15. SURFACE WATER

This chapter provides a summary of the surface water values within the project development area and an assessment of the potential for these values to be affected by direct and indirect impacts associated with the construction, operations and decommissioning phases of the project. For the detailed findings of the project's surface water impacts, refer to Appendix H, Surface Water Assessment – Part A: Fluvial Geomorphology and Hydrology, and Appendix I, Surface Water – Part B: Water Quality. Environmental protection objectives have been developed, and the avoidance, mitigation and management measures to achieve these objectives have been identified. The residual impact assessment assumes that the proposed avoidance, mitigation and management measures have been applied.

Surface water impacts on aquatic ecosystems are described in Chapter 16, Aquatic Ecology. Potential impacts on groundwater values are discussed in Chapter 14, Groundwater.

15.1 Legislative Context, Policies and Standards

The following legislation, policies and guidelines are relevant to identifying values and to providing guidance on mitigating and managing impacts on surface water.

***Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC Act).** This Commonwealth act provides for the protection of matters of national environmental significance, including listed aquatic species and Ramsar sites. Changes to surface water systems have the potential to impact aquatic species and Ramsar sites. Any action with the potential for a significant impact on these must be referred to the Minister for the Department of Sustainability, Environment, Water, Population and Communities and may require approval under this act.

***Environmental Protection Act 1994* (Qld) (EP Act).** The objective of the EP Act is to protect Queensland's environment by promoting ecologically sustainable development, and it governs the management of surface water in regards to coal seam gas fields.

***Water Act 2000* (Qld).** This act provides the framework to deliver sustainable water planning, allocation management and supply processes to ensure the improved security of water resources. The project is within the region covered by the Water Resource (Condamine and Balonne) Plan 2004, which lies under the Water Act. The plan sets a requirement for the taking of or interfering with overland flow; therefore, such activities need an operational works approval under Schedule 3, Table 4 of Sustainable Planning Regulation 2009.

***Water Supply (Safety and Reliability) Act 2008* (Qld).** This legislation applies to service providers registered with the Department of Environment and Resource Management (DERM), particularly those involved in treating, transmitting or reticulating water for drinking purposes. Arrow will be required to operate under this act when providing water commercially. A development permit may also be required in the event that Arrow pursues reuse of coal seam gas water for domestic purposes.

Environmental Protection (Water) Policy 1997 (EPP (Water)). This policy sits under the EP Act. The EPP (Water) also governs the discharge of wastewater to land, surface water, and groundwater, aims to protect designated environmental values, and sets water quality objectives to provide guidance to protect environmental values. The Environmental Protection (Water) Amendment Policy (No 1) 2008 allows for the identification of additional environmental values with respect to water.

Environmental Protection Regulation 2008, Environmental Protection (Waste Management) Policy 2000 and **Environmental Protection (Waste Management) Regulation 2000.** These pieces of legislation are supported by the former Environmental Protection Agency's 2007 operational policy entitled Management of Water Produced in Association with Petroleum Activities (Associated Water).

***Fisheries Act 1994* (Qld).** This act provides for the management, use and protection of fisheries resources in Queensland. In the event that Arrow needs to establish waterway barriers during watercourse crossings, approval must be sought under the Fisheries Act. The Fisheries (Freshwater) Management Plan 1999 under this act lists noxious species.

Coal Seam Gas Water Management Policy 2010. This policy was developed to give direction for the treatment and disposal of coal seam gas water and to the role the government wishes to play in facilitating greater beneficial use. Key features of the policy include discontinuing the use of evaporation ponds as a primary means of disposal of coal seam gas water and making coal seam gas producers responsible for treating and disposing of coal seam gas water.

Water Resource (Fitzroy Basin) Plan 1999 (Qld). The purpose of this plan is to provide a framework for sustainably managing water and the taking of water, establishing water allocations and regulating the taking of overland flow water in the Fitzroy Basin.

Guide to the Proposed Basin Plan: Overview (MDBA, 2010). The pending Murray-Darling Basin Plan is proposed to operate under the Commonwealth *Water Act 2007* and requires the Murray-Darling Basin Authority to determine the volume of water required to maintain and restore environmental assets within the Murray-Darling system. At present, a guide to the proposed basin plan has been released that refers to surface water assets in the project development area, specifically the Condamine-Balonne and Border Rivers catchments.

Queensland Water Quality Guidelines (DERM, 2009d). These guidelines provide a framework for assessing water quality in Queensland through the setting of water quality objectives.

Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000). These guidelines provide a method for assessing water quality through comparison with guidelines derived from local reference values.

15.2 Assessment Methods

The surface water assessment comprised a desktop study and field surveys to characterise the existing environment. Surface water aspects of the project have been examined in two parts: Part A covers fluvial geomorphology and hydrology, and Part B covers water quality. The study methods of the assessment are summarised below.

15.2.1 Desktop Study

The study commenced with an intensive review of existing data and information for areas within the project development area, as well as for the surrounding sub-basins, including:

- Queensland Wetlands Program to obtain watercourse and wetland layers and to identify wetland locations and types.
- Geosciences Australia to obtain watercourse names and to create a 1:100,000-scale digital elevation model.
- Australian drainage basin sub-basin information.

- Aerial imagery supplied by Coffey and Arrow.
- The DERM data for watercourse flow and flood risk, geographic information system information on estimated flooding extents and the water quality database.
- Climatic data from the Bureau of Meteorology (BOM).
- Water quality results from existing environmental authorities for petroleum tenures within the project development area.
- Arrow-supplied project-specific surface water quality data.

The datasets and information listed above were interpreted to inform the surface water assessment. The data sources allowed the following:

- Interpretation of surface water uses, flooding regimes, flood risk, geomorphic character and condition of watercourses within the project development area.
- Generation of a traceable stream network.
- Identification of catchments and subcatchments within the study area at a scale of approximately 1:50,000.
- Assessment of the flooding potential of the major watercourses within the project development area.
- Determination of appropriate surface water quality guidelines and objectives.

15.2.2 Field Surveys

The desktop study identified areas of diverse environmental value, which were verified during the field surveys. Survey sites were selected to reflect a representative range of surface water systems and land uses (such as agriculture, residential, forest parks and mining) within the project development area.

The field survey comprised:

- Collection of surface water quality samples for in situ and laboratory analyses.
- A geomorphic assessment, including a visual inspection and geomorphic categorisation of streams using the River Styles® framework developed by Brierley & Fryirs (2005).
- Site photographs and other general notes and observations.

Field surveys, including benthic sediment sampling, were also conducted as part of the Aquatic Ecology Assessment (for details of details of benthic sediment sampling see Appendix J).

Baseline water quality data was collected at 35 sites during surveys undertaken in October 2009, November 2009 and March 2010. Where possible, the sampling sites were consistent between sampling events. Seasonal fluctuations in water quality were also considered by sampling in the dry and wet seasons. In addition, 11 sites were sampled for water quality during an aquatic ecology assessment in November 2009 (wet season) and May 2010 (dry season). Surface water analytes were consistent with Arrow's existing environmental authorities and relevant regulations and guidelines. (Surface water quality sampling methods for the aquatic ecology assessment are provided in Chapter 16, Aquatic Ecology, and Appendix J, Aquatic Ecology Assessment.)

A total of 112 field sites were visited to categorise the geomorphology and hydrology of watercourses during October and December 2009. All surface water quality sampling, geomorphic field assessment and aquatic sampling sites are shown on Figure 15.1. The size of each watercourse is also provided on Figure 15.1, based on the Strahler stream order classification. Stream order classification considers the hierarchy of tributaries, starting at the top of a catchment where headwater flow paths are assigned first order. Where two first-order streams join, the downstream section is referred to as a second-order stream and so on. Third-order streams and above are generally considered likely to support viable fish populations.

15.3 Existing Environment and Environmental Values

This section provides a detailed description of the existing surface water systems and water quality within the project development area. An overview of the surface water environment, climate and land use is provided, along with a more detailed description of the geomorphology, stream flow, water use, water quality, flooding and wetlands within the project development area. The characteristics of each contribute to the values of the existing environment.

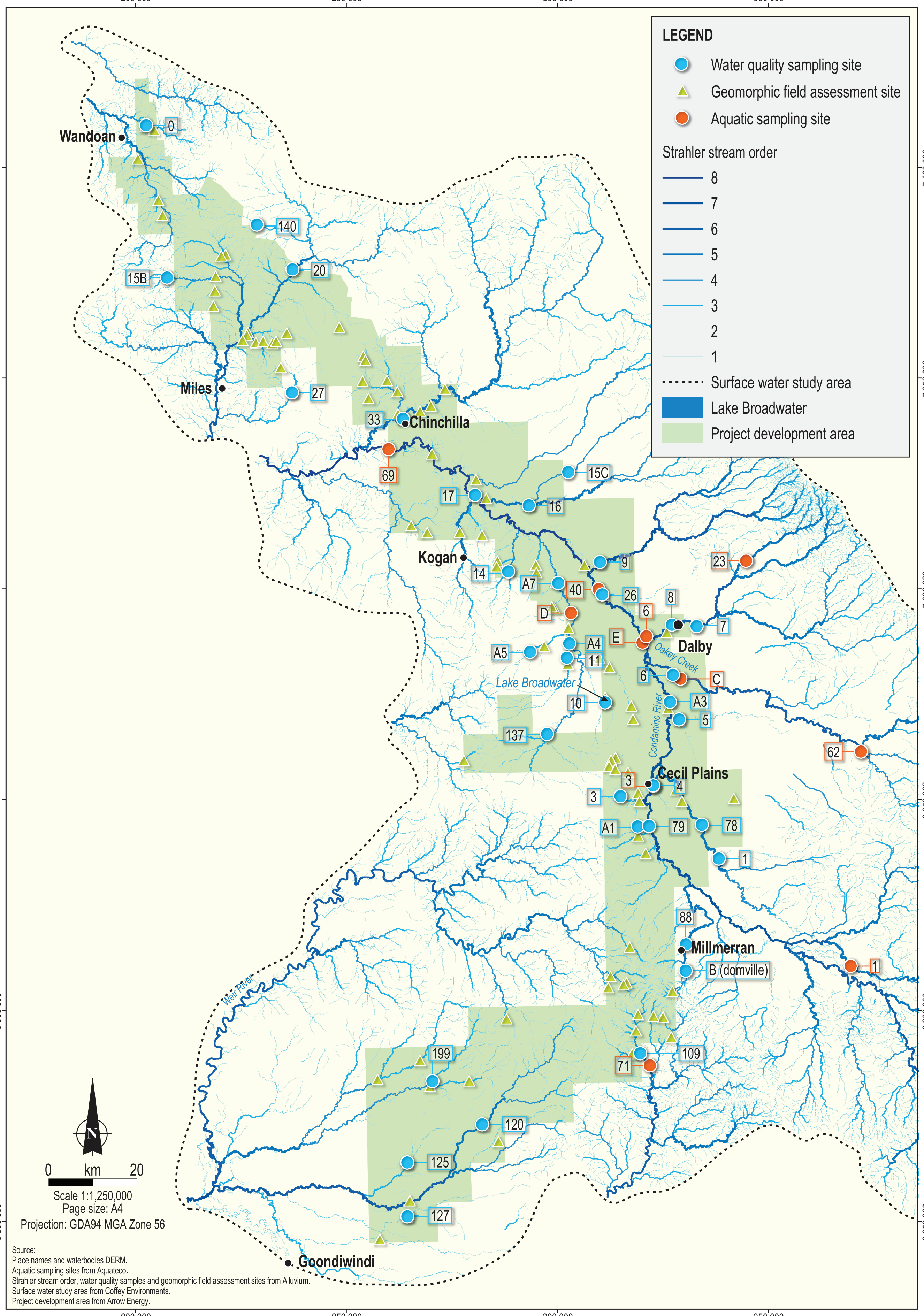
15.3.1 Overview

The regional surface water environment is represented by four drainage basins, all of which intersect the project development area: Condamine-Culgoa Basin (Condamine River and Balonne River), Fitzroy Basin (Dawson River), Border Rivers Basin (Weir and Macintyre rivers and Macintyre Brook), and Moonie Basin (Moonie River). The Condamine-Culgoa, Border Rivers, and Moonie basins form part of the Murray-Darling drainage division, while the Fitzroy Basin is part of the North-East Coast drainage division (Figure 15.2).

Basins can be divided into sub-basins, which can be further divided by catchment and subcatchment. Six sub-basins and 64 subcatchments lie within the project development area (Figure 15.3 shows the subcatchments). The Condamine is the predominant sub-basin within the project development area, accounting for over 50% of the total area. The extent of sub-basins within the project development area is summarised in Table 15.1. Sub-basins can be sizeable, and the project development area occupies only a small portion of any given sub-basin as indicated in Table 15.1.

Table 15.1 Drainage divisions, basins and sub-basins within the project development area the areal relationship between sub-basins and the project development area

Drainage Division	Basin	Sub-basin	Per Cent of the Project Development Area within the Sub-basin (%)	Project Development Area as a Per Cent of the Sub-basin (%)
Murray-Darling	Condamine-Culgoa	Balonne River	13.22	2.92
		Condamine River	52.89	14.76
	Border Rivers	Macintyre Brook	3.37	6.64
		Macintyre and Weir rivers	24.89	13.69
	Moonie	Moonie River	0.70	0.40
North-East Coast	Fitzroy	Dawson River	4.93	0.82



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MXD: 7040AC_04_GIS096_v1_2
File Name: 7040_04_F15.01_GIS_GL

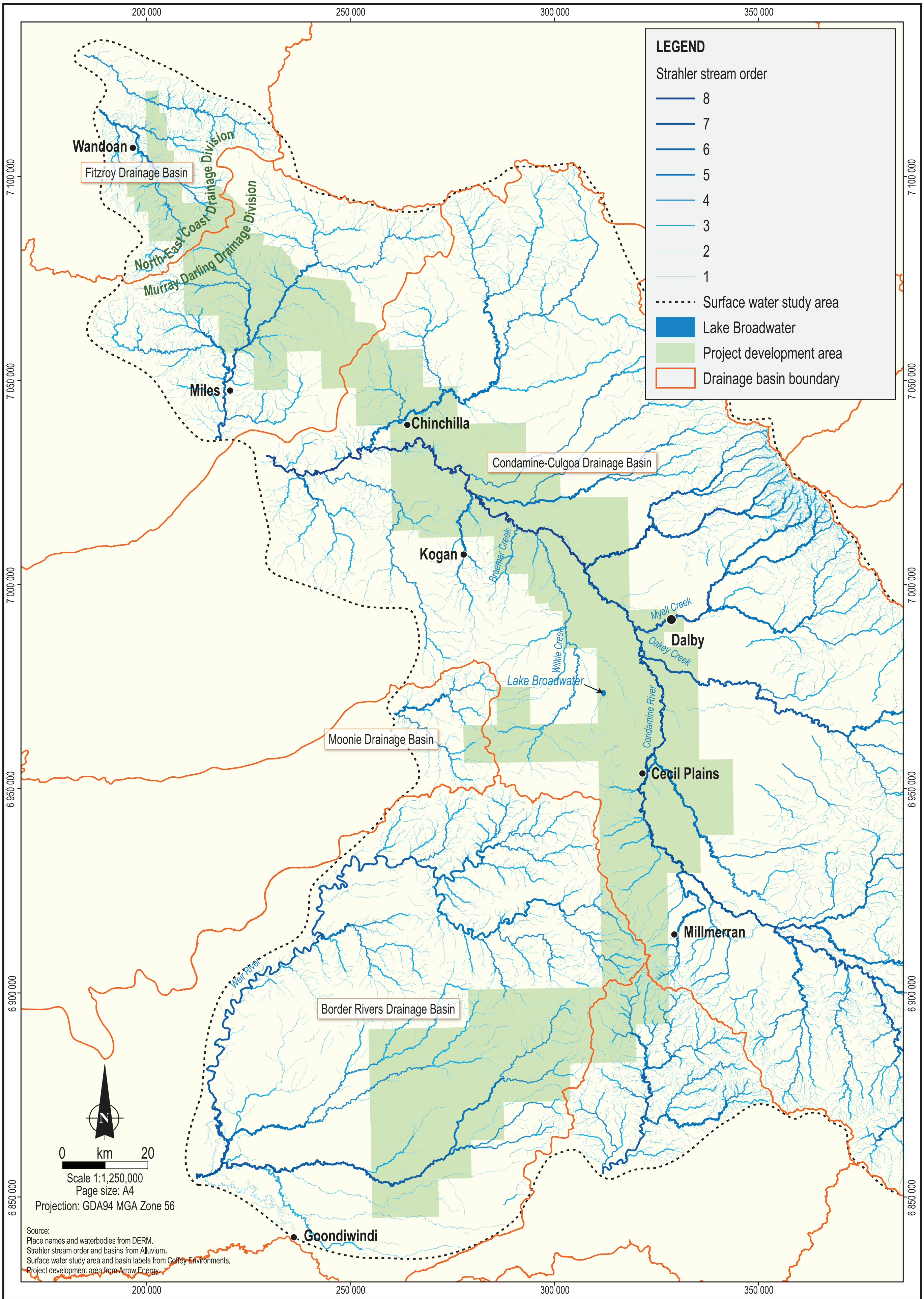
Arrow Energy

Surat Gas Project

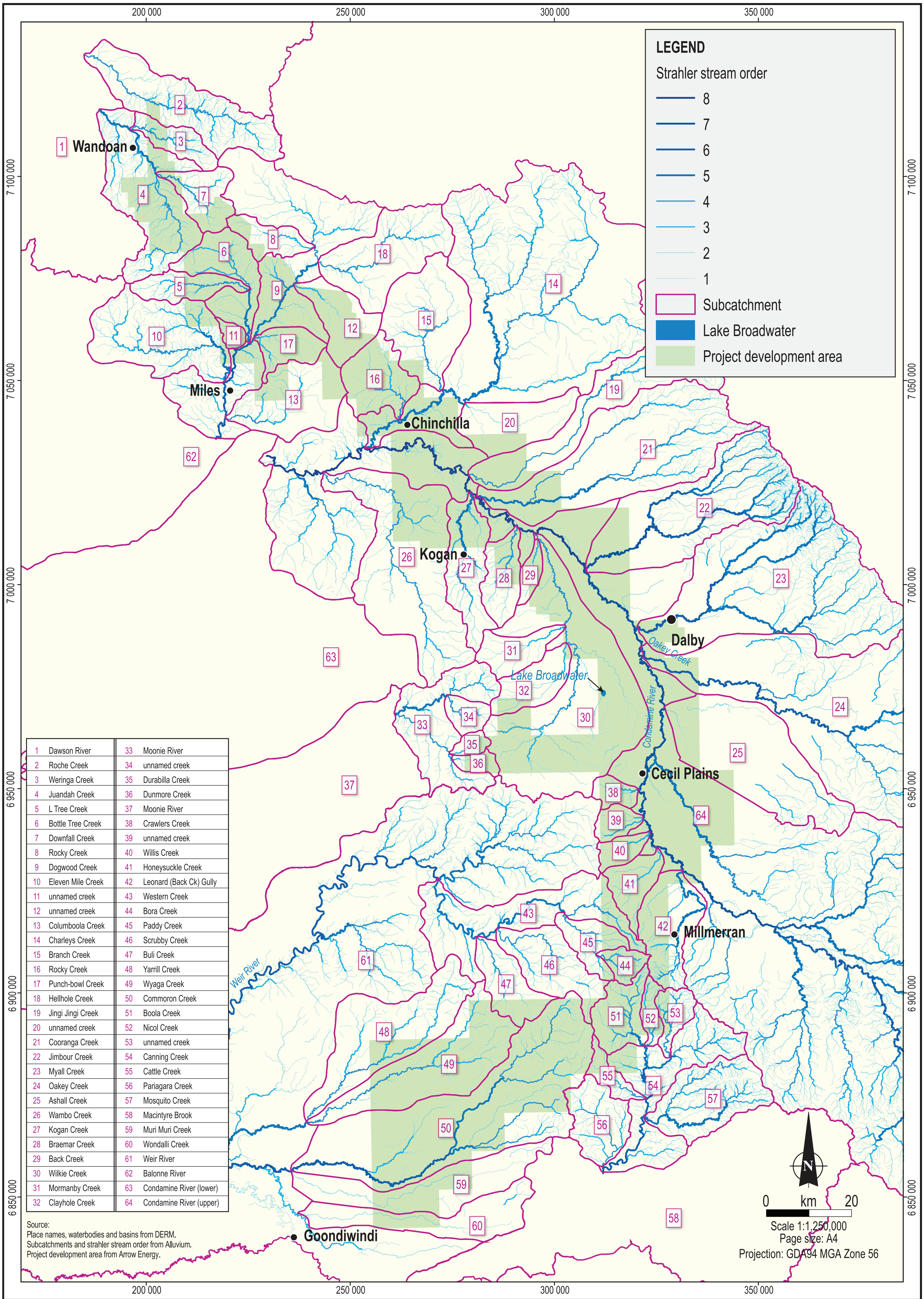
arrow energy go further

Surface water field survey sites

Figure No: 15.1



coffey environments	Date: 13.12.2011 MXD: 7040AC_04_GIS139_v1_4 File Name: 7040_04_F15.02_GIS_GL	Arrow Energy Surat Gas Project	arrow energy go further	Location of project development area in relation to drainage basins	Figure No: 15.2



coffey environments	Date: 06.12.2011 MXD: 7040AC_04_GIS097_v1_3 File Name: 7040_04_F15.03_GIS_GL	Arrow Energy Surat Gas Project	arrow energy go further	Location of project development area in relation to surrounding subcatchments	Figure No: 15.3

The location or origin of each drainage basin is as follows:

- The Condamine-Culgoa Basin forms the northern headwaters of the Murray-Darling river system.
- The Border Rivers Basin, comprising the Weir and Macintyre rivers, lies mostly within Queensland. Macintyre Brook is a major tributary of the Macintyre River, which eventually joins the Weir River near Talwood, Queensland.
- The Moonie Basin contains the Moonie River, a tributary of the Barwon River forming part of the Murray-Darling Basin.
- The Fitzroy Basin is located in central eastern Queensland and contains the Dawson River sub-basin. The Fitzroy River is formed by the confluence of the Dawson and MacKenzie rivers and then flows into the Coral Sea north of Rockhampton.

The study area is characterised by an extensive network of watercourses that are largely ephemeral, with varying geomorphic stream types that provide geomorphic diversity and contribute to habitat diversity. Rivers and creeks within the project development area are generally intermittent, with surface waters in many streams receding to disconnected pools and dry beds during the dry season. Stream orders ranged from a classification of eight, being the largest (e.g., Condamine River) to one, being the smallest. Almost 75% of the watercourses were classified as stream order one, characterised as a stream with no tributaries.

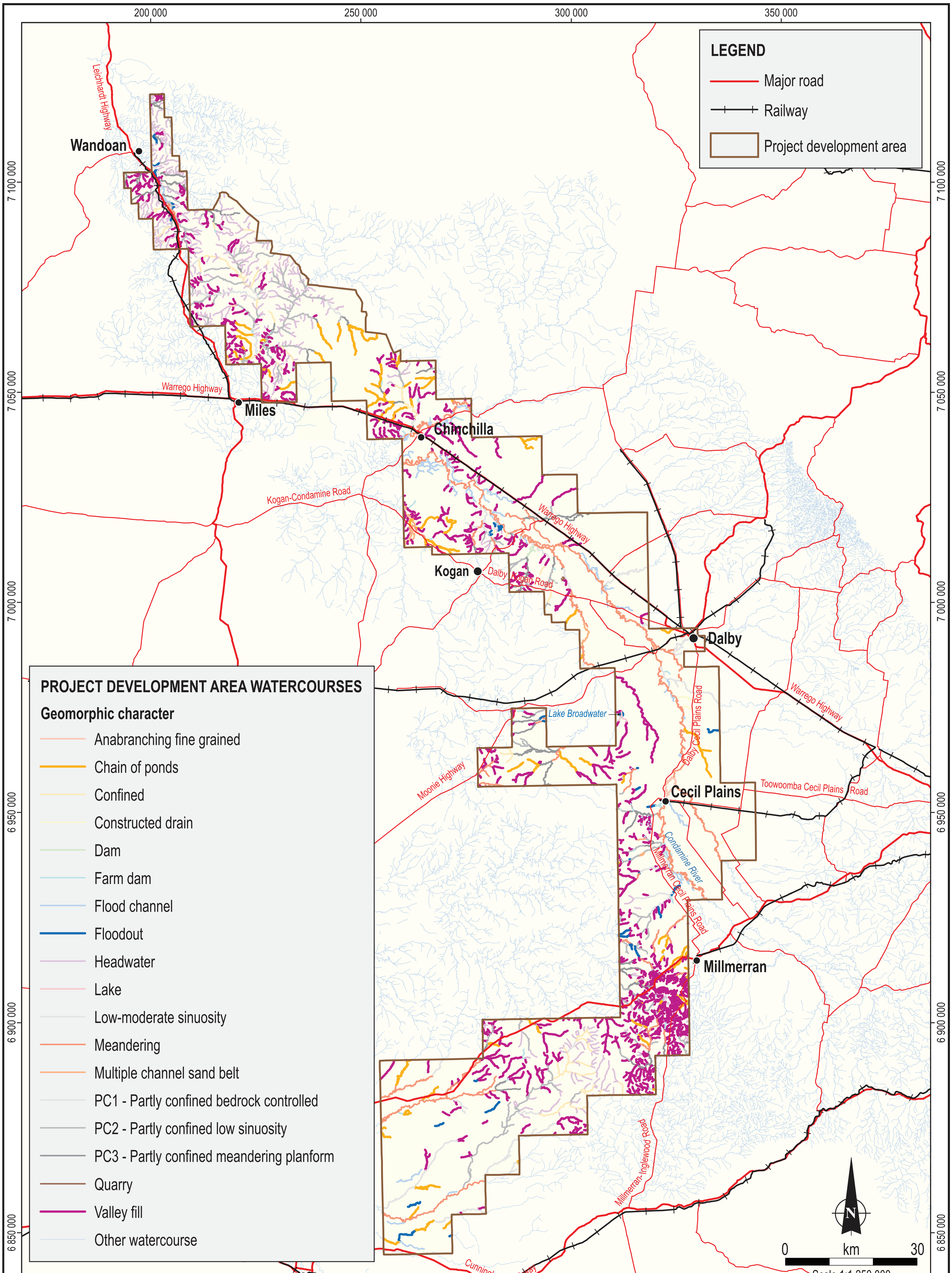
15.3.2 Fluvial Geomorphology

This section describes the fluvial geomorphology (the study of river-related landforms and the processes that shape them) throughout the project development area.

Watercourses and other waterbodies can be classified into groups of similar geomorphic characters using the River Styles® framework (Brierley & Fryirs, 2005). Relevant classifications are presented in Table 15.2. The majority of the watercourse lengths within the project development area were in the geomorphic category valley fill (alluvial and colluvial sediments across a valley floor with no channel). Geomorphic characteristics for watercourses within the project development area are shown on Figure 15.4.

Table 15.2 Watercourse classification by valley setting and River Style®

Valley Setting	River Style®	Examples Within Project Development Area
Wetlands and lakes	Lake	Lake Broadwater
Confined valley setting	Confined	Back Creek
	Partly confined bedrock controlled	Mostly between Wandoan and Miles
	Partly confined low sinuosity	Oakey Creek
	Partly confined meandering	Cooranga Creek
	Headwater	Two major clusters: southwest of Millmerran and southeast of Wandoan
Alluvial valley setting	Chain of ponds	Generally unnamed watercourses
	Floodout	Long Swamp
	Valley fill	Generally unnamed watercourses
	Continuous channel	Wilkie Creek
Flood channel	Flood channel – incising	Condamine River



Source:
Place names and roads from DERM.
Geomorphic character from Alluvium.
Place names and project development area from Arrow Energy.

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Date: 22.11.2011
MXD: 7040AC_04_GIS196_v1_2
File Name: 7040_04_F15.04_GIS_FT

Arrow Energy

Surat Gas Project

arrow energy go further

Geomorphic categorisation within the project development area

Figure No: 15.4

Fitzroy Basin

Clearing has occurred throughout the Fitzroy Basin, including the majority of the headwater reaches and steeper slopes. Many first-order watercourses within this basin have thinner colluvial or alluvial sediments in the valley floor and steeper gradients compared to the Condamine-Culgoa Basin. Thus, these watercourses have been categorised as headwater reaches (rather than valley fills), and an example can be seen in Plate 15.1. Juandah Creek carries moderate sand loads and in general has a low channel capacity within a reasonably broad floodplain (alluvial reaches). Where the valley constricts, channel capacity increases and bedrock occurrence is more frequent (partly confined reaches).

Condamine-Culgoa Basin

The main channels of the Condamine-Culgoa Basin throughout the project development area are set within broad floodplains dominated by fine-grained, often cohesive alluvium. The potential for incision of the bed of these watercourses is limited by low gradients and varying occurrences of bedrock or indurated or cemented Tertiary sediments. There are reaches where varying depths of mobile bed sediment are present over firmer strata, and there are also instances where bank sediments are dominated by non-cohesive fine sediments and are subject to more rapid rates of planform shift than in general across the project area. Certain geomorphic categories of the watercourses have multiple channels where the risk of avulsion is present. Avulsion is the process where a new main channel is created and the former main channel is abandoned or becomes a flood channel.

The Condamine-Culgoa Basin contains some areas of relief, although generally not steep, that occur where there is active erosion of the waterways. In some of these valleys, there are waterways that still have unchannelised valley fill (Plate 15.2) or chain of ponds (Plate 15.3). These are particularly sensitive to disturbance, evidenced by the many that are already undergoing incision or have become fully channelised. In their unchannelised state, these watercourses are of high environmental value due to the habitat they provide, the role they play in attenuating flows (reducing flood peaks and extending base flows in major downstream watercourses) and acting as long-term sediment stores.

The Condamine River has a dominant main channel and often several flood channels (Plate 15.4). One of these is known as an anabranch, but this river is not an actively anabranching system. The anabranch channel, if it was a former main channel, is well decayed and sits at a much higher level in the floodplain. There may be potential for channel development in some of the flood channels, particularly where floodplain width constricts or such development as dams (ring tanks) have a substantive influence on flood hydraulics. Wilkie Creek is an example of a continuous channel as can be seen in Plate 15.5.

Dogwood Creek is a major tributary of the Condamine-Balonne River, with its upper catchment located in the project development area. It is notably different from the rest of the project development area in that the large majority of it has not been cleared for grazing. The majority of first-order streams within Dogwood Creek catchment have been categorised as headwater with thin alluvial or colluvial deposits in very narrow valley floors that are almost continuous with hill slopes. Most of the second-order and greater reaches are partly confined with widespread bedrock. Toward the southern extent of the Dogwood Creek catchment in the project development area, gradients reduce considerably.

Plate 15.1
Headwater

Plate 15.2
Valley fill

Plate 15.3
Chain of ponds

Plate 15.4
Flood channel

Plate 15.5
Continuous channel

Plate 15.6
Floodout

Moonie Basin

The Moonie Basin occupies less than 1% of the project development area, and the geomorphic characteristics do not vary. The project development area covers a very small upper catchment extent of the Moonie River catchment. This area is mostly forested and of reasonably low gradient. The valleys are broad, and all the watercourses are alluvial valley fills for first-order streams and meandering sand bed for higher-order streams.

Border Rivers Basin

The Border Rivers Basin includes sections of Weir River and Macintyre Brook catchments that intersect the project development area.

A small and mostly cleared upper catchment section of the Macintyre Brook catchment intersects the project development area. The majority of the watercourse network is made up of alluvial discontinuous watercourses, with many of them being first-order valley fills that are influenced by contour banks for cropping and grazing of hillslopes. Channelisation has occurred in some watercourses, whereas the remainder remain intact due to the thin, fine-grained cohesive soils in the valley floors. Floodouts (Plate 15.6) can be found scattered throughout the basin. Second- and third-order watercourses include substantive reaches of chain of ponds, many of which have been channelised or are still undergoing incision. The higher-order watercourses are either alluvial continuous or partly confined, more often by a regional terrace than a hillslope.

The Weir River catchment is at the southern extent of the project development area. The upper catchment areas are mostly forested in the steeper areas, with watercourses having substantive shallow bedrock controls. Most watercourses are headwater confined (Plate 15.7) or partly confined (Plates 15.8, 15.9 and 15.10). Downstream to the west, gradients reduce to very flat and all the watercourses are unconfined in broad alluvial plains and, in large flow events, many become interconnected. Most of these flood channels are inactive, and some are becoming chain of ponds. Some of the main channels through this area have channel boundaries dominated by sand; and, in particular where vegetation has been disturbed, there is active bank erosion and excess in-channel mobile sand.

15.3.3 Stream Flow

The hydrology of watercourses, in terms of stream flow quantity, duration and timing, is important in maintaining a sufficient quantity of surface water to protect existing beneficial downstream uses of those waters. Climate and land-use practices are briefly discussed, as these may affect the hydrology of the watercourses. In addition, a summary of hydrology and stream flow characteristics is provided for each of the four drainage basins found in the project development area.

Regional climate can be described as subtropical to semi-arid, characterised by a wet summer and lower winter rainfall. Typically, rainfall and runoff occur in late spring, summer and autumn, with flooding most likely to occur in January and February.

The hydrology of the surface waters flowing through the project development area has been extensively modified by land clearance, dams, weirs and pumping infrastructure. The extent of these modifications varies between the basins. Overland flow characteristics also vary, with vast areas of low-gradient floodplains or terrace surfaces generating little runoff except when saturated or under intense rainfall. When runoff is generated, expansive areas may be inundated.

Plate 15.7
Confined

Plate 15.8
Partly confined bedrock controlled

Plate 15.9
Partly confined low sinuosity

Plate 15.10
Partly confined meandering

Fitzroy Basin

In the Fitzroy Basin, the Dawson River flows north before joining the Fitzroy River, which flows west to the Great Barrier Reef lagoon. Stream networks in the Fitzroy Basin are generally ephemeral, with the Dawson River, Hutton Creek, Baffle Creek and Juandah Creek, among others, being identified as the major streams. Summer rainfall (November to March) dominates, with little or no flow during winter when the streams are reduced to a series of pools, the exception being the Dawson River downstream of Dawson’s Bend where springs maintain a perennial stream. Some of the small tributaries to Juandah Creek flood out on the valley floor or floodplain margin, while others maintain a continuous channel due to greater discharge or energy conditions. Extensive clearing of native vegetation undertaken to facilitate agricultural and grazing activities has resulted in considerable land degradation in the form of sheet, rill and gully erosion within the Fitzroy Basin. Increased sediment loads entering streams have reduced channel capacity and led to an increase in the frequency of overbank flooding. A river gauging station located on the Juandah Creek in the headwaters of the Dawson River showed that the maximum daily flow for each year ranged from 3 m^3 per second (January 1987) to 1,057 m^3 per second (December 2010).

Condamine-Culgoa Basin

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

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. However, given the low-energy conditions of the system and the infrequency of overbank events, there is low potential for this to occur. 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 project development 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).

Moonie Basin

The Moonie River flows southwest and, with the semi-arid climate, is reduced to isolated pools for much of the year, responding to seasonal rains with well-defined flow events. Portions of the Moonie Basin are flat, with low-relief hills bordering floodplains. The majority of floodplain and lowland areas has been cleared for grazing and cropping practices. Local heavy rainfall can cause major flooding downstream, resulting in the inundation of much low-lying land and roads.

Border Rivers Basin

The Border Rivers Basin contains the Macintyre Brook and its tributaries, which flow south and then southwest. The basin also contains the Macintyre and Weir rivers, which generally flow southwest through the project development area. The Border Rivers Basin has been cleared substantially, resulting in changes in vegetation and increased erosion, both of which influence catchment hydrology. Many streams in the Border Rivers Basin are unregulated, with water use being governed by natural flows. Two stations on the Macintyre Brook provide stream flow data that show the maximum daily flow ranges from 4 m^3 per second (February 1993, November 2006 and January 2007) to 1,398 m^3 per second (April 1988).

15.3.4 Water Use

Present and potential water uses for the catchments in the project development 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 project development area, including the Condamine River, Balonne River, Macintyre Brook and Weir River and adjoining streams, such as Charleys, Dogwood and Cattle creeks.

Numerous water storages and weirs are located on the Dawson River and its tributaries, providing water for irrigation and recreational purposes. Water allocations are primarily for agriculture, with cattle grazing forming the major land use in the catchment. Forestry and cropping activities are also widespread.

The Moonie River is subject to water use through weirs and off-channel storages and some pumping of water for unregulated stock and domestic use.

The most common land use within the Border Rivers Basin is grazing on cleared land or in thinned native vegetation. Water consumption is dominated by irrigation, with major crops including cotton, grapes, salad vegetables and orchard fruits.

Other water uses in the project development 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.

15.3.5 Water Quality

Maintaining water quality is important for the survival of aquatic species and the maintenance of a supply of drinking and agricultural water. Surface water quality throughout the project development area, based on field surveys and data provided by DERM, is summarised in this section.

Watercourses mapped in the project development area exhibit a range of conditions from near pristine to highly disturbed. Disturbance of watercourses has resulted in bed and bank erosion to varying levels throughout the project development area. 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, 2009d)).

Water quality results collected during the three baseline surveys in the project development area 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 for relevant catchments in the vicinity of the project development area.

According to the mapped Queensland salinity zones, surface water is of low to moderate salinity within the Fitzroy Basin, moderate to very high salinity within the Condamine-Culgoa Basin, moderate salinity within the Moonie Basin and moderate to high salinity within the Border Rivers Basin.

Electrical conductivity, which is an indicator of salinity, varies widely across the project development area; and DERM (2009d) identified several catchments flowing from the east into the Condamine River as being among the most saline areas of Queensland. This was confirmed during the field investigation, with the highest electrical conductivity results recorded in Myall and Oakey creeks (within the high salinity zone). 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 project development area, the pH and electrical conductivity levels were generally suitable for the protection of slightly to moderately disturbed ecosystems.

Turbidity also varied across the project development area, and overall turbidity values exceeded the guideline values. 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 project development area were generally above guideline values nominated to protect surface waters from eutrophication. Total nitrogen, total phosphorous, fluoride and sulfate showed generally high variability during periods of low flow, with concentrations stabilising during high flows. Several heavy metals, including cobalt, copper, vanadium and zinc, were found above ecosystem protection values in a number of creeks and rivers across the project development area. 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.

There were some differences noted from the sampling sites across the drainage basins. No hydrocarbon-related compounds, pesticides, phenols or polychlorinated biphenyls were detected in the surface water samples collected from the Fitzroy Basin. Some petroleum hydrocarbon compounds and phenols were detected in selected samples taken from the Condamine-Culgoa Basin. 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 the 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.

Sediment quality was generally consistent with interim sediment quality guidelines at most aquatic ecology sites, with the exception of Myall and Oakey creeks, which recorded the highest metal concentrations. Both of these sites also were identified as having generally very high salinity.

There was a similarity in macroinvertebrate populations across the project development areas suggesting that water quality and site conditions are generally comparable with respect to the maintenance of aquatic communities (Chapter 16, Aquatic Ecology).

Overall, water quality characteristics vary throughout the project development area and across the four drainage basins.

15.3.6 Flooding

A review of historical flood information, including extent, levels and frequency, has been undertaken for major waterways within the project development area using information available from BOM (2011c). Floods are defined as follows:

- **Major Flooding.** This causes major inundation of large areas, isolating towns and cities. Major disruptions occur to road and rail links. Evacuations of many houses and business premises may be required. In rural areas, widespread flooding of farmland is likely.
- **Moderate Flooding.** This causes the inundation of low-lying areas, requiring the removal of stock or the evacuation of some houses. Main traffic bridges may be closed by floodwaters.
- **Minor Flooding.** This causes inconvenience, such as closing of minor roads and the submergence of low-level bridges, and makes the removal of pumps located adjacent to the river necessary.

Recent flood information is shown in Table 15.3. Flood records extend back to 1862 and are provided in Appendix H, Surface Water Assessment – Part A: Fluvial Geomorphology and Hydrology. An amalgamation of major floods from 1956 to 1988 is shown in Figure 4.6, and the estimated flood extent on 31 December 2010 is shown in Figure 4.7.

Varying amounts of rainfall over varying time periods can cause flooding in the four drainage basins of the project development area:

- **Fitzroy Basin.** Average catchment rainfalls in excess of 200 mm in 48 hours may cause significant to major flooding and, if in excess of 300 mm in 48 hours, may cause major flooding within the Fitzroy Basin.
- **Condamine-Culgoa Basin.** 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.
- **Moonie Basin.** Rainfall of 50 mm in 24 hours over isolated areas, with lesser rains of 25 mm over more extensive areas, will cause stream rises and the possibility of minor flooding within the Moonie Basin. Isolated flooding can occur if 50 mm of rain falls within 24 hours, whereas widespread major flooding will most likely occur if more than 50 mm of rain falls within 24 hours.
- **Border Rivers Basin.** It is estimated that, for the Border Rivers Basin, rainfall of 50 mm in 24 hours over isolated areas, with lesser rains of 25 mm over more extensive areas, will cause stream rises and the possibility of minor flooding. Rainfall in excess of 50 mm in 24 hours will cause isolated flooding, and generally 50 mm or heavier falls over a vast area in 24 hours will most likely cause widespread major flooding.

Table 15.3 Flooding history at river gauging stations within the project development area

	Depth of Water at the River Height Station Measuring Gauge (m)											
BOM River Height Station*	**Feb 1942**	**Jan/Feb 1956**	**Feb 1976**	**May 1983**	**May 1996**	**Jul/Aug 1998**	**Feb 2001**	**Jan 2004**	**Sep 2010**	**Oct 2010**	**Dec 2010**	**Jan 2011**
Condamine River Catchment												
Warwick (McCahon Bridge)	5.72	6.10	9.10	6.25	6.5	–	5.03	–	–	–	7.90	8.35
Pratten	–	7.32	10.50	8.4	8.5	–	6.5	–	–	–	9.55	9.70
Tummaville	10.08	10.59	11.11	10.2	10.26	–	6.2	–	–	–	11.15	10.91
Centenary Bridge	–	–	8.20	7.45	7.61	–	6.5	6.65	–	–	8.30	8.02
Cecil Plains	–	8.84	9.17	8.5	8.39	–	6.0	5.5	–	–	9.22	8.77
Tipton Bridge	–	7.32	11.36	10.5	10.18	–	7.21	6.3	–	–	–	–
Loudon Bridge	–	10.67	10.89	10.28	10.32	–	–	8.4	–	–	9.22	8.77
Ranges Bridge	–	10.52	11.05	9.75	9.7	–	5.85	7.2	–	–	11.00	–
Warra-Kogan Road Bridge	–	14.00	–	13.71	13.53	–	5.5	8.25	–	–	15.00	14.37
Brigalow Bridge	–	–	13.99	–	13.4	–	6.11	8.88	–	–	14.84	14.15
Chinchilla Weir	–	13.87	13.9	13.51	13.32	–	3.44	7.41	–	–	15.38	14.39
Border Rivers (Macintyre and Weir) Catchment												
Woodspring	–	9.57	8.53	–	6.30	5.70	–	–	3.01	2.98	-	7.60
Inglewood Bridge	–	12.50	11.73	–	9.75	9.15	–	–	–	–	-	9.15
Bangalla	–	11.82	11.90	–	9.82	8.80	–	–	7.47	5.94	-	10.94
Goondiwindi	–	10.27	10.50	–	10.60	10.48	–	–	8.83	8.93	-	10.64
Retreat Bridge	–	14.95	–	–	10.65	9.30	–	–	–	6.95	-	10.34
Gunn Bridge	–	–	–	–	6.52	–	–	–	–	5.44	-	7.31

Source: BOM (2011c).

* There are no river height stations within the project development area for the Fitzroy and Moonie catchments.

A flood frequency analysis was undertaken for major watercourses within the project development area, using stream flow data as the basis. A comparison of peak flows for the flood in December 2010 provided an estimate of the average recurrence interval (ARI).

For the Condamine River, the December 2010 flood event is estimated to be a 30- to 50-year ARI flood event for the project development area upstream of Dalby, whereas from Loudons Bridge to Chinchilla, it is estimated as a 75- to 100-year ARI flood event. For the Condamine River tributaries of Dogwood Creek (near Miles), Oakey Creek (south of Dalby) and Canal Creek (southwest of Millmerran), it was less than a 30-year ARI event. For Juandah Creek, north of the project area, it was estimated as a 30- to 50-year ARI. For the Macintyre Brook gauging stations, located south of the project development area, the event was estimated to be only a 5- to 10-year ARI.

Detailed results are presented in Appendix H, Surface Water Assessment – Part A: Fluvial Geomorphology and Hydrology.

15.3.7 Wetlands

Three types of wetlands – riverine, lacustrine and palustrine – contribute to habitat diversity in the project development 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. Riverine wetlands comprise 4,182 ha in the project development area.

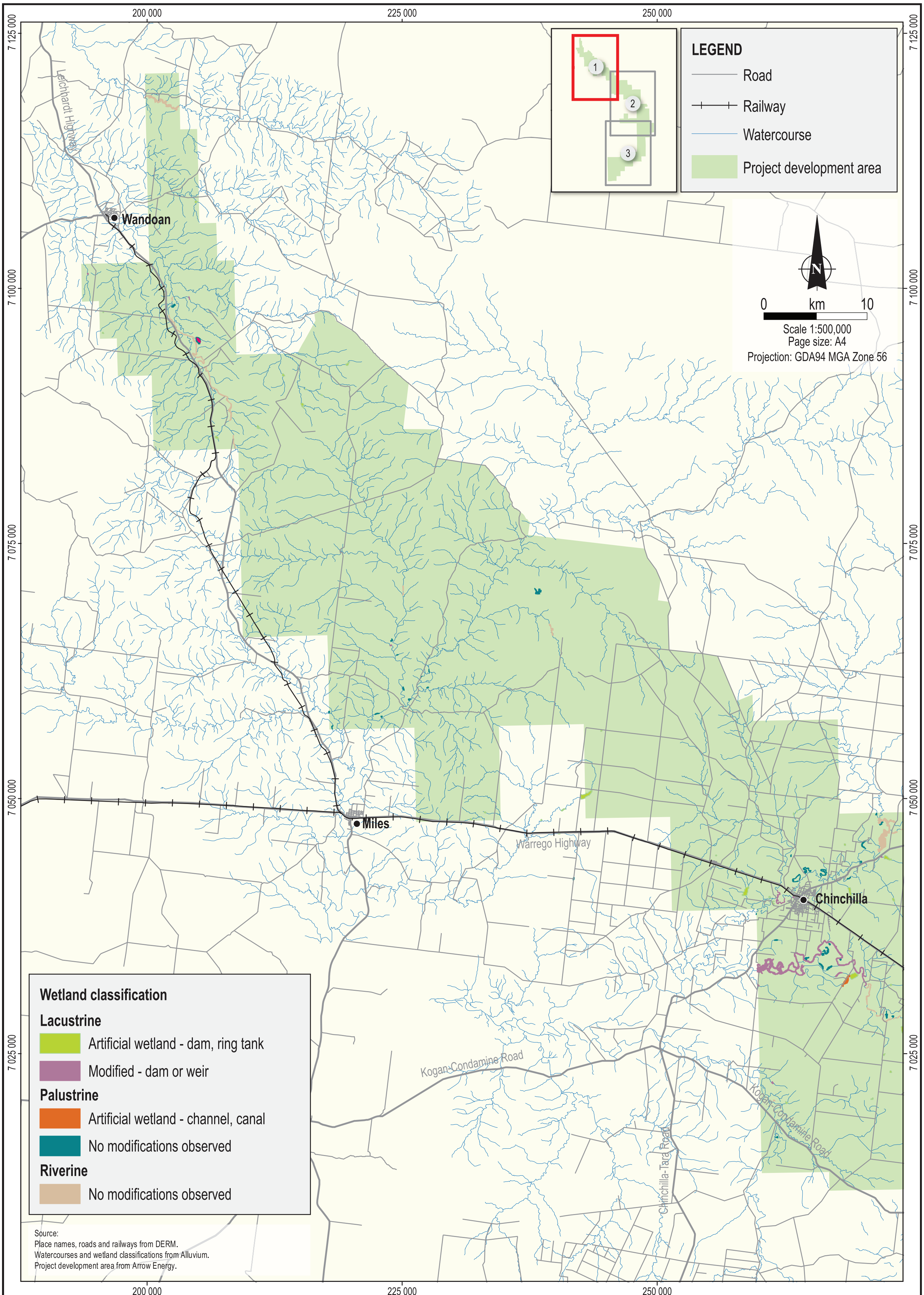
Lacustrine wetlands are large, open, water-dominated systems larger than 8 ha. The open lake part of Lake Broadwater is classified as lacustrine. This definition also applies to modified systems (e.g., dams), which possess characteristics similar to lacustrine systems (e.g., deep, standing or slow-moving waters). Lacustrine wetlands comprise 4,878 ha in the project development area.

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 wetlands comprise 1,544 ha in the project development area.

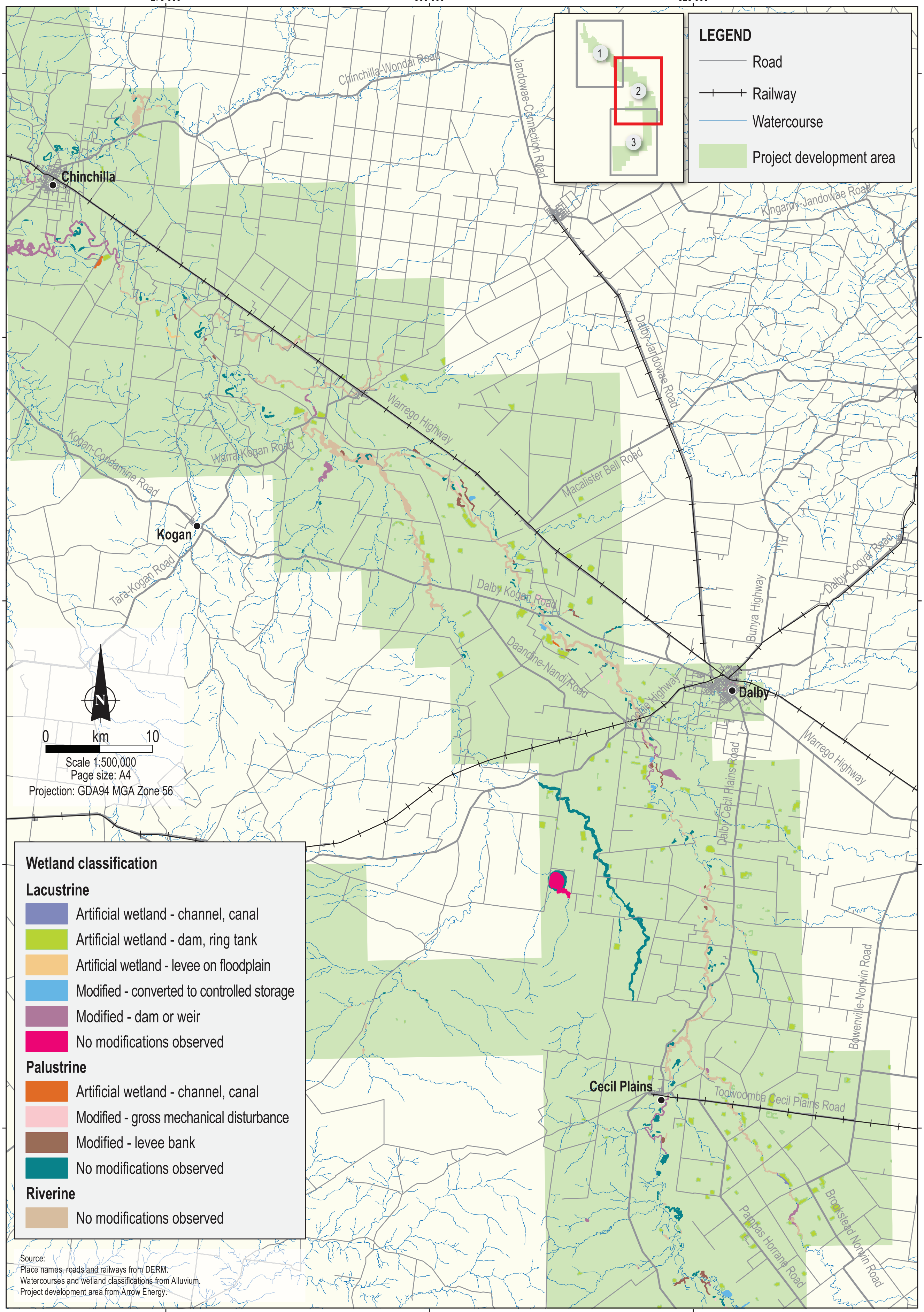
The location of wetlands and their classifications as identified by the Queensland Wetlands Program (DSEWPC, 2011) are shown in Figures 15.5a, b and c. The wetlands are classified by the three wetland types and based on any modifications made or if the wetlands are artificial.

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.

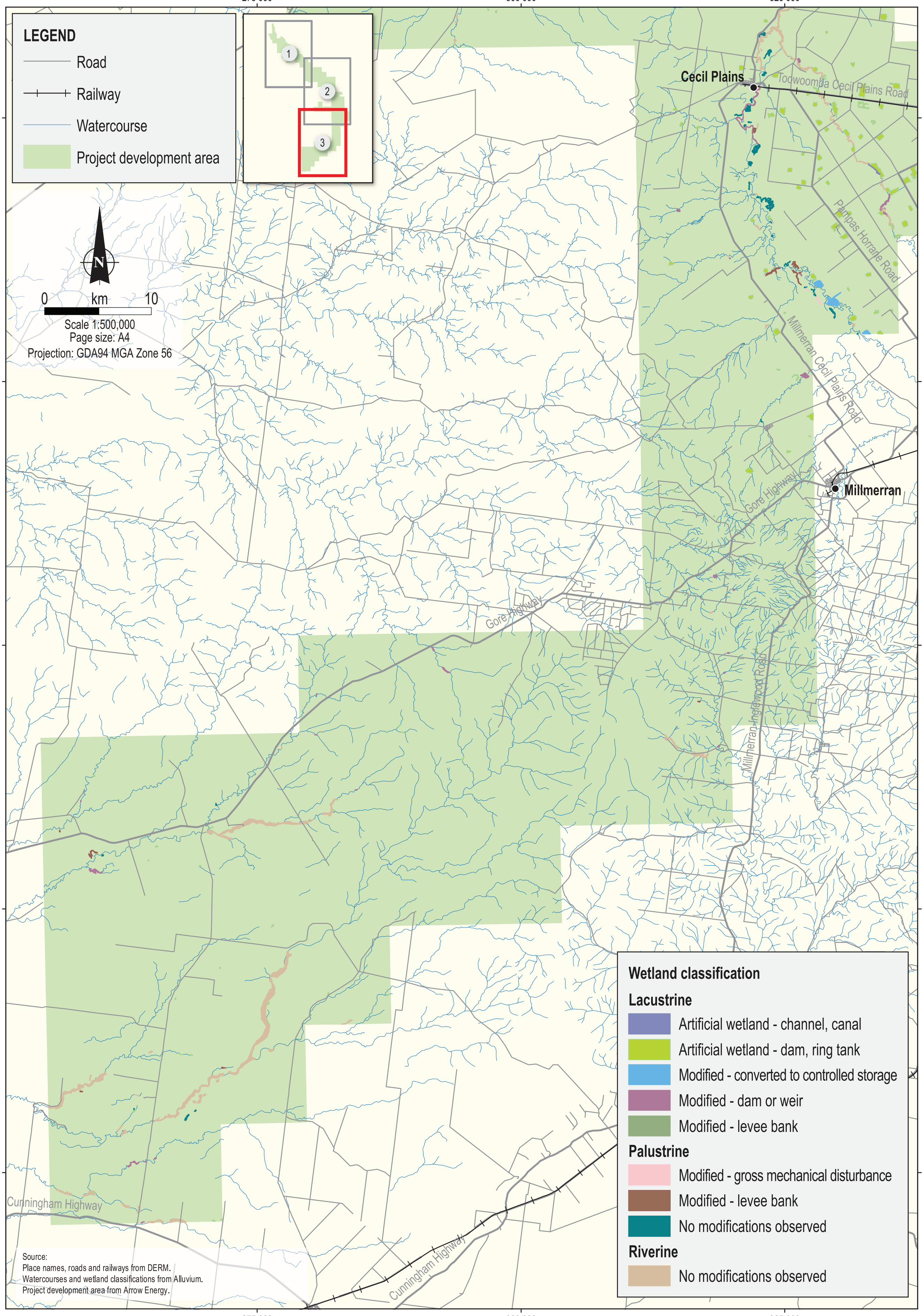
One wetland of national significance is located in the Surat Gas Project development area. Lake Broadwater, west of Dalby, is a semi-permanent freshwater lake used for recreational purposes (e.g., skiing, swimming, boating) and is classified as a conservation park. It is located in the Condamine River catchment and is classified as a Category A environmentally sensitive area (ESA).



coffey environments	Date: 06.12.2011 MXD: 7040AC_04_GIS184a_v1_3 File Name: 7040_04_F15.05a_GIS_FT	Arrow Energy Surat Gas Project	arrow energy go further	Queensland Wetlands Program identified wetlands (northern project development area), Map 1 of 3	Figure No: 15.5a



coffey environments	Date: 06.12.2011 MXD: 7040AC_04_GIS184b_v1_3 File Name: 7040_04_F15.05b_GIS_FT	Arrow Energy Surat Gas Project	arrow energy go further	Queensland Wetlands Program identified wetlands (central project development area), Map 2 of 3	Figure No: 15.5b



coffey environments	Date: 06.12.2011 MXD: 7040AC_04_GIS184_v1_3 File Name: 7040_04_F15.05c_GIS_FT	Arrow Energy Surat Gas Project	arrow energy go further	Queensland Wetlands Program identified wetlands (southern project development area), Map 3 of 3	Figure No: 15.5c

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.

Eight other nationally listed wetlands are located in the Condamine River catchment downstream and outside of the project development area. One of these is Narran Lakes Nature Reserve, which is a Ramsar-listed wetland on the Narran River, a tributary of the Ballone River. The lakes are located in the central north of New South Wales, approximately 340 km southwest of the southernmost point of the project development area. The site is the terminal wetland of the Narran River, which is fed by the Condamine River. Located approximately 75 km northwest of Walgett and 50 km northeast of Brewarrina, Narran Lake provides habitat for migratory species and is of cultural significance to Indigenous people. The wetland is located some 500 km by river from the project development area.

Ramsar wetlands of the Shoalwater and Corio Bays Area comprise five major estuarine and marine environments, which represent the largest area in central east Queensland containing representative coastal, subcoastal, aquatic landscapes and ecosystems. The wetland complex is more than 500 km by river from the project development area.

Due to the large distances between the project development area and the Narran Lakes Nature Reserve and the Shoalwater and Corio Bays Area wetlands, it is unlikely project-related activities will impact upon these wetlands. Consequently, the assessment did not include these sites and remains consistent with Chapter 16, Aquatic Ecology.

15.3.8 Environmental Values

The environmental values have been assessed, and a sensitivity rating has been given to each value. This sensitivity rating, in conjunction with the magnitude of impacts, is used to determine impact significance. The criteria for assigning sensitivity to surface water environmental values are provided in Table 15.4.

Each surface water environmental value identified comprises unique characteristics as described above and dictates the overarching environmental value of each surface water environment. This formed the basis of an assessment from which the sensitivity of the environmental value was determined. Table 15.5 summarises the sensitivity of the surface water environmental values relating to each existing environment.

Table 15.4 Descriptors used to classify the sensitivity of surface water environmental values

Descriptor	Sensitivity		
	High	Moderate	Low
Conservation status	• Wild river status. • World heritage status. • Ramsar status. • EPBC or Nature Conservation Act–listed flora, fauna or communities. • High-value fishery. • International ecotourism destination.	• Local government management. • Species of conservation interest (currently unlisted). • Moderate to marginal fishery values. • State or local ecotourism destination.	• No formal conservation status. • No species, habitat or communities of special conservation significance. • No fisheries value. • Local or no ecotourism value.

Table 15.4 Descriptors used to classify the sensitivity of surface water environmental values (cont'd)

Descriptor	Sensitivity		
	High	**Moderate**	**Low**
Intactness	• Undisturbed, pristine aquatic system. • High-quality aquatic habitat. • Important movement corridor for aquatic species. • Nursery or spawning area for aquatic fauna.	• Moderately disturbed aquatic system. • Moderate- to good-quality habitat. • Limited passage of aquatic fauna. • Limited spawning or nursery opportunities.	• Highly disturbed aquatic system. • Poor-quality aquatic habitat. • Minimal value as movement corridor for fauna. • Minimal value for spawning or nursery use.
Uniqueness or rarity	• Unique on a national or international scale in terms of biota, communities or processes.	• Unique on a regional scale in terms of biota, communities or processes.	• Unique on a local scale in terms of biota, communities or processes.
Resilience to change	• Poor tolerance to disturbance events; minor impacts have catastrophic effect.	• Moderately tolerant or adaptive communities.	• Highly tolerant or adaptive communities able to survive significant disturbance impacts.
Replacement potential	• Disturbance likely to cause irreparable damage or permanent loss of values.	• Communities likely to exhibit moderate to good recovery following disturbance.	• Communities capable of rapidly recovering or regenerating after disturbance events.

Table 15.5 Sensitivity of the surface water environmental values of existing environments

Existing Environment	Characteristics Contributing to the Value	Sensitivity of 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.	High
Wetlands (other)	• Generally high degree of ecological intactness but site-specific variation. • Supports terrestrial and aquatic species. • Contributes to habitat diversity. • Provides aquatic habitat. • Provides ecological processes for maintaining water quality and filtering sediment and other pollutants.	Moderate
High-order streams (permanent and semi-permanent watercourses)	• Moderate degree of ecological intactness with clear evidence of disturbance. • A continuous flow supports benefits of downstream use. • Contributes to habitat diversity. • Chains of ponds are sensitive to disturbance. • Supports recreational activities. • Reduction of flood peaks and extending base flows.	Moderate

Table 15.5 Sensitivity of the surface water environmental values of existing environments (cont'd)

Existing Environment	Characteristics Contributing to the Value	Sensitivity of the Value
Low-order streams (ephemeral watercourses)	• Provides marginal habitat. • Provides marginal ecological processes.	Low

15.4 Issues and Potential Impacts

Potential impacts on surface water environmental values from the project's construction, operations and decommissioning activities include:

- Changes to physical form.
- Changes to hydrology.
- Surface water quality degradation.

15.4.1 Construction

During construction of wells, 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 farmers' assets 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 to physical form and diminished water quality from pipeline or vehicle watercourse crossings causing bed and bank erosion and subsequent mobilisation of sediment.
- Changes to hydrology due to blockages in streams from pipeline watercourse crossings (open-cut crossings).

15.4.2 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 farmers' assets 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.

15.4.3 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.

15.5 Environmental Protection Objectives

The environmental protection objectives for surface water are to:

- Protect Lake Broadwater Conservation Park.
- Avoid or minimise any degradation to water quality, water access, and the physical and biological characteristics of the watercourses and wetlands.
- Maintain surface water amenity for the local community.

15.6 Avoidance, Mitigation and Management Measures

Avoidance, mitigation and management measures have been proposed to achieve the identified environmental protection objectives.

Avoidance, mitigation and management measures will be implemented for each stage of the project to minimise the potential impacts on surface water.

The primary means by which avoidance is achieved is through planning and design and site selection. Arrow's environmental framework focuses on early identification of sensitive locations that should be avoided by project activities, as described in Chapter 8, Environmental Framework.

Many of the proposed mitigation measures are similar for each of the impacts (changed physical form, changed hydrology and water quality degradation) and have therefore been grouped under general mitigation measures. General mitigation measures and mitigations specific to changed physical form, changed hydrology and degraded water quality are described below.

15.6.1 General Mitigation Measures

Avoidance is the primary mitigation measure to manage impacts and will include the following:

- Manage potential impacts on Lake Broadwater Conservation Park (Category A ESA) through implementation of the relevant buffer proposed in Table 15.6 [C156]. Note that, in Table 15.6, the only directly relevant sensitive area for surface water is Lake Broadwater Conservation Park, a Category A ESA; however, the proposed buffers for all category ESAs are provided for completeness. (Regional ecosystems are defined under the *Vegetation Management Act 1999* (Qld) and are discussed in more detail in Chapter 17, Terrestrial Ecology.)

Table 15.6 Proposed buffer distances from the ESA boundary

ESA Category	Proposed Activities within the ESA	Proposed Activities within 200 m of the ESA Boundary	Proposed Activities within a Secondary Protection Zone*
Category A	None	Low-impact activities	Limited petroleum activities within 800 m of the primary protection zone.†
Category B: excluding regional ecosystems with 'endangered' status	Low-impact activities	Low-impact activities	Limited petroleum activities within 300 m of the primary protection zone.†
Category B: regional ecosystems with an 'endangered' status	Limited petroleum activities	Limited petroleum activities	Only limited petroleum activities within 300 m of the primary protection zone.†
Category C: excluding regional ecosystems with an 'of concern' status, state forests and timber reserves	Low-impact activities	Low-impact activities	Limited petroleum activities within 300 m of the primary protection zone.†
Category C: regional ecosystems with an 'of concern' status, state forests and timber reserves	Limited petroleum activities	Limited petroleum activities	Limited petroleum activities within 300 m of the primary protection zone.†

* ESA buffers (derived from the guidelines under the EP Act, Model Conditions for Level 1 Environmental Authorities for Coal Seam Gas Activities) will be applied unless the activity occurs in pre-existing cleared areas or significantly disturbed land within the buffer and no reasonable or practicable alternatives exist.

† The primary protection zone is considered to be within 200 m of the ESA boundary.

- The following definitions relating to project activities apply to the terms used in Table 15.6:
  - **Low-Impact Activities.** These activities include the limited prescribed activities that do not result in the clearing of native vegetation, cause disruption to soil profiles through earthworks or excavation, or result in significant disturbance to land. Examples of such activities include but are not limited to soil surveys; topographic, cadastral and ecological surveys; and traversing land by car or foot via existing access tracks or routes.

  - **Limited Petroleum Activities.** Such activities include single well sites not exceeding 1 ha of disturbance and multi-well sites not exceeding 1.5 ha of disturbance, geophysical surveys, ecological and geological surveys, gathering pipelines from a wellhead to the initial production facility, supporting access tracks, and roads and communication and powerlines necessary for the undertaking of petroleum activities. The definition excludes construction of dams, borrow pits, production facilities and construction camps.

- Avoid permanent pools, chains of ponds, and alluvial islands, where practicable, when selecting watercourse crossing points. [C153]
- 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. [C151]
- 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). [C157]
- 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. [C152]
- 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. [C158]
- Develop an erosion and sediment control plan and install and maintain appropriate site-specific controls. [C034]
- 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. [C164]
- Minimise the disturbance footprint and vegetation clearing. [C020]
- Clear areas progressively and implement rehabilitation as soon as practicable following construction and decommissioning activities. [C015]
- Grade soil away from watercourses. [C169]
- Control sediment runoff from stockpiles. [C107]

- Design water dams in accordance with relevant legislation and Queensland standards and DERM guidelines. [C154]
- Maximise beneficial use of coal seam gas water. [C174]
- Identify strategies to minimise coal seam gas water surface storage and to promote increased efficiency. [C205]
- Apply appropriate international, Australian and industry standards and codes of practice for the handling of hazardous materials (such as chemicals, fuels and lubricants). [C035]
- Apply appropriate international, 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). [C048]
- Develop and implement incident reporting, emergency response and corrective action systems or procedures. Include systems for reporting, investigation and communications of lessons learned. [C171]
- Develop a protocol for the discharge of coal seam gas water to watercourses in a controlled manner under emergency situations, taking the sensitivity of the receiving watercourse into consideration. Conduct discharge events in accordance with specific parameters, including discharge volumes, flows and duration, and water quality. [C498]

15.6.2 Mitigations for Changes to Physical Form

Potential impacts resulting in changes to physical form will be managed with the following measures:

- 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. [C160]
- 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. [C162]
- Design culverts and drains to maintain flow and prevent headward erosion. [C159]
- 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. [C165]
- Retain coarse alluvial material from watercourse crossings for backfill armouring over the finer unconsolidated material. [C166]
- Stabilise and maintain streambanks following watercourse crossings. [C167]
- Inspect rehabilitated watercourse channels and banks following significant flow events and undertake remedial works as required. [C173]

- 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. [C066]

15.6.3 Mitigations for Changes to Hydrology

The following measures address potential impacts to stream hydrology:

- Where practicable, site facilities above the 1-in-100-year ARI flood event. [C155]
- Check for flood warnings or subscribe to flood warning services where relevant during construction of watercourse crossings. [C163]
- Plan construction of watercourse crossings to occur during periods of low rainfall and low flow, when practicable. [C161]
- Decommission infrastructure in such a manner that it will not adversely affect overland or flood flows and in accordance with relevant legislation and regulations. [C178]

15.6.4 Mitigations for Surface Water Quality Degradation

Degradation to surface water quality will be minimised with the following measures:

- Avoid disrupting overland natural flow paths, and where avoidance is not practical, maintain connectivity of flow in watercourses. [C053]
- Install and maintain diversion drains to divert clean surface runoff water around production facilities and away from construction areas. [C024]
- Locate soil stockpiles away from watercourses and wetlands to minimise potential for sediment runoff to enter the watercourse or wetland. [C170]
- Use coal seam gas water for dust suppression on roads or for construction and operations activities authorised in the environmental authority, in accordance with the water quality parameters described in the environmental authority. [C176]
- 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. [C175]
- 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. [C069] Also covered in [C066].
- 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 landholders 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. [C168]
- Minimise the inventory of hazardous materials stored on site. [C177]

- Apply appropriate international, Australian and industry standards and codes of practice for the handling of hazardous materials (such as chemicals, fuels and lubricants). [C035]
- Apply appropriate international, 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). [C048]
- Segregate stormwater discharge from potential contaminant process areas. [C172]

15.7 Residual Impacts

The avoidance, mitigation and management measures outlined above will avoid adverse impacts, or reduce the severity of potential impacts, on surface water environmental values. The significance of any residual impacts associated with project activities are described below. Note that residual impacts on surface water environmental values related to catastrophic events, such as dam failure, uncontrolled releases, or extreme weather events are discussed in Chapter 25, Preliminary Hazard and Risk. As a Category A ESA, Lake Broadwater Conservation Park will be avoided and no clearing or levelling will occur within 200 m of the park. This consequently eliminates direct impacts on this watercourse.

15.7.1 Changes to Physical Form

Changes to physical form could potentially result from site clearance, installation of facilities and pipelines, discharge of hydrotest water and runoff during construction. Erosion could potentially result at watercourse crossings, and generation of sediment may be caused by emergency discharge of associated water and maintenance of access tracks during operations.

Buffer zones restricting project activities will be established around watercourses. These buffers, combined with avoidance and mitigation measures, such as erosion control, bank stabilisation, controlled rate of discharge water, retention of coarse alluvial material for backfill armouring and remedial work, will reduce the magnitude of potential impacts to **moderate** for wetlands and high-order streams and to **low** for lower-order streams.

The significance of residual impacts will range from **low** for wetlands and high-order streams to **negligible** for lower-order streams.

15.7.2 Changes to Hydrology

The impacts that may cause changes to hydrology are related largely to placement of infrastructure, altered flow paths, open-cut watercourse crossings and the emergency discharge of coal seam gas water.

Key mitigations measures to minimise potential impacts on water quality include buffer zones, siting of facilities above the 1-in-100-year ARI flood event, monitoring of flood warnings, and scheduling watercourse crossing construction during the periods of lowest rainfall and channel flow.

After application of the mitigation measures, the magnitude of impact will reduce to **moderate** for wetlands and high-order streams and to **low** for lower-order streams.

The significance of residual impacts will range from **low** for wetlands and high-order streams to **negligible** for lower-order streams.

15.7.3 Surface Water Quality Degradation

Arrow anticipates that the avoidance, mitigation and management measures outlined above will avoid impacts or reduce the severity of potential impacts on surface water quality environmental values by maintaining water quality below relevant guideline values.

Management of localised impacts related to controlled releases of treated coal seam gas water under emergency conditions should consider appropriate discharge locations to ensure that surface water quality objectives are not exceeded.

Once discharge locations are finalised, standard procedures and protocols and design will be undertaken during the detailed engineering process with a view to meeting water quality criteria.

15.7.4 Summary of Residual Impacts

Table 15.7 summarises the potential impacts prior to mitigation, the proposed mitigation and management measures, and the subsequent residual impacts assuming successful implementation of the proposed measures.

15.8 Inspection and Monitoring

Inspection of surface water quality will be implemented to verify the residual impacts throughout the life of the project and to ensure mitigation measures are effective. Monitoring will be undertaken to demonstrate achievement of objectives.

Inspection and monitoring measures will include:

- Routinely monitor buffer zones and project footprint using satellite imagery. [C509]
- 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. [C507]
- Visually inspect physical form and monitor hydrology, turbidity and pH upstream and downstream of central gas processing and integrated processing facility stormwater and coal seam gas water discharge points. [C526]
- Inspect erosion and sediment control measures following significant rainfall events to ensure effectiveness of measures is maintained. [C505]
- Routinely visually inspect 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. [C527]
- Routinely inspect spill containment controls and spill response kits. [C516]
- 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. [C529]
- Routinely measure the volume and quality of treated sewage effluent in accordance with regulatory requirements and approved release limits. [C530]
- Routinely monitor water quality in dams. [C009]

Table 15.7 Summary of surface water impact assessment

Cause of Potential Impacts	Existing Environment	Values Sensitivity	Premitigated Impact		Summary of Mitigation Measures	Residual Impact	
			Magnitude	Significance		Magnitude	Significance
Changes to Physical Form							
Construction • Removal of riparian vegetation and subsequent reduced bank stability and increased erosion and sediment mobilisation causing changes to physical form. • Changes to physical form from controlled and uncontrolled releases of hydrotest fluids. • Placing infrastructure in surface water flow paths causing changes to physical form and flooding. • Changes to physical form from pipeline or vehicle watercourse crossings causing bed and bank erosion and subsequent mobilisation of sediment. **Operation** • Changes to physical form from controlled and uncontrolled releases of coal seam gas water and hydrotest fluids. • Placing infrastructure in surface water flow paths causing changes to physical form and flooding. • Changes to physical form due to scour and generation of sediment at watercourse crossings caused by use and maintenance of access tracks.	Lake Broadwater	High	N/A - Avoidance	N/A - Avoidance	• Use appropriate buffer zones around Lake Broadwater Conservation Park. • Manage potential impacts through consideration of relevant buffer zones from watercourse bank edges. • Avoid wetlands when siting facilities. • Minimise watercourse crossings, where practicable, during route selection. • Avoid sensitive areas when selecting watercourse crossing points. • Design and construct water dams in accordance with relevant legislation, standards and guidelines. • Design, construct and rehabilitate watercourse crossings to minimise impacts on watercourses. • Minimise the disturbance footprint and vegetation clearing. • Develop site-specific management plans for watercourse crossings. • Install and maintain sediment and erosion control structures. • Control sediment runoff from stockpiles. • Grade soil away from watercourses. • Reuse hydrotest water in adjacent pipeline sections, where practicable. • Maximise beneficial use of coal seam gas water.	N/A - Avoidance	N/A - Avoidance
	Wetland (other)	Moderate	High	High		Moderate	Moderate

Table 15.7 Summary of surface water impact assessment (cont'd)

Cause of Potential Impacts	Existing Environment	Values Sensitivity	Premitigated Impact		Summary of Mitigation Measures	Residual Impact	
			Magnitude	Significance		Magnitude	Significance
Changes to Physical Form (cont'd)							
Decommissioning • Changes to physical form due to scour and generation of sediment at watercourse crossings caused by use and maintenance of access tracks. • Activities causing sediment movement into watercourses leading to changes to physical form due to the proximity of works to watercourses and wetlands.	High-order streams (permanent and semi-permanent watercourses)	Moderate	High	Moderate	• Clear areas progressively and implement rehabilitation as soon as practicable. • Develop and implement incident reporting, emergency response and corrective actions systems or procedures. • Control drainage, erosion and sediment on disturbed areas and work sites using appropriate measures. • Design culverts and drains to maintain flow and prevent headward erosion. • Stockpile watercourse bed material in dry watercourse channels adjacent to the construction ROW, avoiding impacts on riparian vegetation and in-stream features.	Moderate	Moderate

Table 15.7 Summary of surface water impact assessment (cont'd)

Cause of Potential Impacts	Existing Environment	Values Sensitivity	Premitigated Impact		Summary of Mitigation Measures	Residual Impact	
			Magnitude	Significance		Magnitude	Significance
Changes to Physical Form (cont'd)							
	Low-order streams (ephemeral watercourses)	Low	Moderate	Low	• Discharge water at a rate and from a location that will not result in erosion. • Retain coarse alluvial material from watercourse crossings for backfill armouring. • Utilise existing stable watercourse crossings, where practicable. • Stabilise and maintain stream banks following watercourse crossings. • Delay clearance of stream banks until the watercourse crossing is due to be constructed, and implement appropriate erosion and sediment control measures. • Undertake remedial works on rehabilitated watercourses, as required.	Low	Negligible

Table 15.7 Summary of surface water impact assessment (cont'd)

Cause of Potential Impacts	Existing Environment	Values Sensitivity	Premitigated Impact		Summary of Mitigation Measures	Residual Impact	
			Magnitude	Significance		Magnitude	Significance
Changes to Hydrology							
Construction • Changes to hydrology from controlled and uncontrolled releases of hydrotest fluids. • Placing infrastructure in surface water flow paths causing changes to hydrology. • Changes to hydrology due to blockages in streams from pipeline watercourse crossings (open-cut crossings). **Operation** • Changes to hydrology from controlled and uncontrolled releases of coal seam gas water and hydrotest fluids. • Placing infrastructure in surface water flow paths causing changes to hydrology. • Changes to physical form due to scour and generation of sediment at watercourse crossings caused by use and maintenance of access tracks.	Lake Broadwater	High	N/A - Avoidance	N/A - Avoidance	• Use appropriate buffer zones around Lake Broadwater Conservation Park. • Manage potential impacts through consideration of relevant buffer zones from watercourse bank edges. • Avoid wetlands when siting facilities. • Minimise watercourse crossings, where practicable, during route selection. • Avoid sensitive areas when selecting watercourse crossing points. • Design and construct water dams in accordance with relevant legislation, standards and guidelines. • Design, construct and rehabilitate watercourse crossings to minimise impacts on watercourses. • Minimise the disturbance footprint and vegetation clearing. • Develop site-specific management plans for watercourse crossings. • Install and maintain sediment and erosion control structure.	N/A - Avoidance	N/A - Avoidance
	Wetlands (other)	Moderate	High	Moderate		Moderate	Moderate

Table 15.7 Summary of surface water impact assessment (cont'd)

Cause of Potential Impacts	Existing Environment	Values Sensitivity	Premitigated Impact		Summary of Mitigation Measures	Residual Impact	
			Magnitude	Significance		Magnitude	Significance
Changes to Hydrology (cont'd)							
	High-order streams (permanent and semi-permanent watercourses)	Moderate	High	Moderate	• Control sediment runoff from stockpiles. • Grade soil away from watercourses. • Reuse hydrotest water in adjacent pipeline sections, where practicable. • Clear areas progressively and implement rehabilitation as soon as practicable. • Develop and implement incident reporting, emergency response and corrective actions systems or procedures. • Control drainage, erosion and sediment on disturbed areas and work sites using appropriate measures. • Maximise beneficial use of coal seam gas water. • Site facilities above the 1-in-100-year ARI flood event, where practicable. • Check for flood warnings during construction of watercourse crossings. • Schedule watercourse crossing construction during the periods of low rainfall and channel flow, when practicable. • Decommission infrastructure in accordance with relevant legislation and regulations.	Moderate	Moderate
	Low-order streams (ephemeral watercourses)	Low	Moderate	Moderate		Low	Negligible

Table 15.7 Summary of surface water impact assessment (cont'd)

Cause of Potential Impacts	Existing Environment	Values Sensitivity	Premitigated Impact		Summary of Mitigation Measures	Residual Impact	
			Magnitude	Significance		Magnitude	Significance
Surface Water Quality Degradation							
Construction • Removal of riparian vegetation and subsequent reduced bank stability, erosion and sediment mobilisation causing diminished water quality. • Degradation of water quality from controlled and uncontrolled releases of hydrotest fluids. • Degradation of water quality from pipeline or vehicle watercourse crossings causing bed and bank erosion and subsequent mobilisation of sediment. • Diminished water quality from spills of hazardous materials or drilling muds. • Removal of terrestrial vegetation leading to increased runoff and sedimentation in the watercourses causing diminished water quality. • Diminished water quality from earthmoving and soil stockpiling leading to increased sedimentation in watercourses. **Operation** • Degradation of water quality from controlled and uncontrolled releases of coal seam gas water or hydrotest fluids.	Lake Broadwater	High	N/A - Avoidance	N/A - Avoidance	• Avoid disrupting overland natural flow paths and, where avoidance is not practicable, maintain connectivity of flow in watercourses. • Install and maintain diversion drains to divert clean surface runoff water around production facilities and away from construction areas. • Locate soil stockpiles away from watercourses and wetlands to minimise potential for sediment runoff to enter the watercourse or wetland. • 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. • 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.	N/A - Avoidance	N/A - Avoidance
	Wetlands (other)	Moderate	High	Moderate		Moderate	Moderate

Table 15.7 Summary of surface water impact assessment (cont'd)

<table>
<tr><th rowspan="2">Cause of Potential Impacts</th><th rowspan="2">Existing Environment</th><th rowspan="2">Values Sensitivity</th><th colspan="2">Premitigated Impact</th><th rowspan="2">Summary of Mitigation Measures</th><th colspan="2">Residual Impact</th></tr>
<tr><th>Magnitude</th><th>Significance</th><th>Magnitude</th><th>Significance</th></tr>
<tr><td colspan="8">Surface Water Quality Degradation (cont'd)</td></tr>
<tr><td rowspan="2">• Increased runoff from compacted areas causing sedimentation in watercourses and diminished water quality.
• Diminished water quality from spills of hazardous materials.
• Contaminated runoff from activities causing surface water degradation.
• Degradation of water quality, injury to people or property from a catastrophic release of a water storage dam.
Decommissioning
• Contaminated runoff from activities causing surface water degradation.
• Increased runoff from cleared areas leading to sedimentation in watercourses and diminished water quality.
• Degradation of surface water quality from earthmoving and soil stockpiling leading to increased sedimentation in watercourses.
• Diminished water quality from spills of hazardous materials.</td><td>High-order streams (permanent and semi-permanent watercourses)</td><td>Moderate</td><td>Moderate</td><td>Moderate</td><td rowspan="2">• Incorporate into an emergency response plan or water management plan procedures for the controlled discharge of treated coal seam gas water under emergency conditions.
• Conduct consultation with landholders and relevant regulatory authorities prior to sourcing and disposing of hydrotest water.
• Develop and implement a hydrostatic testing procedure prior to commencement of hydrotest activities.
• Avoid or minimise harmful chemical additives in hydrotest water.
• Ensure hydrotest water that is discharged or recycled for secondary uses meets relevant statutory water quality guidelines.
• Minimise the inventory of hazardous materials stored on site.
• Store and, where practicable, handle fuels, lubricants and chemicals and hazardous materials in accordance with appropriate standards and codes of practice.</td><td>Low</td><td>Low</td></tr>
<tr><td>Low-order streams (ephemeral watercourses)</td><td>Low</td><td>Moderate</td><td>Low</td><td>Low</td><td>Negligible</td></tr>
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