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AQUATIC ECOLOGY

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16 Aquatic Ecology

This chapter provides a summary of the aquatic ecosystem values within and adjacent to the Project area and an assessment of the potential direct and indirect impacts on aquatic ecosystems associated with the construction, operation and decommissioning phases of Project development. The chapter outlines mitigation and management measures for potential impacts, and identifies residual impacts. A risk-based constraints framework is used to determine the level of environmental management and remediation required and to provide avoidance, mitigation and management measures. The residual impact assessment assumes that the proposed avoidance, mitigation and management measures have been applied. For the detailed description of aquatic ecosystem values and assessment of the Project's potential aquatic ecology impacts refer to the Aquatic Ecology Technical Report (Appendix O) of this EIS. A cross reference to the locations where each of the requirements of the ToR has been addressed is given in Appendix B which references both the study chapters (Sections 1 through 34) and/or the Appendices (A through EE).

Semi-aquatic mammals, amphibians, reptiles, wetland birds and riparian vegetation have been addressed in the Terrestrial Ecology chapter (Section 17) of this EIS.

Matters of national environmental significance (MNES) identified through the aquatic ecology impact assessment are presented in Appendix CC, while Environmentally Sensitive Areas (ESAs) identified in the Project area are assessed in the Environmentally Sensitive Area chapter (Section 18) of this EIS.

16.1 Legislative Context

Commonwealth and state government legislation, plans and policies relevant for managing potential impacts and providing guidance for avoidance, mitigation and management of impacts to the aquatic environment in the study area are detailed below.

Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth)

DSEWPac administers the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act), which promotes the conservation of biodiversity by providing protection for listed MNES. Lists of protected species and communities are contained within the EPBC Act, including listed aquatic species and Ramsar sites.

Environmental Protection Act 1994

The objective of the *Environmental Protection Act 1994* (EP Act) is to protect Queensland's environment by promoting ecologically sustainable development. The EP Act regulates Environmentally Relevant Activities (ERAs), including those relating to mining and petroleum through the development of EIS'. The *Environmental Protection Regulation 2008* provides a mechanism to enforce the EP Act and allows for an assessment of the risk that an ERA poses to ESAs. ESAs include, but are not limited to national and conservation parks, forest reserves and international agreement areas. Under the EP Act, the *Environmental Protection Policy (Water) 2009* (EPP (Water)) governs the discharge of wastewater to land, surface water and groundwater, and sets water quality objectives to protect environmental values.

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Nature Conservation Act 1992

The objective of the *Nature Conservation Act 1992* (NC Act) is to protect areas of high conservation value and define and protect classes of native wildlife, which includes individual species of plants and freshwater animals. The NC Act is administered by the EHP and approval is required to interfere with species listed under the Nature Conservation (Wildlife) Regulation 2006. The NC Act places threatened species into different categories, i.e. extinct in the wild, endangered, vulnerable, near threatened, least concern, international and prohibited, in recognition of their conservation status and what action needs to be taken to protect them. For threatened species, the NC Act defines the management initiatives of each class of wildlife to ensure their ongoing survival in the wild.

Fisheries Act 1994

The *Fisheries Act 1994* provides for the use, conservation and enhancement of the community's fisheries resources and fish habitats in a way that seeks to apply and balance the principles of ecologically sustainable development. Under this Act, the Fisheries (Freshwater) Management Plan 1999 lists declared pest fish species. The Fisheries Regulation 2008 also falls under the Act, and provides guidelines for the taking, possessing or using of fish under various management plans. Fisheries Habitat Management Operational Policy (FHMOP 008) 2009 applies to the assessment of waterway barrier works development applications and the issue of waterway barrier works development approvals by Queensland Department of Agriculture, Fisheries and Forestry (DAFF).

Water Act 2000

The *Water Act 2000* provides the framework to deliver sustainable water planning, allocation management and supply processes to ensure the improved security of water resources. The Act is primarily concerned with water suppliers and is administered through the Water Regulation 2002.

Sustainable Planning Act 2009

The purpose of the Sustainable Planning Act 2009 (SP Act) is to achieve ecological sustainability by managing development processes and the use of premises, and by coordinating and integrating planning at the state, regional and local levels. The SP Act regulates the development of infrastructure outside of a mining lease and provides details of the Development Approval / Operational Works approval process for construction of infrastructure that is 'off lease'. The Sustainable Planning Regulation 2009 provides a mechanism to enforce the SP Act, managing the process by which development takes place and the effects of the development on the environment. The State Planning Policy 4/10: Healthy Waters is made under this Act, and addresses urban stormwater quality and ensures compliance with the EPP (Water).

Land Protection (Pest and Stock Route Management) Act 2002

The *Land Protection (Pest and Stock Route Management) Act 2002* (LP Act) lists declared freshwater plants, and provides a framework for managing pest animals and weeds. The species declared under the LP Act are those with the potential to cause serious economic, environmental or social impacts to Queensland.

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Establishing Environmental Values and Water Quality Objectives for the Waters of the Fitzroy Basin (DERM, 2011a)

A number of regional water quality guidelines have been developed for the protection of aquatic ecosystems within the Fitzroy River Basin and provide details of relevant water quality parameters, as well as indicator organisms for the evaluation of watercourses.

Local water quality guidelines (where they exist) are tailored to the protection of specific environmental values of the intended basin or sub-basin. These guidelines take precedence over state and national water quality guidelines, which are more generic in nature. The following regional water quality guidelines are relevant to the study area:

- Fitzroy River Sub-Basin Environmental Values and Water Quality Objectives (DERM, 2011b);
- Isaac River Sub-Basin Environmental Values and Water Quality Objectives (DERM, 2011c); and
- MacKenzie River Sub-Basin Environmental Values and Water Quality Objectives (DERM, 2011d).

Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000 (ANZECC and ARMCANZ, 2000)

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000 guidelines were developed as part of the implementation phase of the National Water Quality Management Strategy 1992, and provide a national framework for assessing water for ecological, recreational and agricultural use. These guidelines provide a methodology for assessing water quality through comparison with guidelines derived from local reference values.

Queensland Water Quality Guidelines 2009 (DERM, 2009)

The QWQG provide a framework for assessing water quality in Queensland through the setting of water quality objectives.

Regional Vegetation Management Code for Brigalow Belt and New England Tablelands Bioregions

The Regional Vegetation Management code has been prepared in accordance with provisions set out in the *Vegetation Management Act 1999* (VM Act). Although the VM Act does not directly apply to CSG activities, the code encompasses the study area and provides guidelines for appropriate riparian buffer strip width.

Back on Track Species Prioritisation Framework (EHP, 2012a)

The Back on Track species prioritisation framework (Back on Track) is an initiative of the EHP that:

- Prioritises Queensland's native species to guide conservation management and recovery;
- Enables the strategic allocation of limited conservation resources for achieving greatest biodiversity outcomes; and
- Increases the capacity of government, National Resource Management bodies and communities to make informed decisions by making information widely accessible.

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16.2 Assessment Methods

The aquatic ecology baseline assessment comprised a desktop study and field surveys, used to gain an understanding of and describe the existing aquatic environment. A significance assessment approach was used to determine the sensitivity of the aquatic ecosystem values, the magnitude of potential impacts associated with Project activities and the resulting levels of constraint that would be placed on Project activities.

16.2.1 Desktop Study

A review of the existing aquatic ecology information and data was undertaken for areas within and adjacent to (where relevant) the Project area (Figure 16-1). The desktop study incorporated a detailed literature review and searches of the following government, non-government databases and other sources:

- EPBC Act Protected Matters Search Tool (DSEWPaC, 2012);
- Wildlife Online Search Tool (EHP, 2012b);
- Regional Ecosystem and Remnant Vegetation map and High Value Regrowth map Search Tool (EHP, 2012c); and
- Analysis of data held by various agencies that was identified and purchased / procured where available, including Bureau of Meteorology climate data and stakeholder organisation data (fishing clubs and fisheries groups).

Database searches were undertaken to determine if any aquatic flora, fauna or areas protected under existing legislation occur within or adjacent to the Project area.

The Department of Environment and Resource Management (DERM) (now EHP) report on Aquatic Conservation Assessments for the Condamine Basin using the aquatic biodiversity assessment and mapping (AquaBAMM) method (Inglis and Howell, 2009) was also reviewed in the context of the Project. This report assesses the conservation value and current condition of wetlands and sub-catchment of watercourses in the Fitzroy and Burdekin Basins.

16.2.2 Field Survey

Potential aquatic ecology sampling sites representative of the aquatic environment within and adjacent to the Project area were identified through the desktop study. Refinement of these sites was achieved through field reconnaissance and consideration of physical and ecological factors of each site. Of the 25 potential sites identified in the desktop study, 10 were considered suitable for sampling and were reasonably accessible. Following the acquisition of the Bow Energy lease areas in January 2012, an additional five sites were assessed in the late wet (April-May) 2012 survey. However, one site previously assessed in the early wet (October) 2011 survey was not assessed in the late wet period 2012 survey due to land access constraints. The 15 sites selected across both survey periods were considered representative of the aquatic environment across the Project area (see Figure 16-1 and Table 16-1).

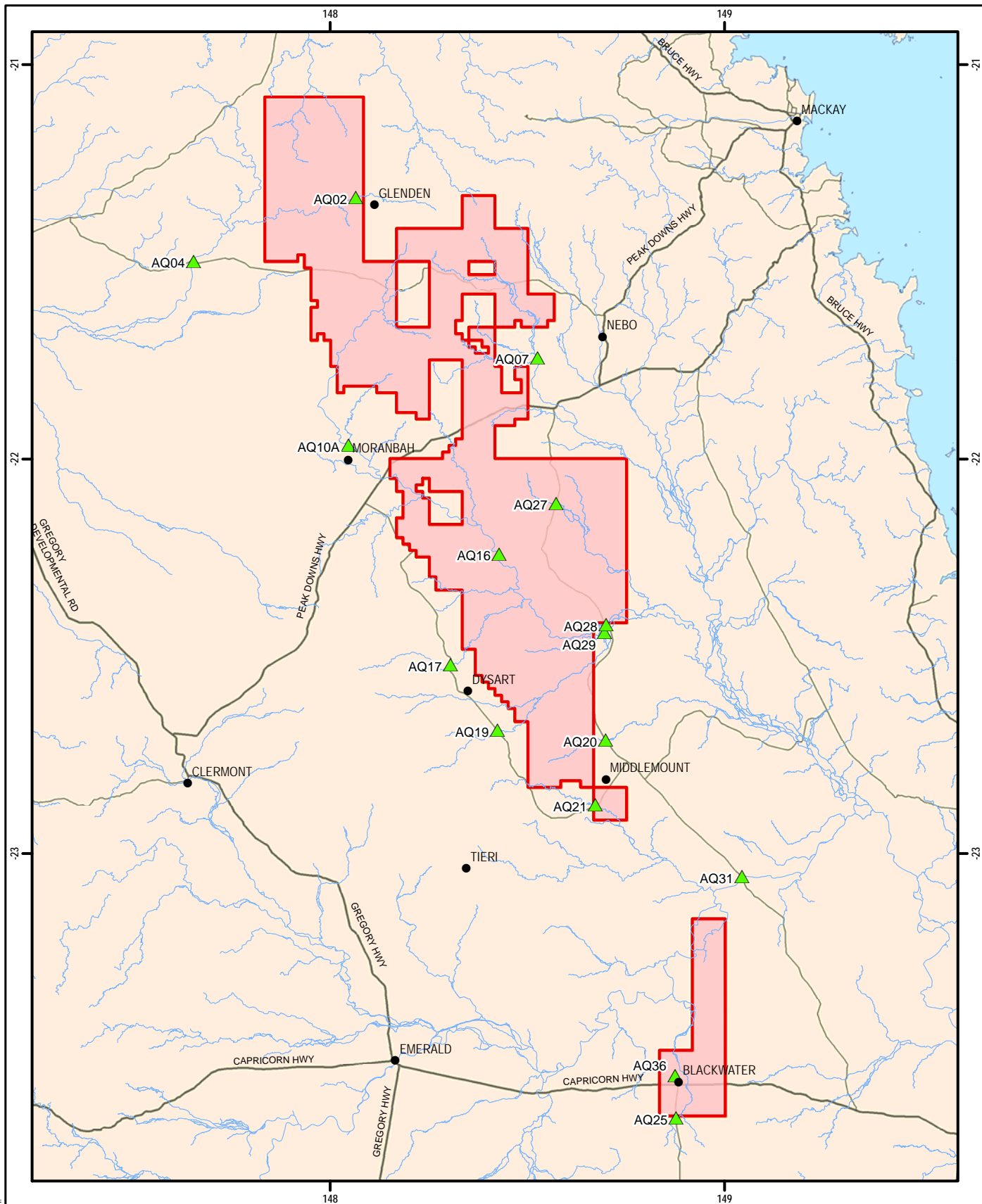
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Thirteen of the sites surveyed were located within the Fitzroy Basin; ten within the Isaac River sub-catchment and three within the Mackenzie River sub-catchment. As little of the Project area extends into the Burdekin Basin, only two suitable sites were identified in the upper reaches of the Suttor / Belyando sub-catchment. Photographs of each site for each survey occasion are shown in the Aquatic Ecology Technical Report (Appendix O) of this EIS.

The aquatic ecology survey sites were sampled and surveyed for the following:

- Physico-chemical water quality parameters were assessed in situ using a multi-probe water quality instrument (model TPS 90FL) and included pH, electrical conductivity, water temperature, dissolved oxygen and turbidity.
- Aquatic flora (macrophytes) to provide a visual assessment of the species present;
- Fish assemblages using a combination of either fine-mesh (6 millimetres (mm)) fyke nets, fine-mesh seine nets, unbaited traps, backpack electrofishing and/or boat electrofishing. The surveys aimed to provide details of the abundance and diversity of species. All fish survey methods were non-lethal and all native fish were returned unharmed to the water.
- Aquatic macroinvertebrates using standard field protocols outlined in the Australian Rivers Assessment System (AusRivAS) Queensland field manual (NRM, 2001). The surveys aimed to provide details of invertebrate assemblages at the sites, which could be compared to reference sites to provide an indication of the health and diversity of the aquatic ecosystems. Due to the limitations of using AusRivAS models on an ephemeral system with low overall diversity, a multivariate statistical approach was also utilised to determine whether the sites upstream of the Project area differed in terms of macroinvertebrate assemblages.
- Aquatic macrocrustaceans using various techniques utilised for surveying macroinvertebrates and fish as well as targeted visual inspections of the sites for the presence of additional crustaceans not collected by other methods.
- Turtles using a combination of either modified fyke nets and/or cathedral turtle nets. Observations were also made during electrofishing surveys.

Data collected through the desktop and field survey were interpreted using modelling, univariate and multivariate statistical analysis. Detailed survey methodology is provided in Section 3.3 in the Aquatic Ecology Technical Report (Appendix O) of this EIS.



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0 10 20 40 km
 1:1,500,000
 Projection: Geographic (GDA94)

■ Boven Gas Project Tenements
— Main Road
— Drainage

▲ Aquatic Ecology Sampling Site

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BOWEN GAS PROJECT EIS

AQUATIC ECOLOGY SAMPLING SITES



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Figure: **16-1**

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Date: 29-01-2013

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Table 16-1 Aquatic Ecology Sampling Sites

Site	Watercourse	Sub-catchment	Coordinates	Stream Order	Sampled	Basin	Predominant Landuse	Hydrology
AQ02	Suttor Creek	Suttor/Belyando River	21°20'12.27"S 148°03'53.24"E	2	Early wet 2011	Burdekin	Grazing	Ephemeral
AQ04	Suttor River	Suttor/Belyando River	21°29'53.09"S 147°39'12.11"E	5	Early wet 2011 Late wet 2012	Burdekin	Grazing, Mining	Permanent
AQ07	Bee Creek	Isaac River	21°44'35.35"S 148°31'32.09"E	3	Early wet 2011 Late wet 2012	Fitzroy	Grazing, Mining	Ephemeral
AQ10A	Isaac River	Isaac River	21°57'53.41"S 148°02'45.66"E	5	Early wet 2011 Late wet 2012	Fitzroy	Grazing, Mining	Ephemeral
AQ16	Isaac River	Isaac River	22°14'28.10"S 148°25'41.60"E	5	Early wet 2011 Late wet 2012	Fitzroy	Grazing, Mining	Ephemeral
AQ17	Phillips Creek	Isaac River	22°31'18.73"S 148°18'18.09"E	3	Early wet 2011 Late wet 2012	Fitzroy	Grazing, Mining	Ephemeral
AQ19	Scott Creek	Isaac River	22°41'16.06"S 148°25'25.82"E	3	Early wet 2011 Late wet 2012	Fitzroy	Grazing	Ephemeral
AQ20	Rolf Creek	Isaac River	22°42'42.37"S 148°41'53.53"E	3	Early wet 2011 Late wet 2012	Fitzroy	Grazing, Mining	Ephemeral
AQ21	Roper Creek	Isaac River	22°52'36.84"S 148°40'19.20"E	3	Early wet 2011 Late wet 2012	Fitzroy	Grazing, Mining	Ephemeral
AQ25	Taurus Creek	Mackenzie River	23°40'16.04"S 148°40'19.20"E	2	Early wet 2011 Late wet 2012	Fitzroy	Grazing, Mining	Ephemeral
AQ27	Devlin Creek	Isaac River	22° 6'41.10"S 148°34'4.98"E	2	Late wet 2012	Fitzroy	Grazing, Mining	Ephemeral

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Site	Watercourse	Sub-catchment	Coordinates	Stream Order	Sampled	Basin	Predominant Landuse	Hydrology
AQ28	Isaac River	Isaac River	22°25'11.33"S 148°41'57.10"E	5	Late wet 2012	Fitzroy	Grazing, Mining	Permanent
AQ29	Stephens Creek	Isaac River	22°26'23.4"S 148°41'40.8"E	4	Late wet 2012	Fitzroy	Grazing, Mining	Ephemeral
AQ31	Mackenzie River	Mackenzie River	23°03'32.03"S 149°02'37.35"E	7	Late wet 2012	Fitzroy	Grazing, Mining, Cropping	Permanent
AQ36	Sagittarius Creek	Mackenzie River	23°33'44.45"S 148°52'28.25"E	2	Late wet 2012	Fitzroy	Grazing, Mining, Urban	Ephemeral

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16.2.3 Impact Assessment Methodology

The construction, operation and decommissioning of the Project may result in a range of potential direct and indirect impacts to aquatic ecosystems.

- Riparian / aquatic vegetation clearing and/or disturbance;
- Loss or fragmentation of aquatic habitat;
- Creation of physical or velocity barriers to the movement of aquatic organisms;
- Physical disturbance to watercourse banks or beds;
- Changes in water or sediment quality or quantity;
- Sediment transport, change in sediment scouring / deposition patterns or smothering of habitat; and
- Introduction and translocation of exotic flora and fauna.

These impacts have been assessed in the context of activities undertaken during construction, operation and decommissioning of the Project. The potential significance of these impacts has been quantified as a function of the sensitivity of aquatic ecosystem values and the magnitude of the potential impact, using the matrix shown in Table 16-2.

Table 16-2 Significance Impact Assessment Matrix

		Sensitivity of Environmental Value		
		High	Moderate	Low
Magnitude of Impact	High	Major	High	Moderate
	Moderate	High	Moderate	Low
	Low	Moderate	Low	Negligible

The magnitude of potential impacts on each species assessed (both unmitigated and residual), are rated as either:

- Major impacts are typically associated with long term, widespread or very severe impacts on iconic environmental values of national or international conservation significance;
- High impacts may relate to lower magnitude impacts on iconic environmental values, or may be the result of long term, widespread or severe impacts on species of state significance;
- Moderate impacts are associated with severe impacts on less sensitive environmental values, or to less severe impacts on environmental values of state or national significance;
- Low impacts are those that are relatively short term, low severity and localised, and that affect environmental values that are marginal or are tolerant of disturbance events; or
- Negligible impacts that are of such low magnitude or affect such low value ecosystems that no mitigation or avoidance strategies are warranted.

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The sensitivity criteria used for the assessment of aquatic ecosystem values and the magnitude of impact criteria are detailed in Sections 3.4.1 and 3.4.2 of the Aquatic Ecology Technical Report (Appendix O) of this EIS. Further information on impact assessment methodology is provided in the Impact Assessment Method chapter (Section 6) of this EIS.

16.3 Existing Aquatic Environment and Environmental Values

This section describes the general characteristics of the aquatic environment and identifies the ESAs of permanent, semi-permanent and ephemeral watercourses.

16.3.1 General Aquatic Ecology Characteristics

Historically the catchment within the study area has been subjected to various levels of environmental disturbance a result of ongoing agricultural activity, mining and some urban development. There is limited data available predating this disturbance, however anecdotal information suggests that there has been a decline in the diversity and abundance of aquatic communities. The species and communities that have prevailed to the present time are generally robust, able to tolerate a wide range of conditions and resilient to disturbance events. This is particularly marked for smaller ephemeral systems, however the number of potentially susceptible species remaining increases with increased stream size. No wetlands occurring within the Project area were listed as significant under the EPBC Act. An Aquatic Conservation Assessment was also undertaken using AquaBAMM to assess the conservation and ecological value of wetland systems in sub-catchments relevant to the Project area (Inglis and Howell, 2009), the results of which are detailed in Section 4.2.2 in the Aquatic Ecology Technical Report (Appendix O) of this EIS.

Fifteen aquatic survey sites were assessed during the field surveys. Due to the dry nature of the catchment, site selection extended over a large percentage of watercourses within the study area. These sites include large permanent flowing watercourses, semi-permanent watercourses and ephemeral watercourses.

Taken holistically, aquatic ecosystems within the study area are in moderately good health, although the site AQ27 (Devlin Creek) was in particularly poor health due to significant oxygen depletion associated with late stages of drying up. As this site was sampled during the late wet 2012 survey, it is likely that this site only retains water for relatively short periods of time.

Fifteen species of aquatic macrophytes were recorded, all of which are native. None of these macrophyte species were considered to be of conservation significance, or listed as pests under the LP Act. Despite the low to moderately disturbed nature of the study area, aquatic weeds were neither widespread nor locally abundant. No threatened aquatic macrophyte species were identified in the study area during database searches. A number of riparian flora and frog species that may utilise aquatic habitats were identified, and have been addressed in the Terrestrial Ecology chapter (Section 17) of this EIS.

Macroinvertebrate assemblages from pool beds and edge habitats were comparable and both were in a relatively healthy condition, typical of ecosystems exposed to low to moderate disturbance.

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Literature searches and field surveys did not reveal any macroinvertebrate species (including macrocrustaceans) of conservational value.

Typical of watercourses which are largely ephemeral, fish assemblages within the study area were relatively species poor, dominated by a small number of taxa. The clear exception to this was site AQ31 (Mackenzie River) the only permanently flowing watercourse in the study area with 13 species of fish recorded from a single survey event. While no fish species were identified in the study area as listed under state or Commonwealth legislation, three species are endemic to the Fitzroy River Basin (golden perch *Macquaria ambigua orientalis*, southern saratoga *Scleropages leichardti* and leathery grunter *Scortum hillii*) and are of some conservation significance being listed under a variety of non-statutory conservation schemes including Australian Society for Fish Biology (2001). Two exotic fish species were recorded across the study area; tilapia (*Oreochromis mossambicus*) in the early wet 2011 survey, and mosquitofish (*Gambusia holbrooki*) in the late wet 2012 survey.

Statistical analysis of macroinvertebrates and fish indicates a high degree of similarity in the composition of populations between survey sites, irrespective of drainage basin. The main differences between macroinvertebrate assemblages were related to low abundances in several of the samples, as opposed to differences in assemblage composition. Differences in fish assemblages were related to stream size and drainage basin. The most notable site differences were recorded at site AQ31 (Mackenzie River), which was had the highest stream order and AQ02 (Suttor Creek), and AQ04 (Suttor River) in the Burdekin Basin, which contained tilapia which have yet to spread to the Fitzroy Basin.

A total of 39 Krefft's turtles (*Emydura macquarii krefftii*) were caught during field surveys, the majority found at site AQ04 (Suttor River). The Fitzroy River turtle (*Rheodytes leukops*) is the only species within the Project area that is listed as a nationally significant aquatic species under the EPBC Act was not recorded during field surveys. The Fitzroy River turtle is listed as 'vulnerable' under both the EPBC Act and state (NC Act) legislation. The white-throated snapping turtle (*Elseya albagula*) is listed as 'least concern' in Queensland (NC Act) and, along with the Fitzroy River turtle, is ranked as a high priority under the EHP Back on Track species prioritisation framework.

The Mackenzie River in the southern section of the Project area is a known habitat for Fitzroy River turtle and white-throated snapping turtle, and ongoing research continues to expand the range that both species are known to exist.

16.3.2 Sensitivity of Aquatic Environmental Values

16.3.2.1 Large Permanent and Semi-Permanent Watercourses

The large permanent and semi-permanent watercourses within the Project area are the Isaac and Mackenzie Rivers. While there are fundamental differences in the hydrology of these rivers (the Mackenzie River retaining reasonable flows throughout the year and much of the Isaac River being reduced to a series of isolated pools), their central role in facilitating the dispersal of aquatic organisms is pivotal in maintaining the health of the aquatic ecosystems throughout and beyond the Project area.

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Permanent and semi-permanent large watercourses are considered to have a **high sensitivity** to potential unmitigated impacts (refer to Table 3.6 in the Aquatic Ecology Technical Report (Appendix O) of this EIS) associated with the Project because:

- They support two turtle species of significance; the Fitzroy River turtle which is listed under both Commonwealth and state legislation; and the white-throated snapping turtle. These are both ranked as a high priority under the EHP Back on Track species prioritisation framework;
- They support a number of fish species of conservation significance, including southern saratoga, a subspecies of golden perch and leathery grunter. These are all endemic to the Fitzroy River Basin;
- They are utilised to varying degrees as recreational fisheries, with the Mackenzie River more frequented by anglers than the Isaac River;
- Ranging from minimally disturbed to moderately disturbed, these systems contain many areas of good quality aquatic habitat known to support a relatively diverse range of aquatic species including fish, turtles and invertebrates. Spawning habitat for aquatic species represents critical spawning habitat;
- These systems are unique at a national scale in terms of biota, communities and processes;
- Deeper and remnant pools provide dry season refugia and core habitat range of aquatic species;
- Deeper and remnant pools provide source populations for watercourses when wet season flows provide connectivity for migration; and
- The communities in large permanent and semi-permanent watercourses tend to be longer lived than those from ephemeral systems and are less likely to recolonise following disturbance. Consequently, there is greater possibility of these species or communities becoming locally extinct.

16.3.2.2 Small Permanent and Semi-Permanent Watercourses

The small permanent and semi-permanent watercourses in the Project area include Bee Creek, Scotts Creek, Stephens Creek, Rolf Creek and Phillips Creek. These systems contain water all year round, although in many cases they are reduced to a series of isolated pools during the dry season.

Small permanent and semi-permanent watercourses are considered to have a **moderate sensitivity** to potential unmitigated impacts (refer to Table 3.6 in the Aquatic Ecology Technical Report (Appendix O) of this EIS) associated with the Project because:

- They support two turtle species of significance; the Fitzroy River turtle which is listed under both Commonwealth and state legislation; and the white-throated snapping turtle. These are both ranked as a high priority under the EHP Back on Track species prioritisation framework;
- They support a number of fish species of conservation significance, including southern saratoga, a subspecies of golden perch and leathery grunter. These are all endemic to the Fitzroy River Basin;
- They are utilised to a limited degree as recreational fisheries. However, they are not considered high value in the context of the overall recreational fishing resources in southeast Queensland and are not heavily used by recreational anglers;
- Ranging from minimally disturbed to highly disturbed, these systems contain many areas of good quality aquatic habitat 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;
- These systems are unique only at a local scale in terms of biota, communities and processes;

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- Deeper and remnant pools provide dry season refugia and core habitat range of aquatic species;
- Deeper and remnant pools provide source populations for watercourses when wet season flows provide connectivity for migration; and
- The communities in small permanent and semi-permanent watercourses tend to be longer lived than those from ephemeral systems and are less likely to recolonise following disturbance. Consequently, there is greater possibility of these species or communities becoming locally extinct.

16.3.2.3 Ephemeral Watercourses

The ephemeral watercourses in the Project area include Suttor Creek, Devlin Creek, Sagittarius Creek and Taurus Creek. A high proportion of the ephemeral systems within the study area are unnamed first or second order systems that flow for very limited periods each year. The simplest of these systems are often little more than drainage lines through agricultural or forested areas. The more substantial examples hold water for longer periods of time and have slightly higher habitat value for aquatic fauna. These systems range from being only slightly disturbed by existing land use activities to being highly disturbed agricultural drainages.

In terms of their sensitivity to disturbance events, ephemeral watercourses within the Project area have the following attributes (refer to Table 3.6 in the Aquatic Ecology Technical Report (Appendix O) of this EIS):

- They have no formal conservation status, no species, habitat or aquatic communities of special conservation significance and no fisheries values potential;
- Primarily provide marginal aquatic habitat due to the short periods during which they contain water, lack of connectivity to larger, permanent watercourses and minimal spawning / nursery habitat. However, due the dry nature of the Project area the few pools that remain are likely to provide crucial refugia for recolonising following the onset of the wet season;
- They are not unique on a local or regional scale and represent a very small proportion of similar aquatic habitat regionally; and
- They are likely to be opportunistically utilised by aquatic fauna and flora that are tolerant of significant disturbance events and which are adapted to rapidly colonise and regenerate when conditions are suitable.

Overall, aquatic communities and values associated with these ephemeral systems are considered to have relatively **low sensitivity**.

16.3.3 Likelihood of Stygofauna Occurrence in the Project Area

Stygofauna are aquatic animals that inhabit groundwater. Stygofauna in Australia are predominantly crustaceans that are between 0.3 and 15 mm in length. However, some worms, insects, snails and other invertebrates, as well as two species of blind fish also contribute to the stygofauna group (Humphreys, 2006). Stygofauna are considered an integral part of the groundwater biodiversity and may be functionally important, especially in the hyporheic zones.

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A desktop assessment was undertaken of the likelihood of stygofauna occurrence in the Project area to support Arrow making informed planning decisions. The full detailed assessment is provided in the Stygofauna Technical Report (Appendix EE) of this EIS.

It is predicted that stygofauna habitat may occur in the Project area, particularly in aquifers along perennial rivers and in fractured areas where there is hydraulic interconnectivity. Where aquifers are associated with highly ephemeral streams, potential habitat is considered to be less likely. Also, further from the main river's alluvium, in the older alluvium and unconsolidated sediments, there is likely to be fewer permanent aquifers, and some of the aquifers may be confined, again making the presence of potential habitat less likely.

Stygofauna presence was considered to be possible along fault zones and in uplifted rock formations where there is fracturing that could provide enhanced hydraulic connectivity (or to other aquifers). Porous rock formations in the Project area are unlikely to contain stygofauna unless the rock is highly permeable and the particle size allows good porosity through the strata. In addition, the likelihood of finding stygofauna in coal seam aquifers is considered to be rare due to low permeability, less connectivity to recharge and water quality properties.

The results of the assessment were used to prepare a preliminary assessment map of likelihood of stygofauna presence in the envisaged Zone of Influence (refer to the Stygofauna Technical Report (Appendix EE) of this EIS).

Based on the likelihood of stygofauna presence in the Project area, a range of management strategies for activities associated with CSG production that may impact on stygofauna were developed. Activities may include, but are not limited to clearing, drilling, and groundwater extraction; not all of which would have the potential to impact on the stygofauna.

Arrow CSG operations follow established well drilling and construction procedures to minimise the potential impact on aquifers that may be intersected. CSG production bores are sealed to prevent gas loss, inter aquifer movement, and to limit the amount of water needed to be pumped.

The shallow aquifers that may be intersected when a CSG well is drilled are isolated from the target coal seams by the cemented steel providing a mechanical barrier between the inside of the well and the surrounding geological formations, to minimise the risk of leakage of drilling fluids or CSG water to the intersected aquifers. This provides zonal isolation behind the casing between different geological formations (to minimise the risk of leakage) and also protects the casing against damage (Arrow, 2011).

The technology used to achieve zonal isolation is very advanced and has been industry tested in differing and adverse conditions around the world. Arrow relies on these procedures to prevent cross-flow of gas or water between different geological layers and minimise the risk of impacts to groundwater values. With the implementation of these procedures it is considered that there is a very low likely hood or risk of potential impacts to identified potential stygofauna habitat from drilling operations conducted in this manner.

Other processing facilities are not considered to potentially directly impact on groundwater resources.

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16.4 Issues and Potential Impacts

Project activities with the potential to cause these direct or indirect impacts on aquatic ecosystem values during the construction, operation and decommissioning phases of the Project are described below. The assessment of potential impacts assumes that industry standard management practices (e.g. for management of construction projects and storage of fuels, lubricants, dangerous goods, wastes, erosion and stormwater) would be applied as baseline mitigation controls.

16.4.1 Site Clearing and Levelling

The removal of riparian or aquatic vegetation, or terrestrial vegetation in close proximity to watercourses, may result in short-term exposure of soil to erosion and sediment transport processes, particularly if sodic soils are disturbed or denuded. This may impact on aquatic ecosystems through the creation of poor water quality or smothering of benthic habitat with sediment. This activity has therefore been assigned an impact magnitude rating of 'Moderate' for both large and small permanent / semi-permanent waterways, and "Low" for ephemeral systems (refer to Section 16.2.3 of this chapter for further information on impact magnitude rating).

16.4.2 Construction of Access Tracks

Constructing tracks to enable access of machinery for the construction, operation and maintenance of wells, gathering lines and overhead power lines may require removing vegetation and earthmoving activities. Impacts on aquatic ecosystems as a result of this activity are largely associated with the construction phase, when freshly denuded and/or disturbed soils are most at risk of erosion. Track construction can also lead to sediment transport. There is potential for the contamination of waterways as a result of fuel, oil or chemical spills, use of herbicides during track maintenance, and increased public access (litter). This activity has therefore been assigned an impact magnitude rating of "Moderate" for both large and small permanent / semi-permanent waterways, and "Low" for ephemeral systems.

16.4.3 Use of Vehicles / Plant / Machinery near Waterways

These activities have the potential to contaminate waterways as a result of fuel, oil or chemical spills, use of herbicides during track maintenance, and increased vehicle access (litter). The geographic extent, duration and severity of these types of events would depend on hydrological conditions and on the nature and volume of the contaminants involved. However, the normal protocol of restricting refuelling and maintenance operations to designated, bunded facilities largely overcomes the potential for such impacts. If tracks are constructed close to waterways or include creek crossings, there is potential for physical disturbance of stream beds / banks and or riparian or aquatic vegetation or habitat. Poorly formed and maintained tracks may be prone to rutting and erosion, which can result in ongoing sediment transport during storm events. Minor, short-term impairment of aquatic communities is the most likely level of severity, although temporary / partial loss of aquatic values is possible. Consequently, this impact has been assigned a "Moderate" impact magnitude rating for both small permanent / semi-permanent waterways, and "Low" for ephemeral systems.

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16.4.4 Waste Management

Specific waste streams associated with the construction and operation of the Project include:

- Sewage and human waste;
- Construction waste;
- Chemical, oil and fuel waste;
- Drilling waste (e.g. bentonite, lubricants and other drilling chemicals);
- Green waste;
- Concentrated brine from reverse osmosis of CSG water; and
- Spoil.

Waste management on site will follow normal or routine operations to minimise impacts on aquatic ecosystems. For further information refer to the Waste Management chapter (Section 28) of this EIS.

Most of these waste streams are very unlikely to occur within or in close proximity of watercourses. If contaminated by waste streams, the potential impacts on aquatic ecosystems may include the creation of poor water quality and contamination or smothering of benthic habitat with sediment. The duration and severity of impacts under normal or routine operations are likely to be moderate. As a result, this activity has been assigned a "Moderate" rating for both small permanent / semi-permanent waterways, and "Low" for ephemeral systems.

16.4.5 Gathering System

It is understood that trenching operations would largely be restricted to the construction phase of the Project, although it may become necessary to excavate gathering lines in the event that emergency maintenance is required. Gathering system includes gas and water lines from wells to facilities, water balancing lines between facilities and dams; and may also include infield high voltage / low voltage power distribution and Supervisory Control and Data Acquisition (SCADA) and telecommunication cables. The potential impacts on aquatic ecosystems as a result of this activity are similar to those described in Section 16.4.2 for Construction of Access Tracks. Impacts are generally likely to be quite localised and of short duration. However, changes to bank and in-stream erosion and sediment transport impacts may be longer term and may result in temporary or partial loss of aquatic ecosystem values; hence this activity has been assigned a "Moderate" impact rating.

16.4.6 Drilling Operations - Sumps for Waste Water / Drilling Product Management

Sumps are often constructed to contain wastewater and drilling products during drilling of wells and bores. Several holes are usually drilled and involve continual wetting of the drill during operations. Formation water extracted during the drilling operations would be removed from the well site and transported to dams or a waste disposal facility. These ground disturbance activities have the potential to impact on the environmental values of soils, vegetation, watercourses and water quality. These impacts are only likely to occur in the event of a severe storm event, when sumps may potentially overflow. At these times, ambient water quality in streams within the study area is likely to be relatively poor, with naturally elevated turbidity and suspended solid loads. Dilution of drilling sump overflow is

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therefore likely to reduce the severity but increase the geographical extent of this impact. This impact has therefore been assigned a “Low” impact magnitude rating.

16.4.7 Altered Surface Water Hydrology

Arrow is exploring the option of waterway discharge with the regulators. Emergency water releases may also become necessary during periods of high rainfall, when demand for beneficial use can be low, but production of treated water remains constant. Unseasonal flows into ephemeral or semi-permanent waterways are more likely to have ecological consequences if they are made during the dry season. The severity and geographic extent for this impact is dependent on seasonal and other conditions within the receiving waters and on the magnitude and duration of discharge. In addition, the potential to facilitate the movement of exotic species could create long-term impacts and these releases have therefore been assigned a “High” magnitude rating across all systems.

16.4.8 Operation and Maintenance Activities

The potential impacts of these activities would vary depending on the nature of the activity. For example, routine inspections of wells and gathering line easements would have negligible impact on aquatic ecosystems. Vegetation management along gathering line easements can be expected to have relatively low impacts if the area is not denuded of vegetation. However, in the event that a gathering line must be excavated for repair or replacement, the impacts could be higher. Access tracks would be permanent. This activity has therefore been assigned a “Moderate” impact magnitude rating except for ephemeral systems, where the magnitude of impacts is considered to be “Low”.

16.4.9 Maintenance of Access Tracks and Gathering Line Easements

The maintenance of access tracks involves management of vegetation, erosion and water runoff. Activities may include vegetation clearing, spraying, grading or resurfacing. The potential impacts on aquatic ecosystems as a result of this activity are similar to those described in Section 16.4.8 for Operation and Maintenance Activities. Track and easement maintenance in the vicinity of waterway crossings has higher potential to impact on aquatic systems, but remains low in terms of extent, duration and severity. They have therefore been assigned an impact magnitude rating of “Low”.

16.4.10 Summary of Potential Impacts

The significance impact assessment of potential unmitigated impacts on aquatic ecosystem values from Project activities are summarised in Table 16–3.

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Table 16-3 Summary of Potential Unmitigated Significance Assessment on Aquatic Ecosystem Values

Activity	Large Permanent / Semi-permanent Watercourses	Small Permanent / Semi-permanent Watercourses	Ephemeral Waterways
Site clearing and levelling	High	Moderate	Negligible
Construction of access tracks	High	Moderate	Negligible
Use of vehicles / plant / machinery near waterways	High	Moderate	Negligible
Waste management	High	Moderate	Negligible
Gathering trenching system	High	Moderate	Negligible
Gathering line or access road creek crossings	High	Moderate	Negligible
Drilling operations	Moderate	Low	Negligible
Altered surface water hydrology	Major	High	Moderate
Operation and maintenance activities	High	Moderate	Negligible
Maintenance of access tracks and gathering line easements	Moderate	Low	Negligible

16.5 Environmental Protection Objectives

The environmental protection objectives for aquatic ecosystems are:

- To avoid or minimise adverse impacts to the aquatic ecology of large and small permanent and semi-permanent watercourses and ephemeral watercourses; and
- To control the introduction or spread of new or existing exotic aquatic flora or fauna species.

16.6 Avoidance, Mitigation and Management Measures

With the exception of two large permanent / semi-permanent watercourses (Mackenzie and Isaac Rivers) that provide potential habitat for two turtle species (Fitzroy River turtle and white-throated snapping turtle) and three fish species (golden perch, southern saratoga and leathery grunter) of some conservation significance, aquatic ecosystem values should pose relatively few constraints on the construction and operations of the Project.

Table 16-4 summarises the risk-based constraints framework used to determine the level of environmental management required for Project activities. The level of constraint assigned to

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watercourses and riparian zones across the majority of the study area is “Moderate”. This reflects that watercourses within the Project area are already subjected to disturbance, largely ephemeral, considered to be of relatively moderate health and contain few listed aquatic species or communities. Large permanent / semi-permanent watercourses, the Mackenzie and Isaac Rivers, have been identified as areas of higher sensitivity and are categorised as areas of “High” constraint.

Table 16-4 Risk-based Constraints Framework

Constraint	Project Activity			Applicable Framework
	Drilling Wells	Installing Gathering lines	Facilities Installation	
'No Go'	N	N	N	Avoidance principle applies. No activity permitted. Procedural and behavioral controls in place to ensure strict compliance.
High	Y	Y	N	Controls apply. These are discussed below.
Moderate	Y	Y	Y	Standard operating procedures apply for wells and gathering lines. Site specific controls must be in place for water treatment and storage facilities to ensure that aquatic ecosystems are un-impacted by altered surface water hydrology.
Low	Y	Y	Y	Standard operating procedures apply.

The following section outlines the specific avoidance, mitigation and management measures that would be implemented to reduce the potential impacts on aquatic ecosystem values from Project activities (described in Section 16.4 of this chapter).

16.6.1 Site Clearing and Levelling

The Waste Management Plan, Erosion and Sediment Control Plan and Weed Management Plan will be designed to avoid or minimise the potential impacts of the Project. If necessary the Water Management Plan may also be prepared, including water resource and water quality management.

As construction activities may require small scale clearing of vegetation to facilitate well or gathering line installation, the adoption of appropriate riparian buffer zones along all watercourses is essential. Buffer zones will be adopted for Project activities (with the exception of required creek crossings), in different areas of constraint, as defined by the Project's constraints mapping (outlined in the Environmental Framework chapter (Section 7) and detailed in Constraints Mapping (Appendix BB) of this EIS).

The buffers outlined below are indicative based on the current regulatory conditions, however these may be subject to change in future. The buffers that will be implemented for the Project will be in line

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with the regulatory requirements at the time of implementation. Indicative buffers at this time include [B196]:

- In areas mapped as high constraint a buffer of 100 m, measured from the bank edge, will be adopted during all phases of the Project, with a further 100 m constrained to low impact activities; and
- For areas mapped as moderate constraint, the following buffer zones, measured from the bank edge, will be adopted during all phases of the Project:
 - a riparian buffer of 50 m width on either side of first and second order streams; and
 - a riparian buffer of 100 m width on either side of third, fourth, fifth and higher order streams.

Where creek crossings for access tracks or gathering lines are required, adopting buffer zones is impractical. Alternative mitigation measures for these activities are outlined in Section 16.6.5.

16.6.2 Construction of Access Tracks

The Waste Management Plan, Erosion and Sediment Control Plan and Weed Management Plan will be designed to avoid or minimise the potential impacts of the Project. If necessary the Water Management Plan may also be prepared, including water resources and water quality management strategies.

It is anticipated that the construction of access tracks will be kept to a minimum, with the preferred use of existing tracks and roads wherever possible. Much of the study area has been previously cleared for agriculture, so access to most areas does not require the removal of vegetation.

Except in the immediate vicinity of creek crossings, tracks will be restricted in riparian zones and durations of impacts minimised, except in the immediate vicinity of creek crossings.

Where waterway crossings are unavoidable, measures will be taken to ensure that the movement of aquatic species is not impacted. The specific measures applied will be negotiated with the Fisheries Queensland (DAFF) personnel when an application for a waterway barriers permit is prepared. Mitigation measures may include fish friendly design of culverts, alternative routes for passage, minimising the amount of dark areas, and providing baffles or other structures to provide resting points out of the stream flow.

During the design and construction of waterway crossings, care will be taken to minimise the footprint of the structure and to avoid unnecessary disturbance to stream beds and banks. Construction will occur during dry months where possible, and the use of machinery and vehicles on stream beds and banks will be avoided.

16.6.3 Use of Vehicles / Plant / Machinery near Waterways

The use of vehicles and machinery near waterways is expected to be minimal, and will be avoided wherever possible and expected to be minimal [B194].

Machinery hygiene protocols will minimise the potential for the introduction and translocation of exotic flora via vehicles and machines.

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16.6.4 Waste Management

The Water Management Plan and Waste Management Plan will be designed to avoid or minimise the potential impacts of Project. For further information refer to the Waste Management chapter (Section 28) of this EIS.

The most significant waste streams associated with the CSG facilities are likely to be treated waste water and concentrated brine. CSG water received at integrated processing facilities is predominantly expected to be treated using reverse osmosis, then balanced to ensure that it is suitable for the intended beneficial use. CSG water received from the field, treated water and brine concentrate will be managed in dams adjacent to integrated processing facilities [B195].

16.6.5 Gathering Systems

The Water Management Plan, Acid Sulphate Soil Management Plan, Erosion and Sediment Control Plan, and Revegetation Plan will be designed to avoid or minimise the potential impacts of the Project. In addition, the Fitzroy River Turtle Management Plan, Waste Management Plan, and Weed Management Plan will be prepared for gathering systems or access road creek crossings.

16.6.5.1 Gathering Trenching Systems

Wherever possible, the gathering lines will be designed to avoid creeks, drainage lines and riparian zones (particularly permanent watercourses or perennial aquatic habitat), thus minimising impacts on aquatic ecosystems.

The most significant potential for impacts may occur where the gathering line crosses waterways. This will be minimised by ensuring that the trenching is perpendicular to the creek, thus minimising the footprint. The width of the easement will also be narrowed at these points, further reducing impacts on stream banks, beds and riparian zones by restricting the area of waterway that may be disturbed.

Trenching within or in the vicinity of watercourses will occur during the drier months of the year, which will reduce the potential for water quality decline as a result of sediment mobilisation. In the case of ephemeral systems, rehabilitation of trench lines will be completed prior to the wet season flow events, so no impacts are anticipated. This strategy will also avoid restricting aquatic biota opportunistic movement into ephemeral systems.

16.6.5.2 Gathering System or Access Road Creek Crossings

Gathering line and access road creek crossings will be kept to a minimum, gathering systems designed so that multiple feeder lines are gathered into one gathering line prior to crossing.

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16.6.6 Drilling Operations – Sumps for Waste Water / Drilling Product Management

The potential impacts of drilling on aquatic systems are associated with spillage, overflow or discharge from sumps used to contain waste water and/or chemicals associated with drilling (e.g. bentonite). The Water Management Plan, Acid Sulphate Soil Management Plan, Erosion and Sediment Control Plan, and Waste Management Plan will aid in minimising the potential impacts of the Project.

16.6.7 Altered Surface Water Hydrology

Unforeseen periods of significant prolonged rain or flooding (outside annual wet season flows) may lead to holding dams reaching their design storage allowance. In these events in order to ensure dam integrity is maintained, emergency discharge of treated water from the water treatment / storage facility may be required. These releases would occur only when beneficial use disposal options are unavailable.

16.6.8 Operation and Maintenance Activities

Vegetation management from operation and maintenance activities along gathering line easements is expected to have relatively low impact. The Water Management Plan, Waste Management Plan, Acid Sulphate Soil Management Plan, Weed Management Plan, Erosion and Sediment Control Plan, and Revegetation Plan will be implemented to avoid or minimise the potential impacts of Project. The likely maintenance and operational activities (including excavation of gathering lines) have been outlined in the preceding discussions and by best practice standard operating procedures.

16.6.9 Maintenance of Access Tracks and Gathering Line Easements

The Water Management Plan, Acid Sulphate Soil Management Plan, Weed Management Plan, Erosion and Sediment Control Plan, and Revegetation Plan will be implemented to avoid or minimise the potential impacts of Project. In addition, for maintenance of road creek crossings a Fitzroy River Turtle Management Plan will also be prepared.

The use of herbicides in the vicinity of watercourses or within riparian zones will be limited to those chemicals registered and approved for use in these areas (e.g. Roundup Bioactive), and in agreement with the landholder.

16.7 Residual Impacts

16.7.1 Site Clearing and Levelling

With the exception of limited track construction to enable access to of machinery for the construction, operation and maintenance of wells, and overhead power lines and gathering line trenching (addressed elsewhere), no clearing or levelling will occur within highly constrained areas. This eliminates potential impacts associated with site clearing and levelling on both large and small

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permanent / semi-permanent waterways. Acceptable buffer distances may change pending the outcomes of discussions between Arrow and EHP.

In terms of preparing sites for the construction of wells, gas and water gathering lines, and CSG water treatment facilities, the application of the Project constraints guidelines outlined in Section 16.6.1 will mean the implementation of a number of buffers along waterways. The buffers outlined below are indicative based on the current regulatory conditions, however these may be subject to change in future. The buffers that will be implemented for the Project will be in line with the regulatory requirements at the time of implementation. Indicative buffers at this time include:

- Establishment of 100 m buffer zones from the bank edge of all 5th and higher order streams. As no clearing or site levelling will occur within this zone, impacts on permanent and semi-permanent waterways will be eliminated. A further 100 m will be designated as restricted to low impact activities;
- Establishment of 100 m buffer zones from the bank edge of all 3rd and 4th order streams; and
- Establishment of 50 m buffer zones from the bank edge of all 1st and 2nd order streams.

16.7.2 Construction of Access Tracks

In terms of constructing access tracks, the application of the constraint guidelines outlined in Section 16.6.2 will have the following implications for the aquatic ecosystems within the Project area:

- Track construction within High constraint areas will be avoided where possible and will be kept to a minimum where this is not possible. Where track construction must occur, the application of other specific mitigation measures outlined in Section 16.6.2 will reduce impact magnitude to “Moderate”; and
- Other specific mitigation measures described in Section 16.6.2 will result in impacts of track construction within these areas, resulting in an impact magnitude rating of “Low”.

16.7.3 Use of Vehicles / Plant / Machinery near Waterways

In terms of constructing access tracks, the application of the constraint guidelines outlined in Section 16.6.3 will have the following implications for the aquatic ecosystems within the Project area:

- The use of vehicles, plant and machinery within highly constrained areas must be avoided where possible. Where this is not possible, use will be kept to a minimum, and the application of other specific mitigation measures outlined in Section 16.6.3 will reduce the impact magnitude to “Low”; and
- Within buffer zones of Moderate constraint area, the use of vehicle, plant and machinery will be minimised. This, along with specific mitigation measures described in Section 16.6.3, will result in an impact magnitude rating of “Low”.

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16.7.4 Waste Management

The following constraints have been placed on waste generation and management: Construction activities in high constraint areas will be kept to limited petroleum activities only¹. This eliminates many waste streams from these areas, including sewage, significant construction waste, concentrated brine and/or spoil; and within buffer zones in High and Moderate constraint areas, the generation of waste will be minimised and generated waste will be removed for disposal at registered facilities. This, along with specific mitigation measures described in the Waste Management chapter (Section 28) of this EIS will result in waste management being assigned an impact magnitude rating of “Low”.

16.7.5 Gathering Systems

16.7.5.1 Gathering Trenching Systems

The following constraints have been placed on gathering line and gathering line trenching under the constraints analysis outlined in Section 16.6.5:

- Trenching within highly constrained areas will be minimised and will comply with the generic and specific guidelines provided in Section 16.6.5.1; and
- Within buffer zones in moderately constrained parts of the Project area, trenching will be minimised and will comply with the generic and specific guidelines in Section 16.6.5.1. Other specific mitigation measures described in Section 16.6.5.1 will ensure that the impact magnitude rating remains “Low”.

16.7.5.2 Gathering System or Access Road Creek Crossings

The following mitigations have been placed on gathering line and access road creek crossings under the constraints analysis outlined in Section 16.6.5.2:

- Creek crossings will be minimised within highly constrained areas, reducing impacts to large permanent / semi-permanent streams to “Moderate”; and
- No specific mitigation (in addition to the generic mitigation strategies in Section 16.6.5.2) is possible for moderately constrained areas, so the impact magnitude rating for these areas will be ‘Moderate’.

¹ **Limited petroleum activities** outlined below are indicative based on current regulatory conditions, however these may be subject to change in future and will be in line with the regulatory requirements at the time of implementation:

- Well sites not exceeding 1 ha disturbance and multi-well sites not exceeding 1.5 ha disturbance. Well sites may include the following infrastructure:
 - well pads;
 - water pumps and generators associated with well operations;
 - sumps for storing drilling muds;
 - flare pits; and
 - ponds used to contain and/or store stimulation fluid;
- Geophysical surveys (including seismic petroleum activities);
- Ecological geological surveys (including seismic petroleum activities);
- Gathering / flow pipelines from a well head to the initial compression facility;
- Supporting access tracks; and
- Communication and power lines that are necessary for the undertaking of petroleum activities and that are located within well sites, well pads and pipeline right of ways without increasing the disturbance area of petroleum activities.

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16.7.6 Drilling Operations – Sumps for Waste Water / Drilling Product Management

The following mitigations outline buffers that are indicative based on the current regulatory conditions, however these may be subject to change in future. The buffers outlined below are indicative based on the current regulatory conditions, however these may be subject to change in future. The buffers that will be implemented for the project will be in line with the regulatory requirements at the time of implementation. Indicative buffers at this time include [B196]:

- In areas mapped as high constraint a buffer of 100 m, measured from the bank edge, will be adopted during all phases of the Project, with a further 100 m constrained to low impact activities; and
- For areas mapped as moderate constraint, the following buffer zones, measured from the bank edge, will be adopted during all phases of the Project:
 - a riparian buffer of 50 m width on either side of first and second order streams; and
 - a riparian buffer of 100 m width on either side of third, fourth, fifth and higher order streams.

16.7.7 Altered Surface Water Hydrology

The following mitigations have been placed on emergency releases of high quality, treated water under the constraints analysis outlined in Section 16.6.7:

- Current dam safety regulations require that treated and untreated water, and brine dams are operated and maintained to avoid overtopping and possible consequential failure; and
- The water released will comply with water quality standards outlined in Arrow's EA for the gas field operation, including the receiving watercourse volume, flow duration and water quality.

As the release of water is likely to only occur during periods of natural river flow, the impacts of releases will be significantly lower (impact magnitude rating of "Moderate") than would occur during dry season conditions (impact magnitude rating "High").

By controlling the timing and manner in which release occurs, the downstream effects are likely to be minimal due to the dilution effect attributable to the high flow rates in the receiving waters during the wetter months. Therefore, the significance of the residual impact of releases to large permanent / semi-permanent streams is "Moderate".

The residual impact on ephemeral streams increases with decreasing stream order as releases are likely to be of a higher magnitude relative to natural high flow.

16.7.8 Operation and Maintenance Activities

The following mitigations have been placed on operational and maintenance activities under the constraints analysis outlined in Section 16.6.8:

- Activities undertaken within highly constrained areas will be restricted to inspection and maintenance of access tracks and gathering lines. The impact magnitude rating will therefore be "Low"; and

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- No specific provision has been made for operational activities within moderately constrained parts of the study area. However, generic environmental controls and the nature of the operation and maintenance activities would result in an impact magnitude rating of “Low”.

16.7.9 Maintenance of Access Tracks and Gathering Line Easements

The following mitigations have been placed on access track and overhead power line maintenance activities under the constraints analysis outlined in Section 16.6.9:

- Access tracks and overhead power lines within highly constrained areas will be kept to a minimum. The impact magnitude rating will therefore be “Low”; and
- No specific provision has been made for operational activities within moderately constrained parts of the study area, However, generic environmental controls and the nature of the operation and maintenance activities result in an impact magnitude rating of “Low”.

16.7.10 Summary of Residual Impacts

The significance impact assessment of residual impacts on aquatic ecosystem values from Project activities and specific mitigation measures are summarised in Table 16-5.

Table 16-5 Summary of Potential Unmitigated Impacts and Residual Impact on Aquatic Ecosystem Values

Activity / Impact	Aquatic Ecosystem	Sensitivity	Potential Unmitigated Impacts		Avoidance, Mitigation and Management Measures	Residual Impacts	
			Magnitude	Significance		Magnitude	Significance
Site Clearing and Levelling							
The removal of riparian or aquatic vegetation, or terrestrial vegetation in close proximity to watercourses may result in short-term exposure of soil to erosion and sediment transport processes, particularly if sodic soils are disturbed or denuded.	Large permanent / semi-permanent watercourses	High	Moderate	High	As construction activities could require small scale clearing of vegetation to facilitate well or gathering line installation, the adoption of appropriate riparian buffer zones along all watercourses is essential. Buffer zones will be adopted for Project activities (with the exception of required creek crossings), in different areas of constraint, as defined by the project's constraints mapping (outlined in the Environmental Framework chapter (Section 7) and detailed in Constraints Mapping (Appendix BB) of this EIS). The buffers outlined below are indicative based on the current regulatory conditions, however these may be subject to change in future.	N/A	N/A
	Small permanent / semi-permanent watercourses	Moderate	Moderate	Moderate		N/A	N/A

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Activity / Impact	Aquatic Ecosystem	Sensitivity	Potential Unmitigated Impacts		Avoidance, Mitigation and Management Measures	Residual Impacts	
			Magnitude	Significance		Magnitude	Significance
	Ephemeral waterways	Low	Low	Negligible	<p>The buffers that will be implemented for the project will be in line with the regulatory requirements at the time of implementation. Indicative buffers at this time include [B196]:</p> <ul style="list-style-type: none"> • In areas mapped as high constraint a buffer of 100 m, measured from the bank edge, will be adopted during all phases of the Project, with a further 100 m constrained to low impact activities; and • For areas mapped as moderate constraint, the following buffer zones, measured from the bank edge, will be adopted during all phases of the Project: <ul style="list-style-type: none"> — a riparian buffer of 50 m width on either side of first and second order streams; and — a riparian buffer of 100 m width on either side of third, fourth, fifth and higher order streams. 	N/A	N/A

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Activity / Impact	Aquatic Ecosystem	Sensitivity	Potential Unmitigated Impacts		Avoidance, Mitigation and Management Measures	Residual Impacts	
			Magnitude	Significance		Magnitude	Significance
Construction of Access tracks							
<p>Constructing tracks to enable access of machinery for the construction, operation and maintenance of wells, gathering lines and overhead power lines may require removing vegetation and earthmoving activities.</p> <p>Impacts on aquatic ecosystems as a result of this activity are largely associated with the construction phase, when freshly denuded and/or disturbed soils are most at risk of erosion, although ongoing sediment transport can be an impact of track construction.</p>	Large permanent / semi-permanent watercourses	High	Moderate	High	<p>Construction of access tracks will be kept to a minimum, with the use of existing tracks and roads preferred wherever possible [B198].</p> <p>Tracks will be restricted in riparian zones and durations of impacts minimised, except in the immediate vicinity of creek crossings [B199].</p> <p>Where waterway crossings are unavoidable, measures will be taken to ensure that the movement of aquatic species is not impacted [B200].</p> <p>During the design and construction of waterway crossings, care will be taken to minimise the footprint of the structure and to avoid unnecessary disturbance to stream beds and banks [B201].</p> <p>Construction that will potentially affect waterways will occur during dry months where possible. The use of machinery and vehicles on stream beds and banks will be avoided wherever possible [B202].</p>	Low	Moderate
	Small permanent / semi-permanent watercourses	Moderate	Moderate	Moderate		Low	Low
	Ephemeral waterways	Low	Low	Negligible		Low	Negligible

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Activity / Impact	Aquatic Ecosystem	Sensitivity	Potential Unmitigated Impacts		Avoidance, Mitigation and Management Measures	Residual Impacts	
			Magnitude	Significance		Magnitude	Significance
Use of Vehicles / Plant / Machinery near Waterways							
There is potential for contaminating waterways from fuel, oil or chemical spills, use of herbicides during track maintenance and increased vehicle access (litter). The geographic extent, duration and severity of such an event would depend on hydrological conditions and on the nature and volume of the contaminants involved. If tracks are constructed close to waterways or include creek crossings, there is potential for physical disturbance of stream beds / banks and or riparian or aquatic vegetation or habitat.	Large permanent / semi-permanent watercourses	High	Moderate	High	The use of vehicles and machinery near waterways will be avoided wherever possible and expected to be minimal [B194].	Low	Moderate
	Small permanent / semi-permanent watercourses	Moderate	Moderate	Moderate		Low	Low
	Ephemeral waterways	Low	Low	Negligible		Low	Negligible

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Activity / Impact	Aquatic Ecosystem	Sensitivity	Potential Unmitigated Impacts		Avoidance, Mitigation and Management Measures	Residual Impacts	
			Magnitude	Significance		Magnitude	Significance
Waste Management							
<p>Specific waste streams associated with the construction and operation of the Project include:</p> <ul style="list-style-type: none"> • Sewage and human waste; • Construction waste; • Chemical, oil and fuel waste; • Drilling waste (e.g. bentonite, lubricants and other drilling chemicals); • Green waste; • Concentrated brine from reverse osmosis of CSG water; and • Spoil. <p>Most of these waste streams are very unlikely to occur within or in close proximity to watercourses. The potential impacts on aquatic ecosystems if contaminated by waste streams include the creation of poor water quality, contamination or smothering of benthic habitat with sediment.</p>	Large permanent / semi-permanent watercourses	High	Moderate	High	<p>A Waste Management Plan will be designed to minimise identified potential impacts.</p> <p>CSG water received from the field and brine concentrate will be stored in dams adjacent to IPFs</p> <p>Sites will develop a plan that considers minimisation, storage, segregation, treatment, reuse, recycling and disposal.</p> <p>Waste will only be disposed of in appropriate, approved disposal sites using approved methods and contractors. Waste tracking records will be maintained, in line with legal requirements [B395].</p> <p>Onsite waste storage areas will be developed in accordance with industry practice and relevant waste management regulations [B391].</p> <p>Appropriate domestic waste storage facilities will be provided at designated work sites to assist in segregation of waste [B396].</p> <p>Contaminated soil or groundwater</p>	N/A	N/A
	Small permanent / semi-permanent watercourses	Moderate	Moderate	Moderate		Low	Low
	Ephemeral waterways	Low	Low	Negligible		Low	Negligible

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Activity / Impact	Aquatic Ecosystem	Sensitivity	Potential Unmitigated Impacts		Avoidance, Mitigation and Management Measures	Residual Impacts	
			Magnitude	Significance		Magnitude	Significance
					<p>that cannot be avoided will be managed through quantification of the type, severity and extent of contamination, and remediated or managed in accordance with the Queensland Government's <i>Draft Guidelines for the Assessment and Management of Contaminated Land</i> 1998 [B397].</p> <p>Liquid waste generated (other than CSG water and sewage) will be stored and periodically removed for disposal or recycling. All waste fluids and muds resulting from drilling activities will be contained in properly lined dams or storage tanks prior to re-use, recycling, treatment or disposal. Putrescible solid waste will be stored in covered containers to prevent odours, public health hazards and access by fauna [B398].</p> <p>Wastewater (sewage) to be collected and transported offsite to a municipal treatment facility or treated onsite [B399].</p>		

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Activity / Impact	Aquatic Ecosystem	Sensitivity	Potential Unmitigated Impacts		Avoidance, Mitigation and Management Measures	Residual Impacts	
			Magnitude	Significance		Magnitude	Significance
Gathering Trenching System							
<p>Trenching operations would largely be restricted to the construction phase of the Project, although it may become necessary to excavate gathering lines in the event that emergency maintenance is required. Gathering system includes gas and water lines from wells to facilities, water balancing lines between facilities and dams; and may also include infield medium voltage / low voltage distribution and SCADA and telecommunication cables.</p> <p>Impacts on aquatic ecosystems as a result of this activity are largely associated with the construction phase, when freshly denuded and/or disturbed soils are most at risk of erosion, although ongoing sediment transport can be an impact.</p>	Large permanent / semi-permanent watercourses	High	Moderate	High	<p>Where the gathering line crosses waterways, trenching will be perpendicular to the creek [B203]. Where practical, the width of the easement would also be narrowed at these points, further reducing impacts on stream banks, beds and riparian zones by restricting the area of waterway that would be disturbed [B204].</p> <p>Where possible, trenching within or in the vicinity of watercourses would occur during the drier months of the year, which will reduce the potential for water quality decline as a result of sediment mobilisation [B205].</p>	Low	Moderate
	Small permanent / semi-permanent watercourses	Moderate	Moderate	Moderate		Low	Low
	Ephemeral waterways	Low	Moderate	Low		Low	Negligible

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Activity / Impact	Aquatic Ecosystem	Sensitivity	Potential Unmitigated Impacts		Avoidance, Mitigation and Management Measures	Residual Impacts		
			Magnitude	Significance		Magnitude	Significance	
Gathering System or Access Road Creek Crossings								
<p>Constructing tracks to enable access of machinery for the construction, operation and maintenance of wells, gathering lines and overhead power lines may require removing vegetation and earthmoving activities.</p> <p>Impacts on aquatic ecosystems as a result of this activity are largely associated with the construction phase, when freshly denuded and/or disturbed soils are most at risk of erosion, although ongoing sediment transport can be an impact.</p>	Large permanent / semi-permanent watercourses	High	Moderate	High	<p>Gathering line and access road creek crossings will be kept to a minimum by designing the gathering system so that multiple feeder lines are gathered into one gathering line prior to crossing [B206].</p>	Low	Moderate	
	Small permanent / semi-permanent watercourses	Moderate	Moderate	Moderate		Moderate	Moderate	Moderate
	Ephemeral waterways	Low	Moderate	Low		Moderate	Low	Low
Drilling Operations – Sumps for Waste Water / Drilling Product Management								
<p>Sumps are often constructed to contain wastewater and drilling products during drilling of wells and bores. Formation water extracted during the drilling operations would be removed from the well site and transported to dams or a waste disposal facility. The potential impacts of drilling on aquatic systems are associated with spillage, overflow or discharge from sumps used to contain</p>	Large permanent / semi-permanent watercourses	High	Low	Moderate	<p>A Water Management Plan, Erosion and Sediment Control Plan, and Waste Management Plan will be designed to avoid or minimise the potential impacts of Project [B207].</p>	N/A	N/A	
	Small permanent / semi-permanent watercourses	Moderate	Low	Low		Low	Low	Low

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Activity / Impact	Aquatic Ecosystem	Sensitivity	Potential Unmitigated Impacts		Avoidance, Mitigation and Management Measures	Residual Impacts	
			Magnitude	Significance		Magnitude	Significance
waste water and/or chemicals associated with drilling (e.g. bentonite).	Ephemeral waterways	Low	Low	Negligible		Low	Negligible
Altered Surface Water Hydrology							
Arrow is exploring the option of waterway discharge with the regulators. Emergency water releases may also become necessary during periods of high rainfall, when demand for beneficial use can be expected to be low, but production of treated water remains constant. Unseasonal flows into ephemeral or semi-permanent waterways are more likely to have ecological consequences if they are made during the dry season.	Large permanent / semi-permanent watercourses	High	High	Major	No specific mitigation measures. Such releases would occur only when beneficial use disposal options are unavailable due to unforeseen issues, such as periods of significant prolonged rainfall or flooding (not annual wet season flows) and the holding dams are near or at Design Storage Allowance. This action would then become necessary to ensure dam integrity is maintained.	Low	Moderate
	Small permanent / semi-permanent watercourses	Moderate	High	High		Moderate	Moderate
	Ephemeral waterways	Low	High	Moderate		High	Moderate
Operation and Maintenance Activities							
The potential impacts of these activities would vary depending on the nature of the activity. Activities may include vegetation clearing, spraying, grading or resurfacing. Vegetation management	Large permanent / semi-permanent watercourses	High	Moderate	High	All of the likely maintenance and operational activities (including excavation of gathering lines) have been covered by the preceding discussions and by best practice	Low	Moderate

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Activity / Impact	Aquatic Ecosystem	Sensitivity	Potential Unmitigated Impacts		Avoidance, Mitigation and Management Measures	Residual Impacts	
			Magnitude	Significance		Magnitude	Significance
along gathering line easements can be expected to have relatively low impacts if the area is not denuded of vegetation. However, in the event that a gathering line must be excavated for repair or replacement, the impacts could be substantially higher.	Small permanent / semi-permanent watercourses	Moderate	Moderate	Moderate	standard operating procedures.	Low	Low
	Ephemeral waterways	Low	Low	Negligible		Low	Negligible
Maintenance of Access Tracks and Gathering Line Easements							
The maintenance of access tracks involves management of vegetation, erosion and water runoff. Activities may include vegetation clearing, spraying, grading or resurfacing.	Large permanent / semi-permanent watercourses	High	Low	Moderate	Limit the use of herbicides in the vicinity of watercourses or within riparian zones. Use non-toxic, non-persistent (i.e., biodegradable) herbicides to treat weeds, except on properties where organic or biodynamic farming is practiced, for which the method of weed treatment is to be agreed with the landowner [B208].	Low	Moderate
	Small permanent / semi-permanent watercourses	Moderate	Low	Low		Low	Low
	Ephemeral waterways	Low	Low	Negligible		Low	Negligible

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16.8 Monitoring and Inspection

This assessment has indicated that aquatic ecosystem values within the Project study area are diverse and intrinsically linked in terms of the availability and quality of aquatic habitat present.

The residual impact assessment has revealed that many of the potential impacts of the Project would be reduced to “Moderate to Low” following the implementation of the specific impact avoidance (constraints) framework and specific mitigation strategies outlined in Section 16.6.

Moderate impacts may occur in the following areas:

- Within permanent waterways as a result of:
 - site clearing and levelling;
 - construction of access tracks;
 - waste generation and management;
 - gathering line / gathering line trenching;
 - gathering lines or access roads creek crossings; and
 - operational and maintenance activities, particularly where these involve excavating the gathering line.
- Within ephemeral waterways if emergency releases of treated CSG water occur during dry season conditions.

All other impacts are expected to be Low impact, with the exception of any emergency releases of treated CSG water into permanent or semi-permanent streams during the dry season, which may have an impact magnitude rating of “High”. These emergency releases would only be undertaken as a contingency, and will only be undertaken in accordance with relevant regulatory approvals on a site specific basis.

16.8.1 Monitoring

Notwithstanding the relatively Low to Moderate residual impacts assessed for the Project, monitoring of the ongoing health of aquatic ecosystems is considered to be important and development of a monitoring program should be undertaken:

- In watercourses that may eventually be subjected to either regulated discharge to streams and/or emergency water releases;
- In sensitive areas or areas of higher ecological value, such as waterways within the highly constrained zones; and
- Monitoring where required will be undertaken, including water quality, aquatic macroinvertebrates, fish, and other aquatic / semi-aquatic fauna [B209].

The reporting of monitoring analysis results would include both standalone and cumulative interpretation to provide for a comprehensive understanding of significant change, if any, over time [B211].

In addition, during construction and operation of the Project, mandatory implementation of the general and specific mitigations measures outlined in Section 16.6, combined with rigorous environmental

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audits of compliance with the Project's Environmental Management System (EMS) are considered important to protect the aquatic systems within the study area.

Environmental auditing processes would include both internal and external audit components to ensure consistency and compliance with the regulatory framework [B212].

16.8.2 Inspection

Inspections will be carried out on a potential incident basis to determine potential impacts to aquatic environments resulting from pollution events; or potential pollution events [B213], that may occur as a consequence of any event defined as a "Reportable / Notifiable Incident" under an approved EMS, including, but not limited to, discharge of, or potential discharge of substances into watercourses.

Where a discharge of a defined substance and or quantity triggers a mandatory incident procedure that includes the need for point-source assessment, at a minimum, water and sediment quality would be assessed at the point source, as well as downstream of that point to the estimated downstream limit of impact [B214].

Reporting protocols will be developed and incorporated into the EMS procedures to ensure an iterative approach towards ongoing best-practice is maintained by learning from, and minimising the potential for subsequent incidents to occur.