeneration.