F

SUPPLEMENTARY SURFACE WATER TECHNICAL REPORT

ENTER HERE

BACK TO CONTENTS

SUPPLEMENTARY REPORT TO THE EIS

arrow energy go further

URS

Report

Bowen Gas Project SREIS

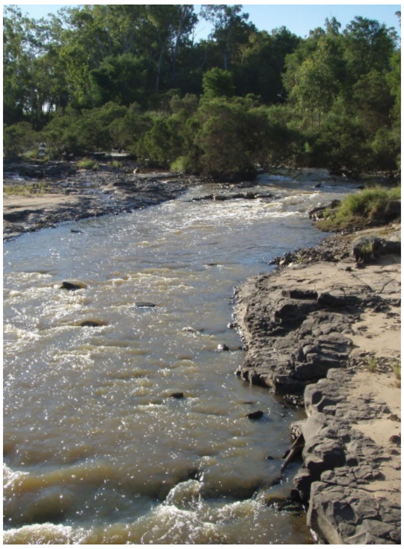
AUSTRALIA

Supplementary Surface Water Technical Report

April 2014
42627140/R001/0

Prepared for:
Arrow Energy Pty Ltd

Prepared by URS Australia Pty Ltd



DOCUMENT PRODUCTION / APPROVAL RECORD

Issue No.	Name	Signature	Date	Position Title
Prepared by	Jessica Grinter		April 2014	Water Quality Scientist
Checked by	Dr Adrian Zammit		April 2014	Principal Water Quality Scientist
Approved by	Dan Simmons		April 2014	Senior Associate Environmental Scientist

Report Name:
Bowen Gas Project SREIS

Sub Title:
Supplementary Surface Water Technical Report

Report No.
42627140/R001/0

Status:
Final

Client Contact Details:

Arrow Energy Pty Ltd
Brisbane

Issued by:
URS Australia Pty Ltd
Level 17, 240 Queen Street
Brisbane, QLD 4000
GPO Box 302, QLD 4001
Australia

T: +61 7 3243 2111
F: +61 7 3243 2199

DOCUMENT REVISION RECORD

Issue No.	Date	Details of Revisions
Rev 0	31/01/2014	Initial Release
Rev 1	10/02/2014	First draft
Rev 2	27/02/2014	Second draft
Rev 3	12/03/2014	Third draft
Rev 4	4/04/2014	Fourth draft
Final	15/04/2014	Final for issue

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

URS

ABBREVIATIONS

Abbreviation	Description
ANZECC	Australia and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
Arrow	Arrow Energy Pty Ltd
CGPF	central gas processing facility
CSG	coal seam gas
DERM	Department of Environment and Resource Management
EC	electrical conductivity
EHP	Department of Environment and Heritage Protection
EIS	Environmental Impact Statement
EPBC Act	*Environment Protection and Biodiversity Act 1999*
EPP (Water)	Environment Protection (Water) Policy 2009
EP Act	*Environment Protection Act 1994*
EV	environmental value
FCF	field compression facility
MNES	Matters of National Environmental Significance
NRM	Department of Natural Resources and Mines
NWQMS	National Water Quality Management Strategy
P&G Act	*Petroleum and Gas (Production and Safety) Act 2004*
QWQG	Queensland Water Quality Guidelines
ROP	Resource Operations Plan
TSS	Total Suspended Solids
SREIS	Supplementary Report to the EIS
Water Act	*Water Act 2000*
WQO	Water Quality Objective
WRP	Water Resource Plan
WTF	water treatment facility

EXECUTIVE SUMMARY

Arrow Energy Pty Ltd (Arrow) is preparing a supplementary report to the Bowen Gas Project (the Project) Environmental Impact Statement (SREIS) to present updates to the project description, address issues identified in the Project Environmental Impact Statement (EIS) as requiring further consideration and/ or information, and to respond to stakeholder comments raised in the submissions on the EIS. This report builds and consolidates the findings and conclusions of the EIS, and provides an updated impact assessment based on a revised project description.

The most significant change to the project description as presented in the EIS which has the potential to impact the surface water environment is the inclusion of preferred general localities of two water treatment facilities (WTFs). Subsequently, the updated project description provides two indicative reaches of the Isaac River main channel for the potential discharge of treated (or in certain instances untreated) coal seam gas (CSG) water, based on the general localities of the two WTFs. Other changes to the project description such as the reduction of well numbers and changes in the infrastructure configuration have also been considered in terms of their potential impacts to the surface water environment.

Baseline Characterisation of Surface Water Environment

The desktop baseline assessment of the surface water environment presented in the SREIS was undertaken to enhance and validate the findings and conclusions of the EIS.

The environmental values (EVs) assessed as part of the Project EIS process were still applicable to the project at SREIS stage. For the purpose of the assessment of potential impacts associated with any CSG water releases from the Project area, EVs associated with surface water quality of the receiving environment for releases have been assessed as moderately sensitive.

Assessment of a large surface water quality data set gathered by mines operating in the project area confirmed the representativeness of the surface water data gathered from field studies undertaken in 2012 as part of the EIS. The combined datasets (operational mine data and EIS data) were subsequently analysed to characterise the surface water condition of the Project area on a sub-catchment basis. Statistical analysis of water quality data for the slightly to moderately disturbed Isaac River main channel indicated they were consistent with the published Water Quality Objectives (WQOs), with the exception of turbidity, total suspended solids and dissolved aluminium; locally derived WQOs for these parameters have been determined following an accepted methodology. Arrow will undertake the appropriate field surveys at confirmed discharge locations as part of the Environmental Authority (EA) application process.

Potential Impacts

Discharge to Watercourses

Arrow's CSG Water and Salt Management Strategy (Appendix D) of the SREIS considers the potential for discharge of treated or untreated CSG water into the Isaac River main channel. A detailed Environmental Flow Analysis of the Isaac River main channel presented in the Hydrology and Geomorphology Technical Report (Appendix G) of the SREIS characterised this waterway as highly ephemeral with an annual brief period of high flow within the period December to March and a prolonged period of no flow from April to November.

The actual discharge conditions will be determined as part of the EA application process once the WTF locations have been finalised, and discharge rates adjusted accordingly to mitigate potential impacts, based on the discharge location selected for each WTF. This report outlines the process or a set of principles which future impact assessments will consider to determine discharge conditions and monitoring requirements to support the EA application. The set of principles provides guidance on the discharge rates, volumes and timing of any CSG water (treated or untreated) release at any point in time and as such demonstrates that Arrow can effectively manage the volumes of CSG water that may be discharged into the Isaac River to minimise environmental impacts.

Erosion and Sedimentation Mobilisation

There is potential for water quality impacts through the various Project activities that cause land disturbance such as construction of central gas processing facilities, WTFs, wells and other infrastructure. However, through the implementation of the recommended mitigation measures, potential impacts on surface water quality can be managed.

Beneficial Use

In line with current guidelines for the beneficial use of CSG water, Arrow has identified a number of options to manage its CSG water during the course of the Project. Beneficial use options which are available to Arrow include the supply of water to domestic and urban users, supply of water to water service providers, supply to nearby coal mines, supply to agricultural users (for crop irrigation and/or stock watering) and use by Arrow for its own operational needs for the Project (such as use of treated water for dust suppression and construction).

Cumulative Impact Assessment

The results presented in this report confirm that the water quality of the Isaac River main channel, as well as that of other sub-catchments within the Project, are slightly to moderately impacted by historic and current landuse including agriculture, mining, and urban development. Continued adherence by all catchment users to conditions set out in EAs of all existing and planned activities in the area, including monitoring of surface water quality, would prevent significant cumulative impacts on the surface water quality. Compared with the cumulative volume of mine affected water released by coal mines operating in the area, the small volume of treated CSG water that may be discharged into the Isaac River in compliance with its EA conditions will not cause any significant impacts.

Mitigation and Management Measures

Mitigation, management and monitoring measures recommended in the Surface Water Technical Report (Appendix N) of the EIS to protect the surface water EVs of the Project area remain relevant. Whilst this technical report specifically addresses the surface water quality aspects of any likely impacts related to activities described in the updated project description, these studies are considered together with Project impacts related to hydrology and geomorphology (Hydrology and Geomorphology Technical Report (Appendix G) of the SREIS) and aquatic ecology (Aquatic Ecology Technical Report (Appendix H) of the SREIS). The different and inter-relating aspects that determine river health such as water quality, river hydrology, geomorphology and aquatic ecology were assessed in order to minimise impacts to all EVs associated with the Isaac River. This approach was utilised in the assessment of impacts associated with potential discharges of CSG water. Ultimately the approach in which discharges of CSG water will be determined (as part of the EA application process) will allow CSG water (treated or untreated) to be discharged to the receiving environment whilst minimising environmental impacts.

1 INTRODUCTION

1.1 Background and Objectives

Arrow Energy Pty Ltd (Arrow) is preparing a supplementary report to the Bowen Gas Project (the Project) Environmental Impact Statement (SREIS) to present updates to the project description, to address issues identified in the Environmental Impact Statement (EIS) for the Project as requiring further consideration and/ or information and to respond to stakeholder comments raised in submissions on the EIS.

The surface water assessment included in the EIS consisted of a desktop study and a field based survey of the surface water quality in sub-catchments of the Project area. The environmental values (EVs) of these surface waters were identified in accordance with the Queensland Water Quality Guidelines 2009 (QWQG) (EHP, 2009a) and the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ, 2000). The EIS surface water assessment considered a conceptual layout of Project infrastructure to identify potential impacts and propose appropriate mitigation measures.

The objectives of this report are to:

- Revise the surface water study in the context of an updated project description;
- Address stakeholder comments relating to the EIS surface water quality assessment;
- Undertake a desktop baseline water quality assessment and derive relevant water quality objectives (WQOs) using data from local operational mines and confirm representativeness of water quality data gathered for the EIS;
- Assess potential impacts associated with the updated project description; and
- Develop an approach that informs and guides the coal seam gas (CSG) water discharge strategy that minimises potential impacts to identified EVs.

This assessment builds on and updates the findings of the surface water assessment included in the Surface Water Technical Report (Appendix N) of the EIS.

A field assessment of the reaches of the Isaac River tentatively identified as potential receiving environments for CSG water releases could not be undertaken due to a lack of rain in the catchment during the 2013/14 wet season. Arrow has committed to undertake field surveys at confirmed discharge locations as part of the EA application process.

1.2 Revised Project Description

The main changes to the project description as presented in the EIS which have the potential to impact the surface water environment of the Project area include the following:

- Identification of preferred localities to locate two water treatment facilities (WTFs);
- Identification of potential reaches on the Isaac River main channel for discharges of CSG water from each WTF;
- Changes to the CSG water and brine management plan, including a reduction in total forecast CSG water production from 276 GL to 153 GL;
- Reduction in wells from 6,625 to approximately 4,000;

- Gas development regions reduced from 14 (constituting 17 drainage areas each of approximately 12 km radius) to 8 (made up of 33 drainage areas each of approximately 6 km radius); and
- Increase of the number of field compression facilities (FCFs) from 10 to 33.

2 LEGISLATIVE FRAMEWORK AND RELEVANT GUIDELINES

This section describes the legislative context, relevant policies and standards at Commonwealth and State level that apply to the Project.

2.1 Commonwealth Legislation and Policies

2.1.1 Environment Protection and Biodiversity Conservation Act 1999

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) outlines requirements relating to the management and protection of national and international flora and fauna of environmental significance, referred to as matters of national environmental significance (MNES) (Volume 1, Chapter 2, Part 3, Division 1). Subdivision FB relates to protection of water resources from CSG development and large coal mining development. Gas project developments can potentially disrupt aquatic ecosystems and therefore have adverse impacts on aquatic species, water resources and Ramsar wetland sites. An action with the potential for a significant impact on MNES must be referred to the Minister for the Commonwealth Department of the Environment (formerly Department of Sustainability, Environment, Water, Population and Communities) and may require approval under the EPBC Act.

The nine MNES under the EPBC Act are as follows:

- World heritage properties;
- National heritage places;
- Wetlands of international importance (often called 'Ramsar' wetlands after the international treaty these wetlands are listed);
- Nationally threatened species and ecological communities;
- Migratory species;
- Commonwealth marine areas;
- The Great Barrier Reef Marine Park;
- Nuclear actions (including uranium mining); and
- A water resource, in relation to CSG development and large coal mining development.

2.1.1.1 Environment Protection and Biodiversity Conservation Amendment Act 2013

Changes made to the EPBC Act on 22 June 2013, resulted in water resources in relation to CSG and large coal mining developments now being considered as a MNES. In accordance with this legislative change, on 17 October 2013, the Commonwealth Minister for Environment determined that water resources were a controlling provision under Sections 24D and 24E of the EPBC Act for the Project. This was due to the information available to the Minister at that time, indicating that the Project may potentially directly or indirectly result in a substantial change to the hydrology and quality of water resources impacted by project activities. In making the decision, the Minister recognised that previously submitted documents, as well as subsequent documentation will be considered in the decision regarding the water resources controlling provision.

2.1.2 National Water Quality Management Strategy

The National Water Quality Management Strategy incorporates a joint national approach with the aim of improving water quality in Australian and New Zealand waterways. It was originally endorsed by the former Agriculture and Resources Management Council of Australia and New Zealand (ARMCANZ) and the former Australian and New Zealand Environment and Conservation Council (ANZECC). It is relevant to the Project in that it has facilitated the provision of regional and national guidelines for assessment of surface water quality and design of monitoring programs (such as the ANZECC and ARMCANZ 2000 guidelines).

2.2 State Legislation and Policies

2.2.1 Environmental Protection Act 1994

The *Environmental Protection Act 1994* (EP Act) aims to:

> *[Protect] Queensland's environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends (ecologically sustainable development).*

The EP Act legislates the management of surface water, including the management and disposal of CSG water. The EP Act was amended in March 2013 to include requirements for site-specific applications related to CSG activities (Section 126). The primary instrument by which surface water management is achieved is the Environmental Protection (Water) Policy 2009 (EPP (Water)). The EP Act is administered by the Queensland Department of Environment and Heritage Protection (EHP).

The following regulations and policies are also relevant under the EP Act:

- Environmental Protection (Waste Management) Policy 2000;
- Environmental Protection (Waste Management) Regulation 2000; and
- Environmental Protection Regulation 2008.

These instruments are supported by the Coal Seam Gas Water Management Policy 2012.

2.2.2 Environmental Protection (Water) Policy 2009

Amongst other functions, the EPP (Water) governs the discharge of wastewater to land, surface water, and groundwater, aims to protect Environmental Values (EVs) and sets water quality objectives to provide guidance to protect EVs.

2.2.3 Coal Seam Gas Water Management Policy 2012

The Coal Seam Gas Water Management Policy 2012 was established to provide direction for the management and disposal of CSG water, and streamline the implementation of existing CSG water management policies under the EP Act. The Policy encourages the management of CSG water '*in a way that protects the environment and maximises its productive use as a valuable resource*'. Under the Policy, CSG water and 'saline waste' must be managed consistently in accordance with defined 'prioritisation hierarchies' and management criteria. Beneficial use is the highest priority for managing CSG water, followed by management and disposal options. It is preferred that saline wastes such as brine or salt residues are processed to create useable products, before considering disposal options.

2.2.4 Petroleum and Gas (Production and Safety) Act 2004

The *Petroleum and Gas (Production and Safety) Act 2004* (P&G Act) provides rights to extract gas and CSG water within the Project tenements.

2.2.5 Water Supply (Safety and Reliability) Act 2008

The *Water Supply (Safety and Reliability) Act 2008* provides a regulatory framework for water service providers, recycled water management schemes, referable dams and flood mitigation responsibilities. In the context of CSG activities, it applies for injection, release or supply of produced water that may directly or indirectly augment a registered drinking water supply.

2.2.6 Water Act 2000

The *Water Act 2000* (Water Act) provides a framework to deliver sustainable water planning, allocation management and supply processes to provide for the improved security of water resources in Queensland. The impacts of the extraction of CSG water from gas seams on groundwater supplies are managed under Chapter 3 of this Act. It also requires the following (in relation to gas extraction activities):

- A water licence for operations which are not activities authorised under the P&G Act that will interfere with surface water or watercourses; and
- A separate license and permit is currently required for the use of associated water for purposes not associated with a Petroleum Lease. This is under revision.

The Water Act and its instruments are administered by the Queensland Department of Natural Resources and Mines (NRM).

2.2.6.1 *Water Resource Plans and Resource Operations Plans*

Water Resource Plans (WRPs) and Resource Operations Plans (ROPs) are governed by the Water Act. They were developed to help meet the challenges of growth and climate change, and protect the water resources of Queensland. These objectives are consistent with the National Water Initiative, agreed to in 2004 on a national level. WRPs establish a framework for sharing water between human consumptive needs and EVs. ROPs are developed in parallel with WRPs and provide a framework by which objectives from which the WRPs are implemented, including water allocations and administrative directions.

Surface water resources within the Project area are primarily managed by the Fitzroy Basin Water Resource Plan 2011 and the Burdekin Basin Resource Plan 2007.

2.2.7 Fisheries Act 1994

The *Fisheries Act 1994* provides for the management, use, development and protection of fisheries resources and fish habitats in Queensland. It is administered by the Queensland Department of Agriculture, Fisheries and Forestry.

2.3 Relevant Guidelines and Standards

Various water quality guidelines were used to assess the quality of surface waters within the Project area against defined reference conditions, which enabled the quantification of water quality objectives. Applicable guidelines are briefly described below.

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

The ANZECC and ARMCANZ (2000) guidelines were developed under the National water quality management strategy, and provide a framework for assessing water quality by comparison with guidelines derived from local reference values. Guideline values were developed and classified on the following criteria:

- Level of environmental disturbance of surface waters (e.g. highly or slightly to moderately disturbed waters);
- Freshwater or saline surface water;
- Waterbody elevation i.e. upland or lowland aquatic environments; and
- Biogeographic region such as southeast or tropical Australia.

The guidelines also state that:

> *the old single number guidelines [1992; incorporated into current 2000 guidelines] are regarded as guideline trigger values that can be modified into regional, local or site specific guidelines by taking into account factors such as the variability of the particular ecosystem or environment, soil type, rainfall and level of exposure to contaminants. Trigger values are concentrations that, if exceeded, would indicate a potential environmental problem, and so 'trigger' a management response e.g. further investigation and subsequent refinement of the guidelines according to local conditions.*
> (Volume 1, Chapter 2, p2-10)

This report refers to both physicochemical and toxicant guideline values from ANZECC and ARMCANZ (2000); and further explanation is provided in Section 7.2.

2.3.2 Queensland Water Quality Guidelines 2009

The Queensland Water Quality Guidelines 2009 (EHP, 2009a) provide a framework for assessing water quality in Queensland through setting water quality objectives. Further explanation is provided in Section 5.1.

2.3.3 Monitoring and Sampling Manual 2009

The Monitoring and Sampling Manual (EHP, 2009b) was developed by the former Queensland Department of Environment and Resource Management (DERM) in 2009, to provide "common techniques, methods and standards for sample collection, handling, quality assurance and control, custodianship and data management, for use by the Queensland Government agencies, relevant persons and other organisations". Surface water monitoring conducted in association with the Project will be designed and implemented as directed by this manual where practicable (in addition to the sources referenced above).

2.3.4 AS/NZS 5667 (1998) Water Quality – Sampling

The Australian / New Zealand Standard for Water Quality Sampling is a standard prepared by the Joint Technical Committee EV/8, Methods for Examination of Waters. The standard provides guidance on the design of surface water sampling programs, sampling techniques and the preservation and handling of samples.

3 ASSESSMENT METHODOLOGY

3.1 Study Area

The study area was first delineated for the Project EIS assessment in 2012, and encompasses 7,670 km^2. It spans the Fitzroy and Burdekin River Basins in eastern/central Queensland, stretching from the headwaters of the Bowen and Suttor Rivers (Burdekin basin) in the north, to the Mackenzie River in the south. The majority of the study area is located within the Isaac-Connors catchment of the Fitzroy Basin. A map of the study area and associated sub-catchments is provided in the Surface Water Technical Report (Appendix N) of the EIS, while the sub-catchments and their corresponding key watercourses are outlined in Table 3-1.

Table 3-1 Study sub-catchments and key watercourses within the Project Study Area

Basin	Catchment	Study Sub-catchment	Key Watercourses
Burdekin	Bowen River	Bowen River Tributaries	Kangaroo Creek Exe Creek
	Suttor River	Suttor River Tributaries	Suttor Creek Eaglefield Creek
Fitzroy	Isaac River	Isaac River Main Channel	Isaac River
		Isaac River Northern Tributaries	Eureka Creek Platypus Creek Fisher Creek Ceil Creek Devlin Creek Cherwell Creek Boomerang Creek Ripstone Creek Harrow Creek Hughes Creek One Mile Creek
		Isaac River Western Upland Tributaries	Scott Creek Phillips Creek Stephens Creek
		Connors River Central Tributaries	Cooper Creek Bee Creek Harrybrandt Creek
	Mackenzie River	Mackenzie River Main Channel	Mackenzie River
		Mackenzie River North-Western Tributaries	Roper Creek
		Mackenzie River Southern Tributaries	Taurus Creek Sagittarius Creek Blackwater Creek Sirius Creek Rockland Creek Two Mile Gully Speculation Creek Burngrove Creek Deep Creek

3.2 Surface Water Quality

3.2.1 Desktop Assessment

In response to submissions made by EHP as part of the Project EIS approvals process, a detailed desktop assessment of surface water quality was undertaken throughout the study area. Field sampling was undertaken by URS on behalf of Arrow for the EIS between April and May 2012. A total of three field visits were undertaken across 22 locations (1-3 April; 24-28 April, and 20-24 May 2012). Details for each of the sampling locations are included in the Surface Water Technical Report (Appendix N, Section 7.2.2.2 and Table 7-3) of the EIS. Field assessments of the water quality of the Isaac River in the localities identified as potential receiving environments for CSG water releases could not be undertaken for the SREIS due to a lack of rain in the catchment during the 2013/14 wet season. Arrow has committed to undertake field surveys at confirmed discharge locations as part of the EA application process.

This assessment included a review of data originally collected in the three field studies during April and May 2012, and also incorporated further data points obtained from operational mines within the Bowen Basin. This data was generally collected during the period between 2010 and 2013. For the purposes of this report, it has been assumed that all operational mine data used in this assessment was collected according to the Monitoring and Sampling Manual (EHP, 2009b) and the guidelines set out in AS/NZS 5667 (1998). All data was integrated into a single database including data from earlier monitoring (2012). Table 3-2 provides a summary of the number of data points available for analysis in each study sub-catchment, once all datasets were combined.

The data sets for the Isaac River Main Channel, the Isaac River Northern Tributaries, the Isaac River Western Upland Tributaries and the Mackenzie River Southern Tributaries are sufficiently large and encompass a wide enough period of time to be considered as adequate for the derivation of water quality percentile values; the QWQG (EHP, 2009a) and ANZECC and ARMCANZ (2000) guidelines recommend 24 data values collected over 24 months to derive true percentile values.

Table 3-2 Number of data points (n) for combined dataset, by study sub-catchment

Study sub-catchment	Number of Data Points (*n*) available from the Project* (2012)	Number of Data Points (*n*) available from operational mines* (2010 - 2013)	Total *n*
Bowen River Tributaries	6	0	6
Suttor River Tributaries	2	0	2
Isaac River Main Channel	8	361	369
Isaac River Northern Tributaries	1	1,062	1,063
Isaac River Western Upland Tributaries	0	419	419
Connors River Central Tributaries	5	0	5
Mackenzie River Main Channel	2	0	2
Mackenzie River North-Western Tributaries	4	0	4

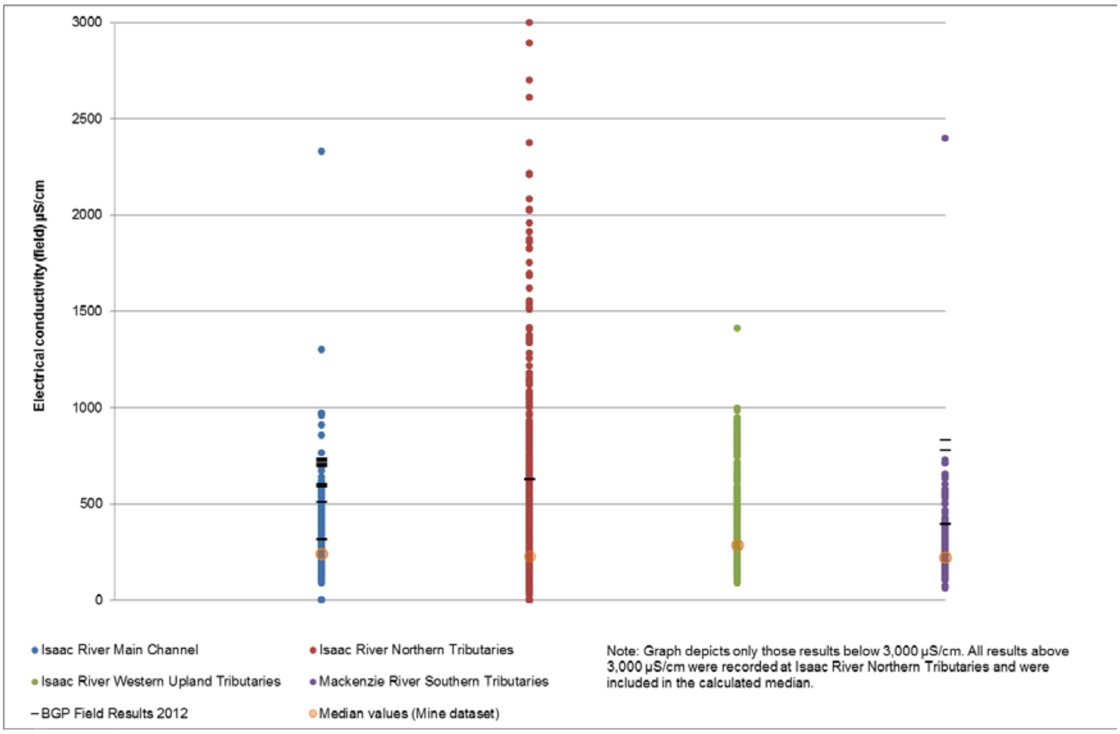
Study sub-catchment	Number of Data Points (*n*) available from the Project* (2012)	Number of Data Points (*n*) available from operational mines* (2010 - 2013)	Total *n*
Mackenzie River Southern Tributaries	3	384	387
TOTAL	**31**	**2,226**	**2,257**

**Note: The number of data points depicted in this table are intended to provide an indication of the volume of data available for analysis; however, it is important to note that sampling frequency varies between parameters within the dataset.*

In the updated project description the Isaac River main channel has been tentatively identified as the receiving environment of potential CSG water discharges. The large number of data for the Isaac River Main channel allows for the robust assessment of its baseline character, which facilitates the assessment of potential impacts as a result of WTF construction and potential CSG water discharge. No activity that would impact the surface water quality of other streams such as the Bowen, Suttor, Mackenzie and Connors has been updated since the EIS.

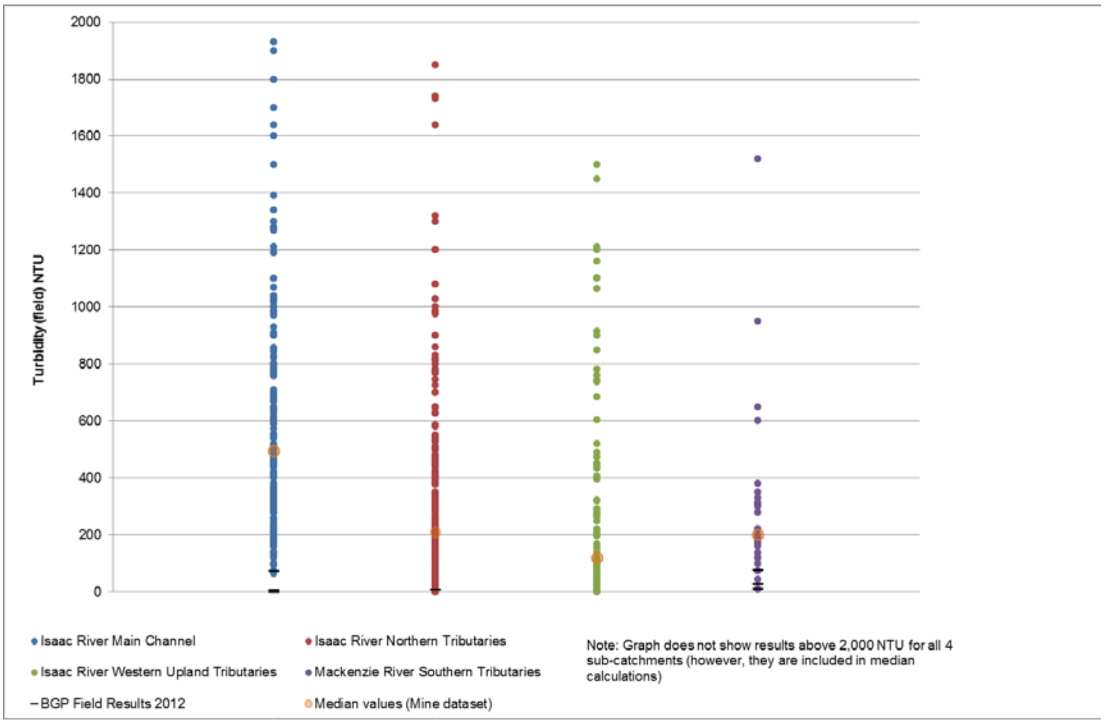
To assess the validity and representativeness of the field data collected by URS between April and May 2012 and presented in the EIS (herein referred to as 'Project data'), the data was compared with the larger water quality dataset from operational mines. Figure 3-1 to Figure 3-5 below provide a basic illustration of the representativeness of the Project data using a number of key water quality indicators, namely electrical conductivity (EC); turbidity; pH; nitrate, and dissolved zinc. Median values for each of these parameters were used to characterise the water quality of each of the sub-catchments using operational mining data. The median is the most appropriate statistical indicator given that the number of samples available within each sub-catchment (*n*) was highly variable thereby potentially skewing any averages such as mean or percentile. Although data was not collected for the 'Isaac River Western Upland Tributaries' sub-catchment for the Project in 2012, the operational mining data was still included in each of the figures to provide context of trends throughout the wider Isaac River catchment (i.e. variation between main channel of Isaac River, and the northern and western upland tributaries).

Figure 3-1 Comparison of Project data against operational mining results for Electrical Conductivity, 2010 - 2013



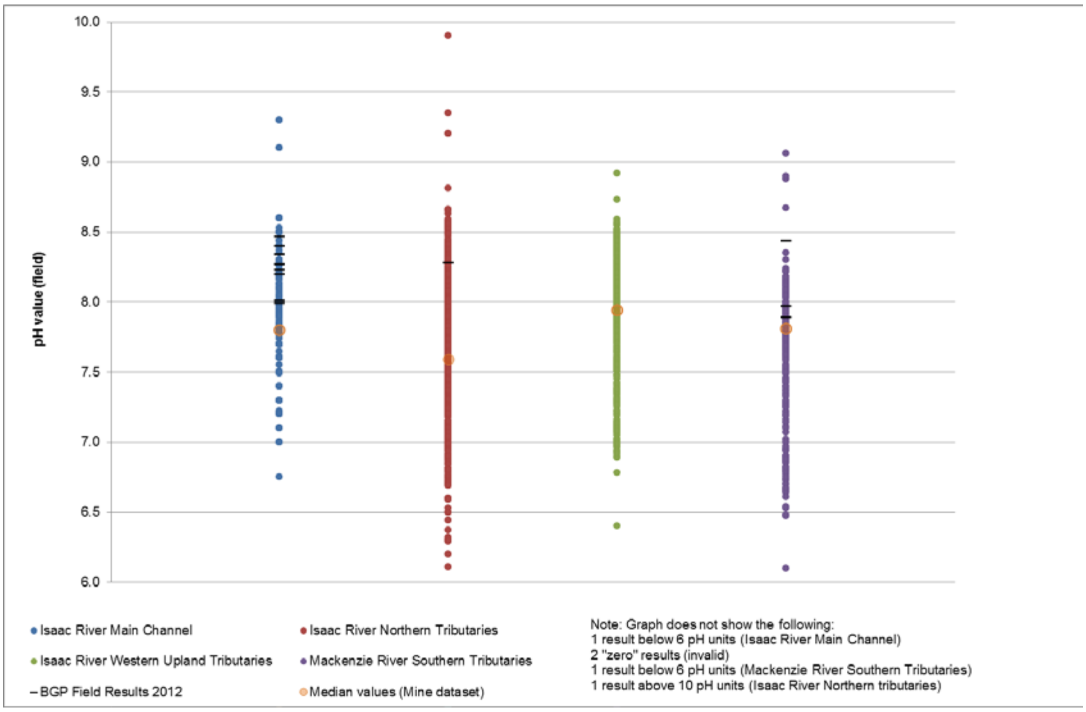
Assessment of water quality data sourced from operational mines indicated that the EC levels of the waters in each of the sub-catchments was highly variable with EC values ranging by one to two orders of magnitude (e.g. EC within the Isaac River main channel ranged between 0 to 2,330 µS/cm) (Figure 3-1). The results also indicate that despite the Project results for EC being higher than the median values for the operational mining dataset in each respective sub-catchment, they were still within the range of data recorded for EC between 2010 and 2013. The wide fluctuation of stream EC levels is typical of ephemeral streams such as those found in the Project area.

Figure 3-2 Comparison of Project data against operational mining results for Turbidity, 2010 - 2013



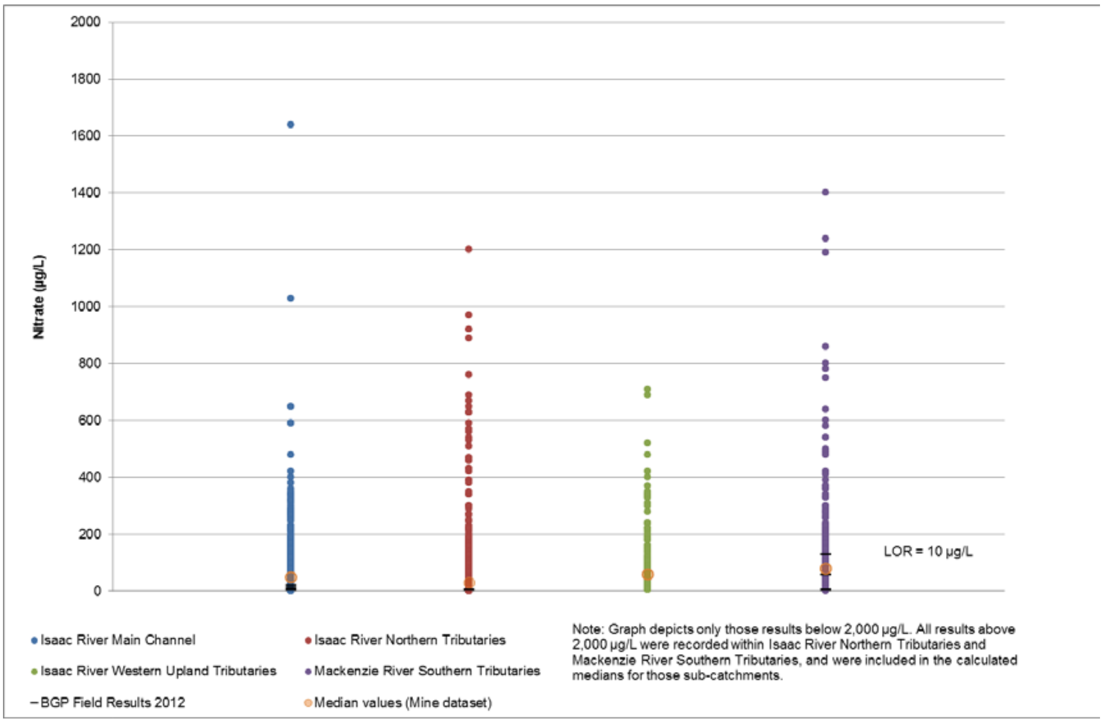
Similarly, scatter plots of turbidity for each of the sub-catchments using the operational mining dataset indicated that all of these waters had large turbidity fluctuations; for example the levels of turbidity in the Isaac River Main Channel ranged from 1.2 NTU to 5,830 NTU between 2010 and 2013 (Figure 3-2). This assessment also indicates that the Project turbidity results were clearly lower than the median values for operational mining data within each sub-catchment, but well within the range of values for each of these sub-catchments measured in this period. The wide fluctuation of stream turbidity levels is typical of ephemeral streams such as those found in the Project area.

Figure 3-3 Comparison of Project data against operational mining results for pH, 2010 - 2013



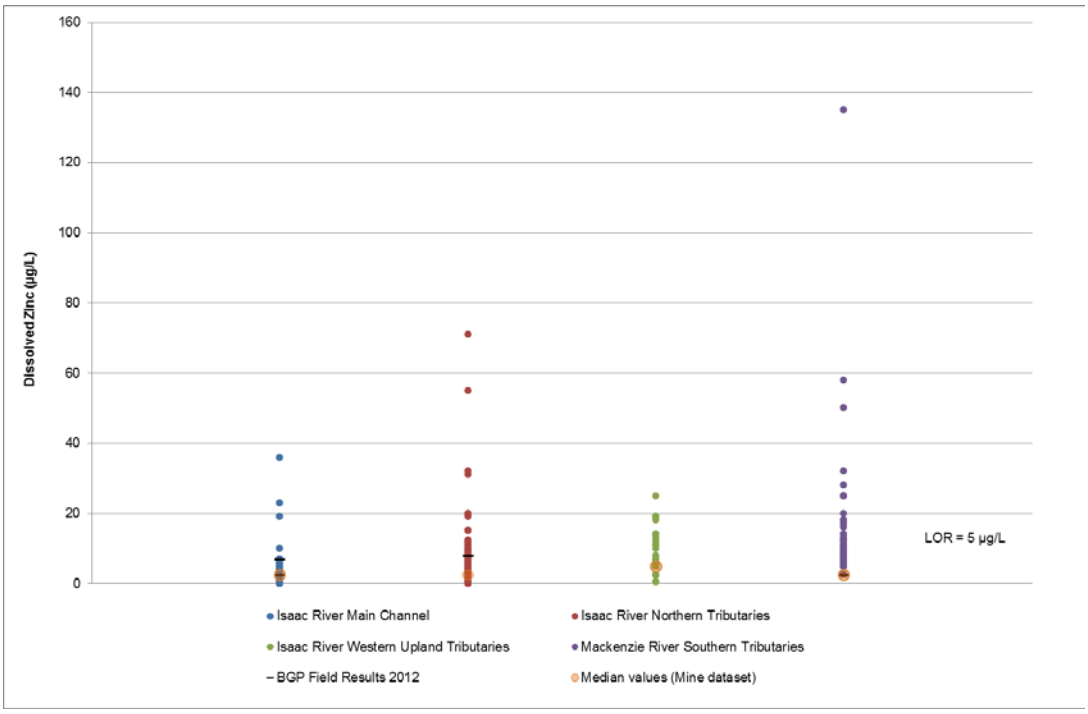
Assessment of operational mining water quality data indicates that surface water pH has fluctuated significantly for each of the sub-catchments. For example, the pH of waters in the Isaac River Main Channel ranged from pH 5.4 to 9.3 (Figure 3-3). The data also shows that the Project results for pH tended to be elevated above the operational mining median values in each sub-catchment. However they remained within the range of between 7.5 and 8.5 pH units.

Figure 3-4 Comparison of Project data against operational mining results for Nitrate, 2010 - 2013



A similar assessment for levels of nitrate in each of the sub-catchments indicates that levels of this nutrient varied considerably. For example, nitrate concentrations ranged between 0 µg/L (undetectable concentrations) to 1,640 µg/L for the Isaac River Main Channel (Figure 3-4). The Project results for nitrate were representative of the operational mining dataset in general, when compared against the median mining values. It should be noted however, that the Limit of Reporting (LOR) of 10 µg/L for nitrate may have lowered the median significantly within such a large dataset. The variability observed in nitrate levels may be a result of the streams' ephemeral character as well as a product of agricultural activities in the area.

Figure 3-5 Comparison of Project data against operational mining results for Dissolved Zinc, 2010 - 2013



A comparison of Project data with the operational mine dataset by means of a scatter plot indicated that the data obtained for the EIS in 2012 closely represent levels of dissolved zinc measured by operational mines (Figure 3-5).

Given the comparison of the two data sets shown in Figure 3-1 to Figure 3-5, it is clear that the results were representative of the condition of the wider surface water environment, and the sample locations selected as part of the baseline monitoring program for the Project EIS can be considered appropriate and representative of the defined study sub-catchment. As such, it was deemed appropriate to proceed with analysing the available dataset (including data from both the Project and operational mines) as a whole to assess water quality trends within the existing surface water environment.

Further analyses of water quality trends throughout each sub-catchment; including assessment of the relationship between stream flow and EC, and spatial and temporal variations, are provided in Section 4.

4 SURFACE WATER QUALITY

This section provides an assessment of the existing condition of the surface water environment within the Project study area, in terms of water quality. It focusses on the conditions within the Isaac River Main Channel in particular, as this is the sub-catchment in which preferred localities for two WTFs have been tentatively identified. Additional data received from mining operations within the region were used to supplement data presented in the Project EIS, to analyse existing surface water quality trends. This information was also used to review the existing WQOs assigned for the study area at the EIS stage, and to develop sub-regional WQOs where appropriate (according to QWQG) (EHP, 2009a).

4.1 Water Quality Objectives

WQOs are defined under the Water Act and EPP (Water) for the purpose of protecting the identified EVs for a particular receiving environment. Local guideline values may be defined within the relevant WRP at a sub-basin level, while regional guideline values can be applied under the QWQG (EHP, 2009a). Where specific regional values are not available, default values are defined at a national level under the *National Water Quality Management Strategy* (NWQMS). The NWQMS WQOs are usually derived from the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC and ARMCANZ 2000).

Preliminary WQOs for the protection of EVs associated with the surface water bodies within the study area were identified during the EIS approvals process in 2012 (refer to the Surface Water Technical Report (Appendix N, Section 7.1) of the EIS). They are included in Table 4-1 and are applied to existing water quality data for the purpose of describing the existing conditions (including natural variability) of the surface water environment within the study area.

The overall purpose of the water quality assessment within this SREIS, given that greater volumes of data are now available for the Project study area, is to determine whether the WQOs that were identified for the EIS are still appropriate. On the basis of the significant data now available, the baseline character of the surface water environment is characterised by undertaking statistical analysis of data (hence the requirement for large data sets) to compare percentiles with published WQOs. The adequate characterisation of the surface water environment (by means of statistical analysis and WQOs) is a pre-requisite to meaningful assessments of potential impacts arising from Project activities. This process of deriving WQOs for the Project area is based on the methodology recommended in the QWQG (EHP, 2009a).

4.1.1 WQOs for Physico-chemical Stressors in Surface Water

The WQOs for physico-chemical stressors were derived on a regional scale from the QWQG (EHP 2009a; Central Coast region) for study sub-catchments within the Burdekin Basin, and from Schedule 1 of the EPP (Water) for sub-catchments within the Fitzroy Basin, where available.

Table 4-1 WQOs for physico-chemical stressors in surface waters within the Project study area (derived from ANZECC and ARMCANZ 2000, and EHP 2009a and 2011)

Parameter	Water Quality Objectives			
	Upper Isaac River	Connors River	Mackenzie River	Suttor River and Bowen River* (Burdekin Basin)
Suspended Solids (mg/L)	55	15	110	N/A
Sulphate (mg/L)	25	5	10	N/A
Total Nitrogen (µg/L)	500	485	775	250
Total Phosphorus (µg/L)	50	75	160	30
pH (pH units)	6.5-8.5	6.5-8.5	6.5-8.5	6.5-7.5
Ammonia Nitrogen (µg/L)	20	20	20	10
Oxidised Nitrogen (NOx) (µg/L)	60	60	60	15
Organic Nitrogen (µg/L)	420	420	420	225
Filterable reactive Phosphorus (µg/L)	20	20	20	15
Chlorophyll-a (µg/L)	5	5	5	N/A
Dissolved oxygen (% sat)	85-110	85-110	85-110	90-110
Turbidity (NTU)	50	50	50	25
Conductivity (EC) base flow (µS/cm)	720	430	310	200-500#
Conductivity (EC) high flow (µS/cm)	250	250	210	N/A

**Guidelines for Burdekin Basin sub-catchments were derived from EHP 2009a Table 3.2.1a, regional guideline values for physico-chemical indicators – Central Coast region freshwater upland streams; elevation typically between 200 – 350 metres above sea level in Bowen and Suttor Rivers based on digital elevation models developed for geomorphology assessment undertaken for EIS*

#80th percentile value for EC (derived from QWQG (EHP, 2009a), Figure G-3, Appendix G)

N/A- not available

4.1.2 WQOs for Toxicants in Surface Water

Additional WQOs pertaining to toxicants were derived from the relevant ANZECC and ARMCANZ (2000) guidelines for the protection of the 95th percentile of species in slightly to moderately disturbed aquatic ecosystems (Table 3.4.1, p3.4-5, ANZECC and ARMCANZ (2000)). The WQOs for protection of aquatic ecosystems against toxicants (namely heavy metals) are outlined in Table 4-2. They are applicable across all study sub-catchments, as local or regional guidelines are currently not available for toxicants, the ANZECC and ARMCANZ (2000) guidelines are recommended as a default. Iron is sometimes detected at significant levels within Queensland's freshwater systems, yet there is currently no defined value for aquatic ecosystem protection against the toxic effects of iron published within Australia. In the absence of site-specific WQOs, and in accordance with ANZECC and ARMCANZ (2000) recommendations, a guideline value has been identified from the Canadian Water Quality Guidelines (CCME, 1999). This should therefore be considered as indicative only, as an interim guideline prior to development of site-specific WQOs.

Adjustments have also been made to WQOs for selected heavy metals based on the observed hardness of surface waters within each sub-catchment (Table 4-3). Categories of hardness and associated conversion factors for toxicants are detailed in Table 3.4.4 of the ANZECC and

ARMCANZ (2000) guidelines. WQOs for relevant toxicants were adjusted accordingly, as illustrated in Table 4-3.

Table 4-2 WQOs for toxicants in surface waters within the Project study area

Parameter	Water Quality Objective(s)	Source/Reliability
Aluminium (µg/L)	55 if pH>6.5 0.8 if pH <6.5	Moderate Reliability with 95% protection of fresh water ecosystems (ANZECC and ARMCANZ 2000)
Chromium (III) (µg/L)	See Table 4-3	Low Reliability with 95% protection of fresh water ecosystems (ANZECC and ARMCANZ 2000)
Copper (µg/L)	See Table 4-3	High Reliability with 95% protection of fresh water ecosystems (ANZECC and ARMCANZ 2000)
Iron (µg/L)	300	Canadian WQ Guideline level (CCME 1999)
Lead (µg/L)	See Table 4-3	Low Reliability with 95% protection of fresh water ecosystems (ANZECC and ARMCANZ 2000)
Nickel (µg/L)	See Table 4-3	EPP (Water) 2011 – ANZECC and ARMCANZ 2000 Default
Zinc (µg/L)	See Table 4-3	EPP (Water) 2011 – ANZECCand ARMCANZ 2000 Default
Molybdenum (µg/L)	34	Low Reliability (ANZECC and ARMCANZ 2000)
Selenium (µg/L)	11 (Total Se only)	High Reliability with 95% protection of fresh water ecosystems (ANZECC and ARMCANZ 2000 Default)
Uranium (µg/L)	0.5	Low Reliability (ANZECC and ARMCANZ 2000)
Vanadium (µg/L)	6	Low Reliability (ANZECC and ARMCANZ 2000)

Table 4-3 Conversion of ANZECC and ARMCANZ (2000) guideline values based on observed hardness of local waters

Study sub-catchment	Median hardness (mg/L)	Hardness category (from Table 3.4.4, ANZECC and ARMCANZ 2000)	Cadmium (µg/L)	Chromium(III) (µg/L)	Copper (µg/L)	Lead (µg/L)	Nickel (µg/L)	Zinc (µg/L)
Bowen River Tributaries	514	Extremely hard	27.72	12.6	90.78	99	72	27.72
Suttor River Tributaries	612	Extremely hard	27.72	12.6	90.78	99	72	27.72
Isaac River Main Channel	71	Moderate	0.54	8.25	3.5	13.6	27.5	20
Isaac River Northern Tributaries	69	Moderate	0.54	8.25	3.5	13.6	27.5	20
Isaac River Western Upland Tributaries	110	Moderate	0.54	8.25	3.5	13.6	27.5	20
Connors River Central Tributaries	393	Extremely hard	27.72	12.6	90.78	99	72	27.72
Mackenzie River Main Channel	139	Hard	0.84	12.21	5.46	25.84	42.9	31.2
Mackenzie River North-Western Tributaries	281	Very hard	1.14	16.17	7.28	40.12	57.2	41.6
Mackenzie River Southern Tributaries	54	Soft	0.2	3.3	1.4	3.4	11	8
ORIGINAL WQO (Table 3.4.1, ANZECC and ARMCANZ (2000))			**0.2**	**3.3**	**1.4**	**3.4**	**11**	**8**

4.2 Existing Water Quality

A general overview of water quality trends within and between sub-catchments is provided below. Due to the large and variable nature of the available surface water quality dataset, as described in Section 4.2.1, it is important to understand the significance of the data in terms of how they represent the baseline patterns of the existing surface water environment (both spatial and temporal) in a statistical sense. A brief description of the significance of the available data for each study sub-catchment is therefore included. Due to the nature of the proposed Project activities in relation to the Isaac River, it was deemed most relevant to focus primarily on the assessment of the surface water environment within the Isaac River Main Channel. The water quality data set for other sub-catchments within the Project area can be used for further assessments related to other project infrastructure, where applicable, as this information becomes available.

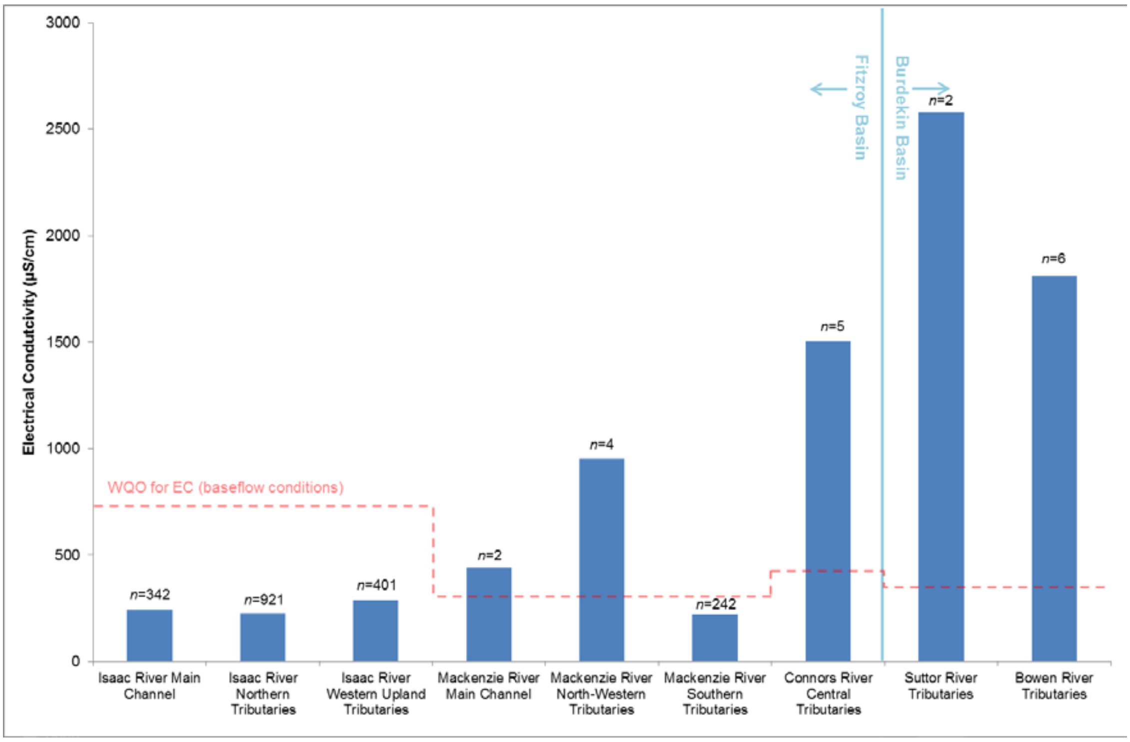
4.2.1 General overview of surface water quality throughout the Project study area

Statistical analysis for the median and 80th percentile values of the full water quality data set has been undertaken (see table in Appendix A). For reasons of practicality and ease of interpretation comparisons of water quality between the various sub-catchments has been undertaken using a number of key parameters as surrogates of the various classes of water quality parameters as follows:

- Physico-chemical stressors:
  - EC; and
  - Turbidity;
- Nutrients:
  - Total nitrogen;
- Toxicants
  - Dissolved and total aluminium; and
  - Dissolved and total zinc.

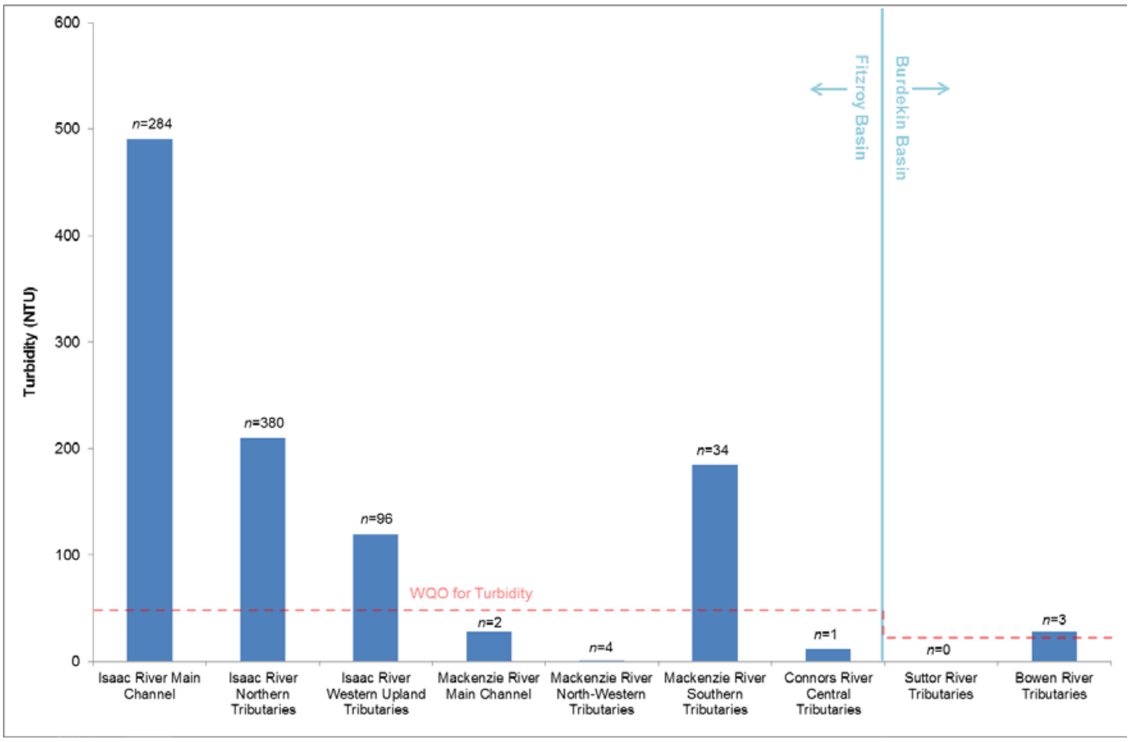
Figure 4-1 to Figure 4-5 provide a graphical representation of median results observed for each of the parameters listed, across all study sub-catchments.

Figure 4-1 Comparison of median EC values observed across all sub-catchments, against relevant WQO



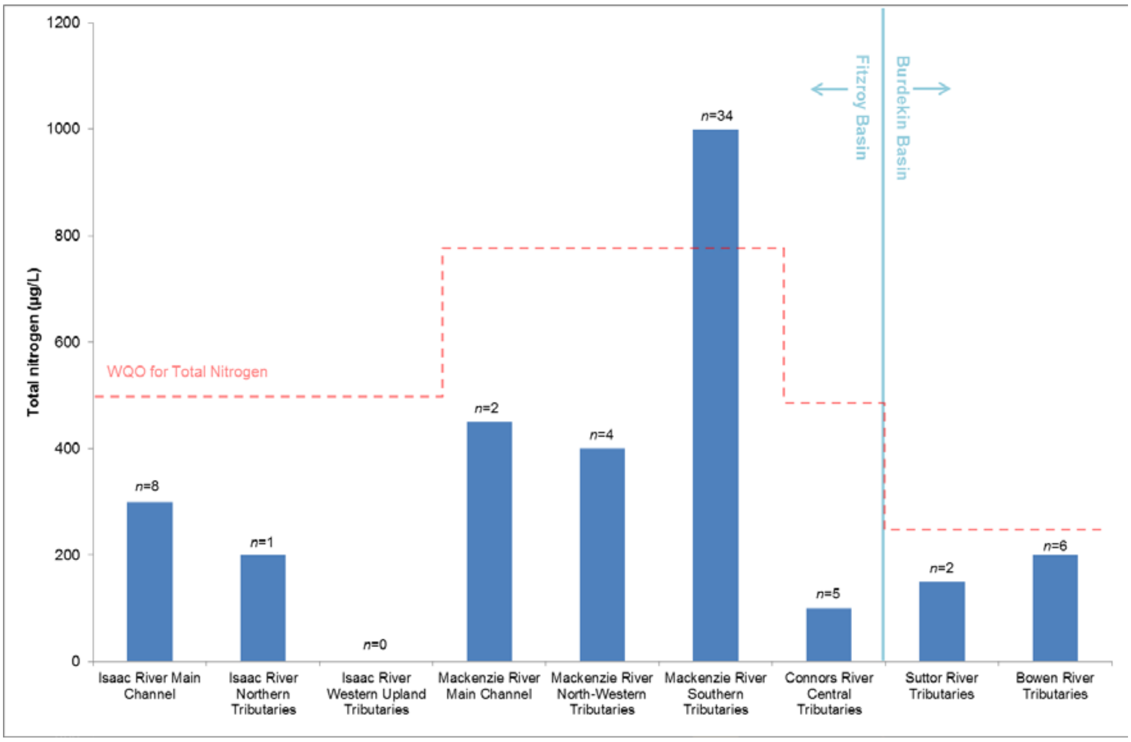
Whilst the data presented in Figure 4-1 shows that EC in the Mackenzie River Main Channel and Mackenzie River North-Western Tributaries, Connors River Central Tributaries, and Burdekin Basin sub-catchments (Suttor and Bowen River Tributaries) exceeded the recommended WQOs, these sub-catchments (with the exception of Mackenzie River Southern Tributaries) also had the lowest sampling frequencies (*n*) in the dataset. In this instance, the actual median EC values for these sub-catchments may be significantly different to the values represented above once further data becomes available. This is consistent with the observation that those sub-catchments which had a large and statistically significant data set had EC levels that were compliant with their relevant WQO.

Figure 4-2 Comparison of median turbidity values observed across all sub-catchments, against relevant WQO



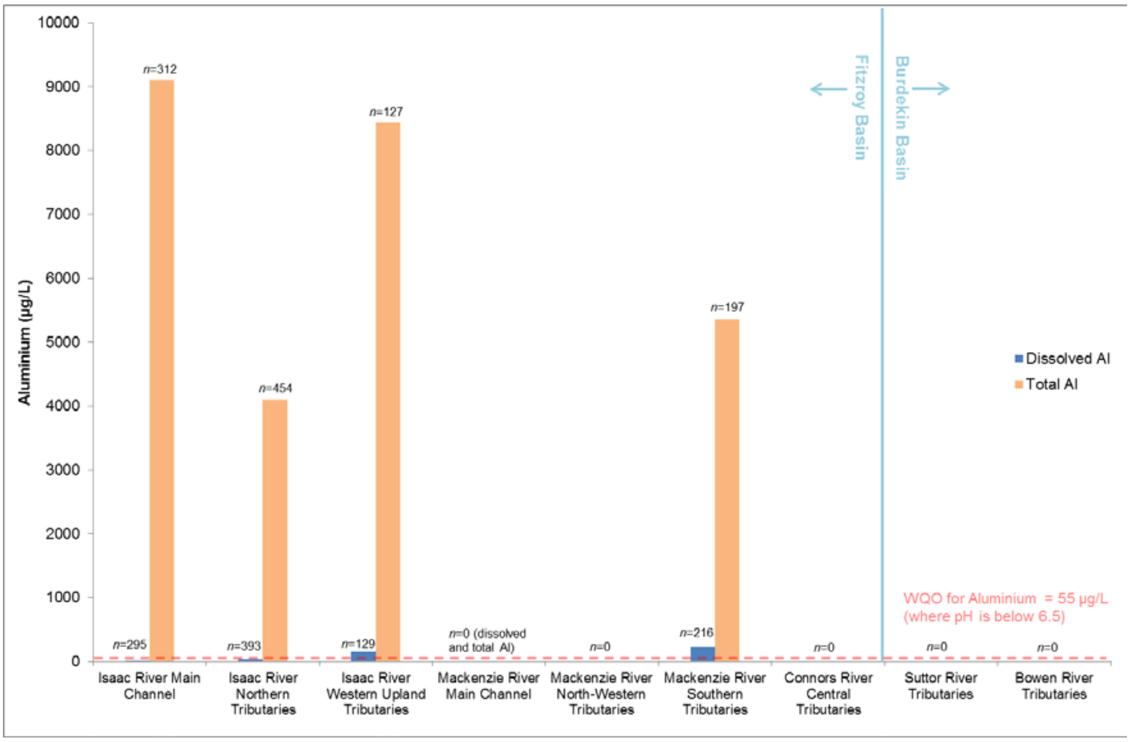
The Isaac River sub-catchments appeared to have the highest levels of turbidity compared to the rest of the study area (Figure 4-2). Due to the comparatively high sampling frequencies for the data used to compile those results, the trends observed in the Isaac River and its tributaries are significant and should be taken into consideration for the derivation of WQOs. Similarly, the Mackenzie River Southern tributaries also appeared had an elevated median of almost 200 NTU. In the event that significant disturbance of these sub-catchments be proposed, further turbidity measurements would be required to adequately characterise the baseline turbidity levels of these waterways.

Figure 4-3 Comparison of median total nitrogen values observed across all sub-catchments, against relevant WQO



Levels of total nitrogen seemed to be well below the applicable WQOs for most sub-catchments, with the exception of the Mackenzie River Southern Tributaries. The median levels for total nitrogen need to be interpreted cautiously given the low number of sampling for each of the sub-catchments, with the exception of the Mackenzie River Southern Tributaries. The elevated level of total nitrogen in the waterways of the Mackenzie River Southern Tributaries may be a function of land use.

Figure 4-4 Comparison of median values observed for total and dissolved aluminium across all sub-catchments, against relevant WQO

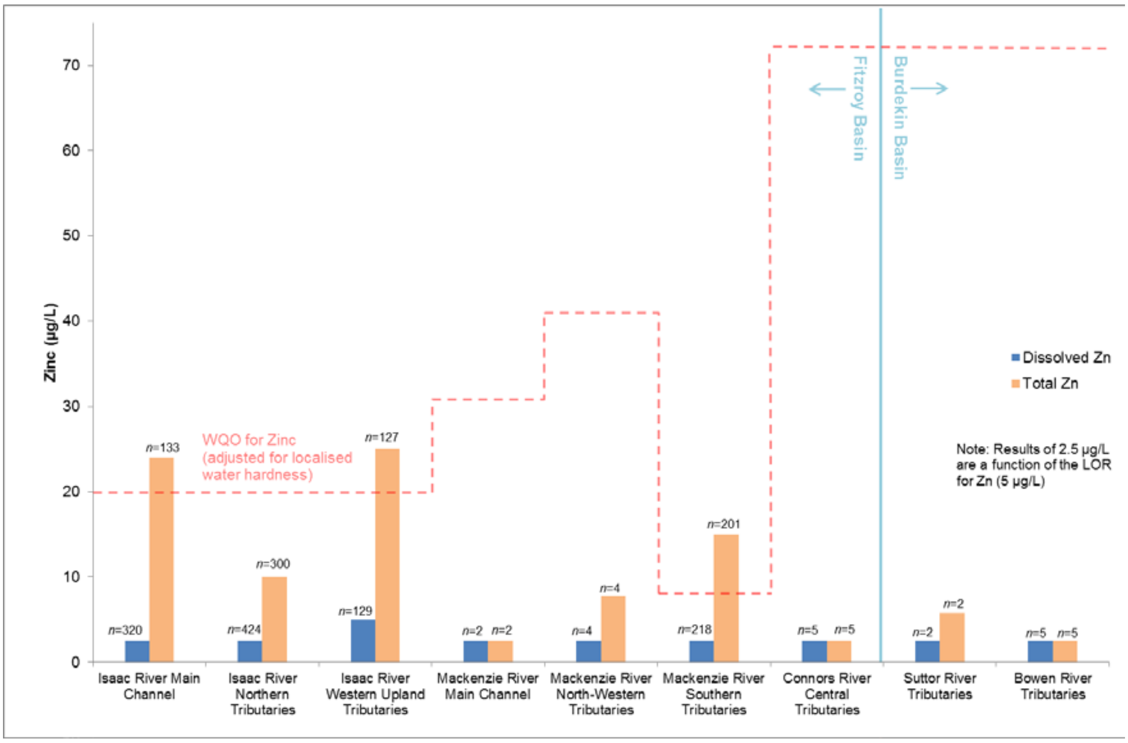


A marked dominance of total aluminium compared with the soluble fraction (dissolved aluminium) was obvious across those sub-catchments with sufficient data available for analysis, as shown in Figure 4-4 above. Observed concentrations of total aluminium within the three Isaac River sub-catchments (median values ranging between 4,100 and 9,100 µS/cm) were not significantly different from those observed in the Mackenzie River Southern Tributaries sub-catchment (median value of 5,360 µS/cm), which had a similar level of data resolution.

The Isaac River Western Upland Tributaries and Mackenzie River Southern Tributaries were the only sub-catchments where the median values for dissolved aluminium (150 µg/L and 220 µg/L, respectively) exceeded the existing WQO of 55 µg/L. It is possible that soils within these two sub-catchments are naturally more highly mineralised than soils in the other sub-catchments. This is supported by soil chemical data presented in the Soils and Land Suitability Technical Report (Appendix K) of the EIS. The elevated baseline concentration of dissolved aluminium will need to be considered during the establishment of water quality objectives for the Project.

Figure 4-5 below provides a similar comparison between dissolved and total zinc. Relevant WQOs for total zinc were exceeded in the Isaac River Main Channel; Isaac River Western Uplands, and Mackenzie River Southern Tributaries sub-catchments. As with aluminium (and as is expected for most metals in surface water) total zinc was dominant over dissolved zinc in all sub-catchments with sufficient data volumes available for analysis. Levels of soluble zinc in surface water are considered to be much more ecologically important than the level of total zinc; adsorbed or insoluble zinc (bound to sediment or as insoluble salts) is not considered to be bioactive nor available for uptake by aquatic fauna and flora. More data is required to determine whether the observed trends are also true for sub-catchments like the Mackenzie River Main Channel; Mackenzie River North-Western Tributaries; Connors River Central tributaries, and Suttor and Bowen River Tributaries; all of which had less than five data points in the available dataset and as such did not provide significant results.

Figure 4-5 Comparison of median values observed for total and dissolved zinc across all sub-catchments, against relevant WQO



4.2.2 Surface water quality assessment for the Isaac River Main Channel sub-catchment

At this point in time, Project development near watercourses is limited to within the Isaac River Main Channel sub-catchment. Sites for the construction of two WTFs and potential CSG water discharge points have been provisionally located near the Isaac River. Further information on mitigation of the potential impacts arising from these activities is included in Section 6 and Section 8.

Table 4-4 provides a statistical summary of water quality results obtained for the Isaac River Main Channel sub-catchment between 2010 and 2013. Highlighted values are those where the existing WQO was exceeded.

Table 4-4 Statistical results for surface water quality parameters within Isaac River Main Channel sub-catchment

Parameter (units)	Existing WQO	20th percentile value	Median (50th percentile) value	80th percentile value
Physico-chemical stressors				
pH	6.5 - 8.5	7.5	7.8	8.1
EC (µS/cm)	720	162	244	428
Dissolved oxygen (%Sat)	85 - 110	0	95	98.5
Dissolved oxygen (mg/L)		7.5	8.6	9.2
Turbidity (NTU)	50	280	491	1030
Temperature (°C)		20.1	21	24.7
Total Suspended Solids (mg/L)	55	202	340	594
Hardness (mg/L)		52	71	87
Sulphate - SO_4 (mg/L)	25	1	5	21
Fluoride (µg/L)		50	100	120
Nutrients				
Ammonia (µg/L)	20	5	15	40
Nitrate (µg/L)		10	50	170
Nitrogen as N (µg/L)	500	200	300	360
Nitrite + Nitrate (µg/L)		10	10	90
Alkalinity - hydroxide (mg/L)		0.5	0.5	0.5
Alkalinity - carbonate (mg/L)		0.5	0.5	0.5
Alkalinity - bicarbonate (mg/L)		150	188	221
Total Alkalinity (mg/L)		150	188	225
Total Organic Carbon (mg/L)		10	25	25
Total Petroleum Hydrocarbons (TPH)				
C_6-C_9 (µg/L)		10	25	25
C_{10}-C_{14} (µg/L)		25	25	25
C_{15}-C_{28} (µg/L)		50	100	100
C_{29}-C_{36} (µg/L)		45	90	100
C_{10}-C_{36} (µg/L)		25	100	590
Dissolved Toxicants				
Aluminium (µg/L)	55	0.5	0.5	350
Arsenic (µg/L)	24	0.5	30	50
Boron (µg/L)	370	25	40	60
Barium (µg/L)		0.0	79	107.2
Beryllium (µg/L)		0.05	0.05	0.1
Cadmium (µg/L)*	0.54	0.05	0.5	1.0

Parameter (units)	Existing WQO	20th percentile value	Median (50th percentile) value	80th percentile value
Chromium (µg/L)*	8.25	0.5	0.5	0.5
Cobalt (µg/L)		0.5	2.0	3.0
Copper (µg/L)*	3.5	2	5	218
Iron (µg/L)	300	0.5	0.5	248
Lead (µg/L)*	13.6	0.5	0.5	2.5
Manganese (µg/L)	1900	0.05	0.05	2.5
Mercury (µg/L)	0.6	0.05	0.5	1.0
Molybdenum (µg/L)	34	0.5	2.0	3.0
Nickel (µg/L)*	27.5	2.0	2.5	2.5
Selenium (µg/L)	11	0.05	0.05	2.5
Silver (µg/L)	0.05	0.0	0.0	0.0
Uranium (µg/L)	0.5	0.2	2.5	2.5
Vanadium (µg/L)	6	2.4	2.5	5.0
Zinc (µg/L)*	20	2.5	2.5	2.9
Total Heavy Toxicants				
Aluminium (µg/L)	55	3200	9100	17000
Arsenic (µg/L)	24	2.0	30	60
Boron (µg/L)	370	30	50	70
Barium (µg/L)		0.0	146	188.8
Beryllium (µg/L)		0.25	0.25	0.25
Cadmium (µg/L)*	0.54	0.25	7	21
Chromium (µg/L)*	8.25	2.5	8	18
Cobalt (µg/L)		4	9	16
Copper (µg/L)*	3.5	9.8	5100	15920
Iron (µg/L)	300	2.5	11	9892
Lead (µg/L)*	13.6	5.0	130	340
Manganese (µg/L)	1900	0.05	0.05	224
Mercury (µg/L)	0.6	0.05	2.5	2.5
Molybdenum (µg/L)	34	2.5	8.0	21
Nickel (µg/L)*	27.5	2.5	2.5	16
Selenium (µg/L)	11	0.25	0.4	2.5
Silver (µg/L)	0.05	0.25	0.5	0.8
Uranium (µg/L)	0.5	0.4	17.5	40
Vanadium (µg/L)	6	6.0	20.5	37
Zinc (µg/L)*	20	9.0	24	39

Note: WQOs for parameters marked with an asterisk (*) have been adjusted to account for localised water hardness (based on median value from the available dataset) as per Table 3.4.4 of the ANZECC and ARMCANZ (2000) guidelines.

Results for total and dissolved silver were deemed to be of poor quality for analysis, as the basic statistical values were highly influenced by the LOR value (generally ranging from 0.1 to 1 µg/L depending on laboratory analysis methods used) which was low compared with a WQO of only 0.05 µg/L.

Statistical analysis of the water quality data set indicated that certain water quality parameters exceeded the sub-regional WQOs; as such, locally derived background values may need to be developed. Median levels of turbidity, total suspended solids, dissolved arsenic, dissolved copper and dissolved uranium were not compliant with the Isaac River Main Channel sub-catchment WQOs. The exceedance of dissolved uranium over the WQO is not of particular concern, as it appears that this result may have been due to the influence of a comparatively low LOR (typically 1 µg/L). Therefore a locally derived WQO is not necessary for uranium. However, locally derived WQOs would be more appropriate for the remainder of these parameters. Based on the statistical values presented in Table 4-4 above, revised local (sub-regional) WQOs for the Isaac River Main Channel are recommended in Section 5.15.1. Upon confirmation of final discharge locations these sub-regional WQOs may need to be updated in the event that site-specific baseline water quality monitoring is undertaken as part of the EA application or amendment stage.

4.2.2.1 Relationship of EC and flow in the Isaac River Main Channel

To understand the variability of water quality in response to flow rate, EC levels and daily discharges in the Isaac River main channel have been assessed using data from NRM stream gauges.

Data from the Deverill stream gauge (130410A) indicates a strong relationship between EC and flows (Figure 4-6). The results show that for flows less than approximately 200 m^3/s the EC levels fluctuates very significantly between approximately 100 µS/cm to 1,400 µS/cm, whereas at high flows (greater than 200 m^3/sec) EC stabilises at approximately 150 µS/cm. These results are consistent with the WQOs for the Isaac River set at 720 µS/cm for low flows and 250 µS/cm for periods of high flow. In order to maximise the information on the relationship between stream flow and EC for the Isaac River main channel, the flow and EC data was transformed into $\log_e$ plots using the methodology of Harvey and Jones (2003) (Figure 4-7). The transformed plot indicates that the relationship between flow and EC in the Isaac River is biphasic, with a distinct inflexion point occurring at a discharge rate of approximately 3.5 m^3/sec. At stream flows greater than 3.5 m^3/sec EC levels in the Isaac River main channel decrease with increasing flows which means that this variability would need to be taken into consideration for potential releases. Given that treated CSG water has EC values that are typically below 720 µS/cm (WQO for low flow) means that discharges of treated water could occur at low flows, as long as EV's are protected. During periods of high flows, when EC values in the river are at 250 µS/cm, CSG water can be released at discharge rates that ensure EC levels are managed during a regulated discharge.

Figure 4-6 Relationship between EC and stream flow for the Isaac River Main Channel

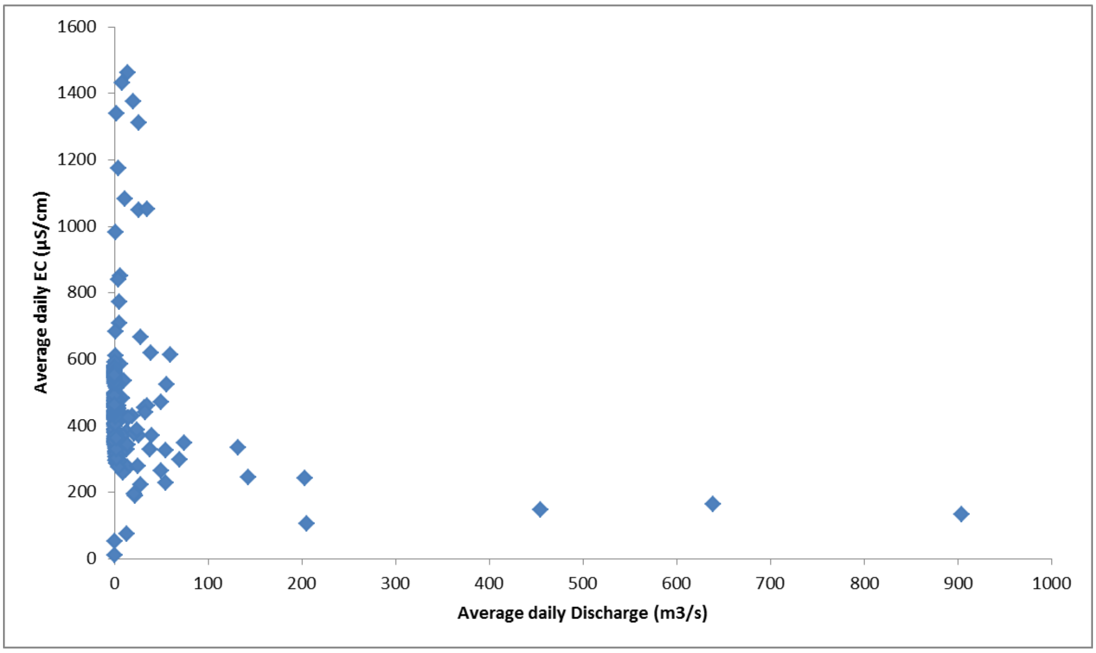
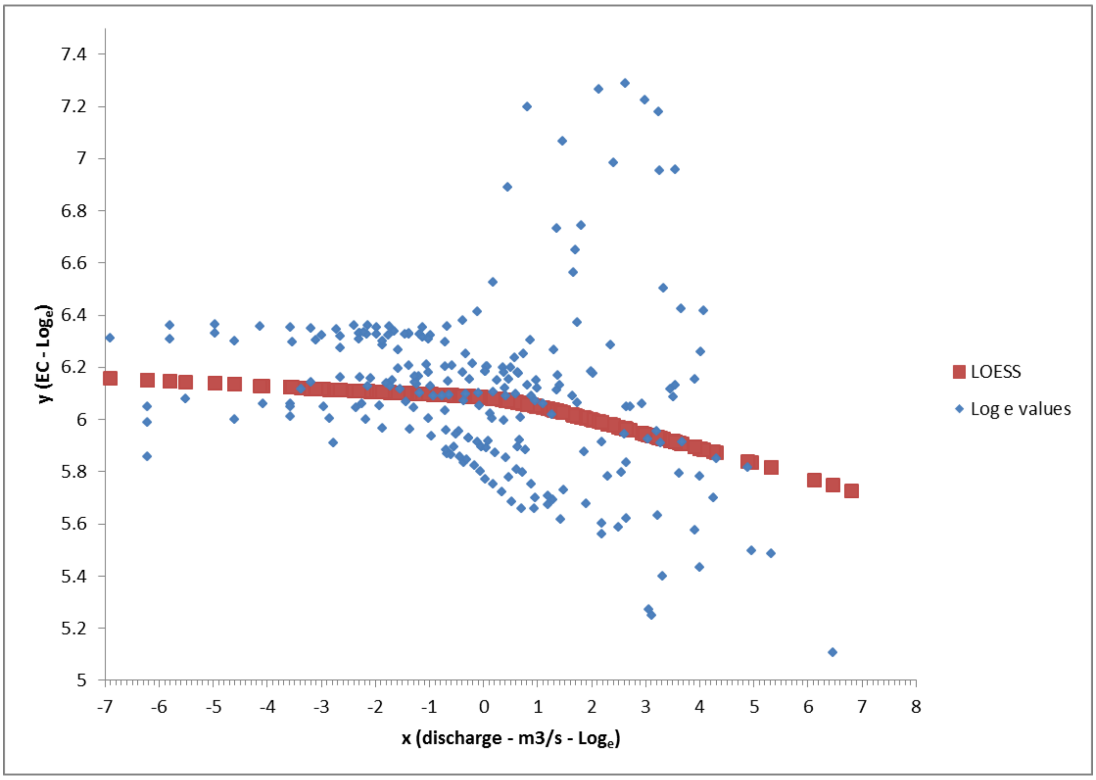


Figure 4-7 Plot of log$_e$ EC versus log$_e$ stream flow using the NRM Deverill (130410A) gauge data



5 SUMMARY OF EXISTING SURFACE WATER ENVIRONMENT

Characterisation of the surface water environment of the Isaac River main channel indicates that the baseline water quality complies with most of the published WQOs. Where baseline water quality does not comply, locally derived WQOs have been proposed. The results of this assessment are summarised below.

5.1 Proposed sub-regional WQOs

Sub-regional guidelines were developed for those parameters that were consistently exceeded within the Isaac River Main Channel. These included:

- Turbidity;
- Total suspended solids (TSS); and
- Aluminium (based on results for dissolved aluminium within the sub-catchment).

The recommended revised WQOs were developed using methodology outlined in the QWQG (EHP, 2009a). Monitoring locations within the Isaac River Main Channel were assessed to be slightly to moderately disturbed and therefore within the ‘Case B’ group of sub-regional sites classified in Section 4.3.5 of the QWQG (EHP, 2009a). Case B type locations “do not fully meet reference site requirements but are in a reasonable condition”; this assessment is true in general across the sub-catchment, although some monitoring sites may be more impacted than others. Given that the specific locations of these monitoring sites are unknown, their suitability as reference sites cannot be confirmed. Notwithstanding the above, based on the available sample population for water quality assessment, the derived sub-regional WQOs for the Isaac River Main Channel are considered to be appropriate for consideration during the EA application process.

The sub-regional WQOs shown in Table 5-1 comprise the average values of medians (50^{th} percentiles) derived from individual monitoring locations across the sub-catchment. The QWQG (EHP, 2009a) recommend the adoption of local guideline values where they fall within the “calculated ranges of the 20^{th} and 80^{th} percentiles (plus/minus one standard error)”. The median (50^{th} percentile) values were selected to provide a more conservative recommendation, given the uncertainties associated with the source data described above. It is noted that although the median value observed for dissolved copper did exceed the existing WQO (refer to Section 4.2.2), it was still within one standard error of the calculated ranges of the 20^{th} and 80^{th} percentile values, therefore a revision of the WQO for copper was not warranted. A detailed summary of the calculations undertaken to derive sub-regional WQOs are included in Appendix B of this report.

Table 5-1 Calculated Sub-regional WQOs for selected parameters within the Isaac River Main Channel

Parameter	20th percentile values		Median (50th percentile) values		80th percentile values		Existing regional WQO	Revised sub-regional WQO
	Mean	Standard error (±)	Mean	Standard error (±)	Mean	Standard error (±)		
Turbidity (NTU)	188.5	50	354.1	102.9	704.3	225.3	50	354
TSS (mg/L)	187.6	40.5	261.9	47.1	400.1	67	55	262
Aluminium (µg/L)*	177.9	45.8	375.1	123.6	818.9	392.5	55	375

**Based on water quality results for dissolved fraction*

5.2 Environmental Values

The EVs assessed as part of the EIS process (Surface Water Technical Report (Appendix N, Section 4) of the EIS) are still applicable to the Project at SREIS stage. For the purpose of the assessment of potential impacts associated with CSG water releases from the Project area (contained in Section 6 of this report), EVs associated with surface water quality, geomorphology and hydrology of the receiving environment for releases have been assessed as moderately sensitive.

Moderately sensitive EVs are those where:

- The EV is recorded as being important at a regional level, and may have been nominated for listing on recognised or statutory registers;
- The EV is in a moderate to good condition despite it being exposed to threatening processes. It retains many of its intrinsic characteristics and structural elements;
- It is relatively well represented in the systems/area in which it occurs but its abundance and distribution are limited by threatening processes;
- Threatening processes have reduced its resilience to change. Consequently, changes resulting from Project activities may lead to degradation of the prescribed value; and
- Replacement of unavoidable losses is possible due to its abundance and distribution.

6 IMPACT ASSESSMENT

An assessment of the potential impacts to the surface water environment arising from proposed activities associated with the Project was completed for the EIS. The EIS assessment outlined standard operational measures that would be taken to minimise the potential impacts identified at the time. In the interim, the proposed activities associated with the Project have been refined, and further detail is available in terms of the footprint and location of key elements of the Project infrastructure; expected peak flows for produced water, and designed water treatment capacity across the Project area.

Thus, the purpose of the SREIS surface water impact assessment is to validate findings of the EIS impacts and mitigation measures, and highlight any gaps in knowledge or proposed activities that will be further refined during the preparation stage of the EA application(s) for the Project.

The discussions of mitigation measures within this section contain references to earlier management options outlined in the Surface Water Technical Report (Appendix N) of the EIS. These activities, their potential associated impacts to surface waters, and applicable mitigation measures, are discussed further in Table 6-4.

Whilst this technical report specifically addresses the surface water quality aspects of any likely impacts related to activities described in the updated project description, these studies are considered together with Project impacts related to hydrology and geomorphology (Hydrology and Geomorphology Technical Report (Appendix G) of the SREIS), and aquatic ecology (Aquatic Ecology Technical Report (Appendix H) of the SREIS). The different and inter-relating aspects that determine river health such as water quality, river hydrology, geomorphology and aquatic ecology were assessed in order to minimise impacts to all EVs associated with the Isaac River. This complex interrelationship is depicted in Figure 6-1.

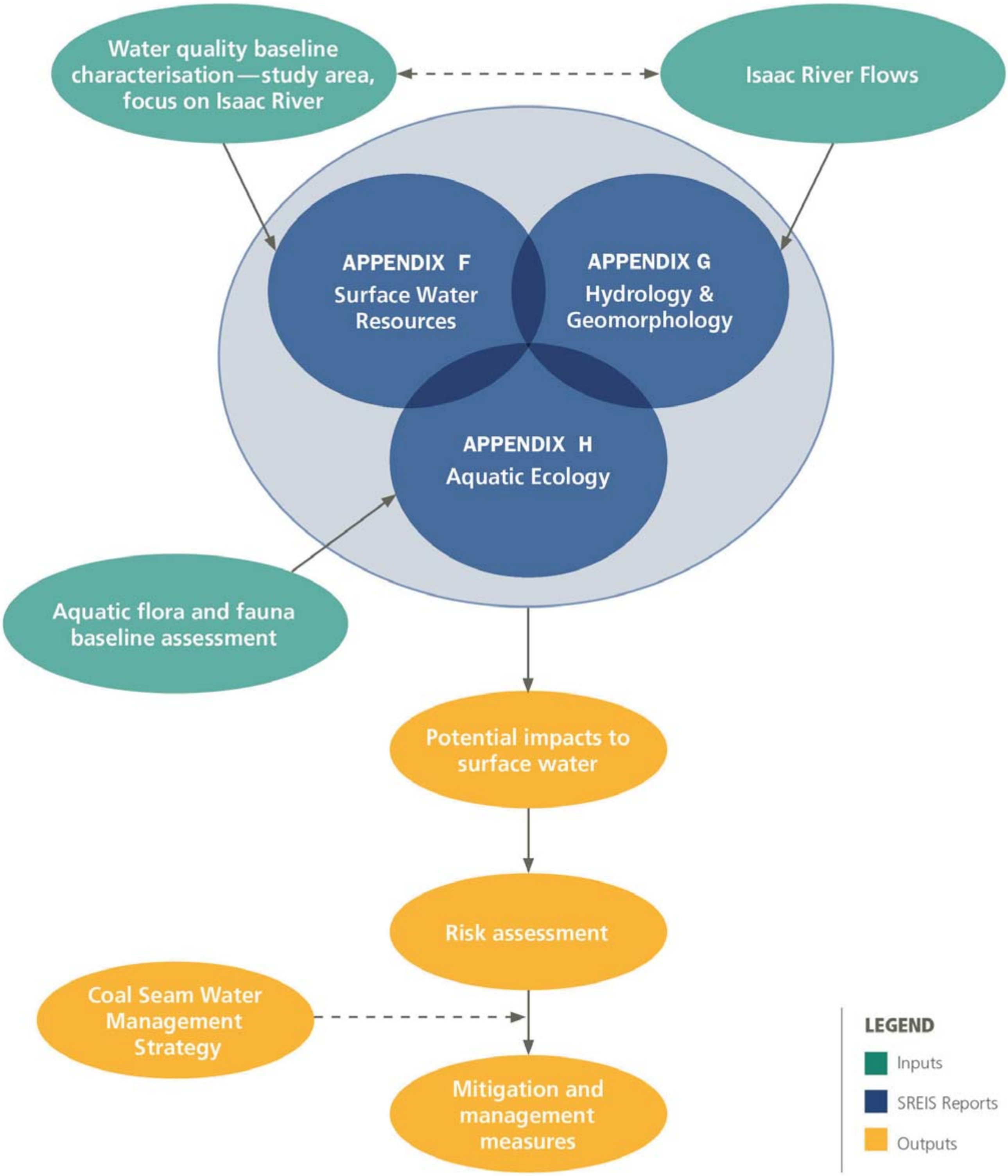
This approach was utilised in the assessment of impacts associated with potential discharges of CSG water. Ultimately the approach in which discharges of CSG water will be determined (as part of the EA application process) will allow CSG water (treated or untreated) to be discharged to the receiving environment whilst minimising environmental impacts.

6.1 Impact Assessment Methodology

The assessment of the potential impacts of the development of the Project on surface water resources was undertaken in the context of EVs, as defined by the EPP Water, using a significance assessment methodology. This type of assessment was adopted to provide an understanding of the vulnerability of the surface water environment. The methodology was previously developed and used in Arrow’s Surat Gas Project EIS (Arrow, 2011). The significance and magnitude of impacts identified by this study are summarised in Table 7-1.

The significance of an impact was assessed by considering the vulnerability or sensitivity of the EV and the magnitude of the impact, before and after the application of mitigation and management measures. It assumes that the impact will occur and that the significance will be identified and assessed. The significance of the residual impact was assessed assuming successful implementation of proposed mitigation and management measures.

Potential cumulative impacts on surface water quality are discussed in Section 9.



arrow energy go further

BOWEN GAS PROJECT SREIS

OVERVIEW OF IMPACT ASSESSMENT PROCESS FOR THE SURFACE WATER ENVIRONMENT

URS

SURFACE WATER TASK MANAGEMENT

Figure: **6-1**

File No: **42627140-g-2103.cdr** Drawn: **RG** Approved: **BC** Date: **05-03-2014** Rev. **A** A4

6.1.1.1 *Sensitivity of Environmental Values*

An EV's sensitivity was determined by its susceptibility or vulnerability to threatening processes and consequently, its intrinsic value. Criteria for sensitivity are presented in Table 6-1.

Table 6-1 Criteria for Sensitivity

Sensitivity	Description
High	The EV is listed on a recognised or statutory state, national or international register as being of conservation significance. The EV is intact and retains its intrinsic value. The EV is unique to the environment in which it occurs. It is isolated to the affected system/area which is poorly represented in the region, territory, country or the world. It has not been exposed to threatening processes, or they have not had a noticeable impact on the integrity of the EV. Project activities would have an adverse effect on the value.
Moderate	The EV is recorded as being important at a regional level, and may have been nominated for listing on recognised or statutory registers. The EV is in a moderate to good condition despite it being exposed to threatening processes. It retains many of its intrinsic characteristics and structural elements. It is relatively well represented in the systems/areas in which it occurs but its abundance and distribution are limited by threatening processes. Threatening processes have reduced its resilience to change. Consequently, changes resulting from project activities may lead to degradation of the prescribed value. Replacement of unavoidable losses is possible due to its abundance and distribution.
Low	The EV is not listed on any recognised or statutory register. It might be recognised locally by relevant suitably qualified experts or organisations e.g., historical societies. It is in a poor to moderate condition as a result of threatening processes which have degraded its intrinsic value. It is not unique or rare and numerous representative examples exist throughout the system / area. It is abundant and widely distributed throughout the host systems / areas. There is no detectable response to change or change does not result in further degradation of the EV. The abundance and wide distribution of the EV ensures replacement of unavoidable losses is achievable.

6.1.1.2 *Magnitude of Impacts*

The magnitude of an impact on an EV is an assessment of the geographical extent, duration and severity of the impact. Criteria for magnitude are presented in Table 6-2.

Table 6-2 Criteria for Magnitude

Magnitude	Description
High	An impact that is widespread, long lasting and results in substantial and possibly irreversible change to the EV. Avoidance through appropriate design responses or the implementation of site-specific environmental management controls are required to address the impact.
Moderate	An impact that extends beyond the area of disturbance to the surrounding area but is contained within the region where the project is being developed. The impacts are short term and result in changes that can be ameliorated with specific environmental management controls.
Low	A localised impact that is temporary or short term and either unlikely to be detectable or could be effectively mitigated through standard environmental management controls.

6.1.1.3 Significance of Impacts

The significance of an impact on an EV was determined by the sensitivity of the value itself and the magnitude of the impact it experiences. The significance assessment matrix presented in Table 6-3 shows how, using the criteria above, the significance of an impact was determined.

Table 6-3 Significance Assessment Matrix

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

The classifications (major, high, moderate, low or negligible) for significance of an impact are as follows:

- **Major** significance of impact - arises when an impact will potentially cause irreversible or widespread harm to an EV that is irreplaceable because of its uniqueness or rarity. Avoidance through appropriate design responses is the only effective mitigation.
- **High** significance of impact - occurs when the proposed activities are likely to exacerbate threatening processes affecting the intrinsic characteristics and structural elements of the EV. While replacement of unavoidable losses is possible, avoidance through appropriate design responses is preferred to preserve its intactness or conservation status.
- **Moderate** significance of impact - although reasonably resilient to change, the EV would be further degraded due to the scale of the impact or its susceptibility to further change. The abundance of the EV ensures it is adequately represented in the region, and that replacement, if required, is achievable.
- **Low** significance of impact - occurs where an EV is of local importance and temporary and transient changes will not adversely affect its viability provided standard environmental management controls are implemented.
- **Negligible** significance of impact - impact on the EV will not result in any noticeable change in its intrinsic value and hence the proposed activities will have negligible effect on its viability. This typically occurs where the activities occur in industrial or highly disturbed areas.

6.1.2 Comparison of EIS and SREIS scenarios

The following table provides a summary of the key changes to the Project (arising since completion of the EIS), and offers an additional assessment of potential impacts that may be associated with those changes.

Table 6-4 SREIS Impact Assessment Summary

Project component	EIS scenario (2012)	SREIS scenario (2014)	Associated potential impacts	Key changes in degree of potential impact	Applicable mitigation measures
Drainage areas	• 17 'drainage areas' of approximately 12 km radius, over approximately 8,000 km^2 Project area.	• 33 'drainage areas' of approximately 6 km radius, over approximately 8,000 km^2 Project area.	• Alteration of flows and flow paths. • Erosion and sediment mobilisation, including sediment adsorbed metals and pesticides. • Improper disposal of wastes from construction and operations activities. • Potential release of contaminants to watercourses (adverse effects on surface water quality).	• Reduction in size of each drainage area, but increase in number of drainage areas; contributing to an overall reduction in the intensity of development on a regional scale. • May result in increased localised impacts compared with EIS scenario.	• Mitigation measures outlined in Sections 9.2.1, 9.2.2 and 9.2.3 of the Surface Water Technical Report (Appendix N) of the EIS still apply.
Production wells	• 6,625 production wells drilled over 40 years. • Single well pads only.	• Approximately 4,000 production wells drilled over 36 years. • Multi-branch lateral wells will be clustered together onto multi-well pads.	• Alteration of flows and flow paths. • Erosion and sediment mobilisation.	• Reduced intensity of development on a regional scale, however the introduction of multi-well pads may increase the degree of potential localised impact and risk to surface waters.	• Mitigation measures outlined in Sections 9.2.2.1, 9.2.2.2 and 9.2.2.3 of the Surface Water Technical Report (Appendix N) of the EIS still apply.

Project component	EIS scenario (2012)	SREIS scenario (2014)	Associated potential impacts	Key changes in degree of potential impact	Applicable mitigation measures
Gas compression infrastructure	• Four integrated processing facilities (IPFs) of 800 m x 250m area, with dams up to 1 km^2 in area. • One field compression facility (FCF) per drainage area, with a footprint of up to 200 m x 250 m.	• Two CGPFs in the locality of Peak Downs and of Red Hill (as well as close to the Isaac River). • One FCF per drainage area (skid-based, modular design with footprint up to 200 m x 380 m in area).	• Alteration of flows and flow paths. • Erosion and sediment mobilisation.	• Reduced footprint and number of CGPFs. • Larger footprint area for FCFs.	• Mitigation measures outlined in Sections 9.2.1.1 to 9.1.2.4, and 9.2.2 of the Surface Water Technical Report (Appendix N) of the EIS still apply.
WTFs	• Maximum dam footprint 0.6 km^2. • WTFs may have peak flows of between 15-30 ML/d of field produced water, allowing that some areas will produce more water than others.	• Water Transfer Stations in field (pumping and surge tanks); typically associated with an FCF. • One WTF associated with each CGPF. Feed water dams, treated water dams, and brine storage facilities will be located at each WTF. • WTF1: Expected peak flow capacity of 12.9 ML/d. • WTF2: Expected peak flow capacity of 20 ML/d. • Raw water can be transferred between WTFs (current concept). • Water storage and pumping facilities at each FCF to move water to the WTFs.	• Controlled release of treated (and in certain instances untreated) CSG water to surface watercourses (potential adverse effects on surface water quality). • Uncontrolled release of treated or untreated CSG water, and contaminated process water to grade and/or watercourses due to flooding, dam failure or spills (from water gathering lines; trucks transporting wastewater and treated water from water transfer stations). • Reduced risk of adverse impacts to water quality, with fewer discharge points (a function of having fewer WTFs).	• Reduction in number of WTFs, but retained a similar treatment capacity to that proposed for the EIS scenario. • Significant reduction in maximum area for WTF dams, potentially decreasing the overall impact of WTF construction/operation. • Potentially lower risk of uncontrolled release to surface waters, due to reduced number of WTFs and discharge locations. • No change in potential impacts associated with FCFs, as specific locations have not yet been identified (refer to impacts presented in EIS).	• Mitigation measures outlined in Sections 9.2.1.1 to 9.1.2.4, and 9.2.2 of the Surface Water Technical Report (Appendix N) of the EIS still apply. • Section 9.2.2.4 of the Surface Water Technical Report (Appendix N) of the EIS specifically applies to any releases from WTFs to the receiving environment, along with information outlined in Sections 7.1 and 8 of this report.

Project component	EIS scenario (2012)	SREIS scenario (2014)	Associated potential impacts	Key changes in degree of potential impact	Applicable mitigation measures
Linear Infrastructure (e.g. roads and pipelines)	• Network of roads and pipelines designed to cater for project layout.	• Updated linear infrastructure to be constructed as per project concept layout.	• Alteration of flows and flow paths. • Erosion and sediment mobilisation.	• Extent of linear infrastructure required reflects updates to the project description under the SREIS scenario. The linear infrastructure required for the updated project description is considerably less, thereby minimising potential impacts.	• Mitigation measures outlined in Sections 9.2.1.1 to 9.1.2.4, and 9.2.2 of the Surface Water Technical Report (Appendix N) of the EIS still apply.

7 CSG WATER RELEASE IMPACTS AND BENEFICIAL USE OPTIONS

As stated in the revised project description (Section 1.21.2), CSG water will be produced throughout the Project life cycle. Produced water will be processed by water treatment facilities, and as required be stored at water transfer stations (at FCFs, prior to being pumped or transported to WTFs co-located at the CGPFs); in feed water dams (storage and settlement dams, prior to being processed through a WTF), and in treated water dams (for storage of treated CSG water prior to beneficial use or release). Water will firstly be directed to beneficial uses (detailed in Section 7.2 below), but may need to be released to surface watercourses periodically if any of the following conditions occur:

- Constraints to supply for beneficial use;
- Unforeseen events such as significant weather events; or
- The structural and operational integrity of dams is at risk.

With the flow regime data presented in the Hydrology and Geomorphology Technical Report (Appendix G) of the SREIS and an understanding of the maximum expected level of salinity in both the receiving environment and produced water (from Bowen Basin formations), it is possible to manage the impacts that may be associated with CSG water releases.

7.1 Discharge to watercourses

The characterisation of the baseline condition of the Isaac River indicates that Arrow is able to manage the possible controlled releases of treated or untreated CSG water without causing significant impacts to the receiving waterway. Site-specific assessments of the water quality at the confirmed locations of potential CSG discharge points will be undertaken as part of the EA application process. Discharge of CSG water has the potential to adversely impact the receiving waterways by affecting the EVs associated with receiving water's quality, stream flow and geomorphic conditions. As such the discharge rates, timing, frequency and duration of CSG water releases that will be considered as part of the EA process will address a number of variables including stream flows, stream water quality and CSG water quality. As an overarching objective, discharge of treated or untreated CSG water is considered appropriate only where disposal to receiving waterways will not significantly impact the EVs of the aquatic environment, in line with legislative requirement.

In the case of uncontrolled releases of CSG water the magnitude and significance of impacts would depend on the quality of CSG water released and the flows of the receiving environment. These impacts have been assessed to range from low to moderate (Table 7-1).

Table 7-1 Impact assessment for CSG water release scenarios on the Isaac River

Coal seam water release scenario	Contributing factor	Potential impacts	Magnitude of impact	Significance of impact
Uncontrolled release of *untreated* CSG water	Flooding (dams over capacity; inundation of infrastructure)	Slight increase in receiving environment salinity, although unlikely to exceed receiving environment 80th percentile value of 428 µS/cm as Isaac River flows will likely be at greater than 75th percentile flow volume for flooding to occur.	Low	Low
	Dam failure	During periods of low flow, sudden release of large volumes of moderately saline water will impact the baseline salinity and the natural flow regime. Potential inundation of riparian margins and floodplain areas not usually inundated during dry season. Transport of large quantities of sediment and large woody debris downstream. During periods of high flow, there may be a slight increase in salinity within the receiving environment, however it is unlikely to exceed Isaac River 80th percentile value of 428 µS/cm.	High	High
	WTF operational emergency	Similar impacts to those listed above for dam failure, but of lower magnitude and significance.	Moderate	Moderate
Uncontrolled release of *treated* CSG water	Flooding (dams over capacity; inundation of infrastructure)	Possible decrease in salinity within receiving environment (due to dilution), depending on the EC of the receiving environment during flood. Some impact may be evident to hydrology and geomorphology, with an increase in water level and discharge depending on extent of flood.	Low	Low
	Dam failure	During periods of low flow, sudden release of large volumes will be outside of the natural flow regime. Potential inundation of riparian margins and floodplain areas not usually inundated during dry season; slight exacerbation of high water level during wet season. Mobilisation and transport of large quantities of sediment and large woody debris downstream	Moderate	Moderate
	WTF operational emergency	Similar impacts to those listed above for dam failure, but of lower magnitude and significance.	Low	Low
Uncontrolled release of both *treated and untreated* CSG water	Flooding (dams over capacity; inundation of infrastructure)	Potential water quality impacts resulting from combined sources (higher salinity of treated CSG water, combined with large volumes of both streams) could be difficult to interpret. However during periods of significant rain events overspills are likely to be quickly diluted in the receiving environment	Low	Low

Coal seam water release scenario	Contributing factor	Potential impacts	Magnitude of impact	Significance of impact
	Dam failure	This event is considered to be highly unlikely (i.e. for more than one dam to fail on site at the same time), however if it did occur there may be the following impacts: – During periods of low flow, sudden release of large volumes will be outside of the natural flow regime. – Potential inundation of riparian margins and floodplain areas not usually inundated during dry season; exacerbation of high water level during wet season. – Mobilisation and transport of large quantities of sediment and large woody debris downstream.	High	High
	WTF operational emergency	This event is considered to have a higher probability of occurrence than for dam failure in the same scenario. It is more likely to be able to be moderated or controlled using emergency engineering solutions. However, the same impacts as listed for dam failure (above) would apply, albeit at a reduced extent.	Moderate	Moderate
Controlled release of *untreated* CSG water	Release according to EA conditions (where beneficial use is not appropriate/available)	Insignificant impacts to the stream hydrology and water quality would be expected.	Low	Low to negligible
Controlled release of *treated* CSG water	Release according to EA conditions (where beneficial use is not appropriate/available)	Insignificant changes to the stream hydrology and water quality would be expected	Low	Low to negligible

7.2 Beneficial Use Options for CSG Water

The Project has identified a number of potential beneficial use options for both treated and untreated CSG water, outlined in Table 7-2.

Table 7-2 Potential beneficial use options for treated and untreated CSG water

Potential beneficial Use	Type of water (treated or untreated)	Circumstances under which option may be utilised
Domestic and urban use	Treated	Arrow would develop a Recycled Water Management Plan, and negotiate a program for augmentation of domestic water supply within the Project area.
Supply to water service providers	Treated	Treated water from the Project is supplied to existing water service providers (e.g. Sunwater) who use it to supplement supply to their customers.
Direct supply to coal mines	Treated and untreated	Where a coal mine is located in proximity to one of the WTFs, it may be feasible to supply treated or untreated water directly to the mine. The quality of the supplied water will depend upon the requirements of the mine and upon their available water treatment capacity.
Agricultural use	Treated	If third party agricultural users are located within suitable proximity to WTFs, supply of water may be a viable option. The third party will accept responsibility for water once in their possession (i.e. from a defined transfer point).
Own use (Project operations)	Treated	Water may be used for Project activities, e.g. for dust suppression or for construction activities.

8 RESIDUAL IMPACTS

Table 8-1 below provides a summary of the impacts that potentially remain in association with the proposed Project activities, after the management and mitigation measures described in Section 7 are applied. Mitigation, management and monitoring measures recommended in the Project EIS surface water quality report to protect the surface water EVs of the Project area remain relevant.

Table 8-1 Residual impacts to surface water potentially arising from Project activities

Project component	Associated potential impacts	Applicable mitigation measures	Residual impact	Magnitude of residual impact	Significance of residual impact
Drainage areas	• Alteration of flows and flow paths. • Erosion and sediment mobilisation. • Improper disposal of wastes from construction and operations activities. • Potential release of contaminants to watercourses (adverse effects on surface water quality).	• Mitigation measures outlined in Sections 9.2.1, 9.2.2 and 9.2.3 of the Surface Water Technical Report (Appendix N) of the EIS still apply.	• Potential release of sediment and contaminated water to overland flows paths if management controls fail (for example, sediment fence is washed away or vandalised).	Low	Low
Production wells	• Alteration of flows and flow paths. • Erosion and sediment mobilisation.	• Mitigation measures outlined in Sections 9.2.2.1, 9.2.2.2 and 9.2.2.3 of the Surface Water Technical Report (Appendix N) of the EIS still apply.	• Potential localised impact to surface water quality if engineering/management control options fail (potential for larger volume of sediment to be mobilised from multi-well pads, on a local scale only).	Low	Low to negligible
Gas compression infrastructure	• Alteration of flows and flow paths. • Erosion and sediment mobilisation.	• Mitigation measures outlined in Sections 9.2.1.1 to 9.1.2.4, and 9.2.2 of the Surface Water Technical Report (Appendix N) of the EIS still apply.	• Potential localised impact to surface water quality in surface water catchments containing FCFs, if engineering/management control options fail (potential for larger volume of sediment to be mobilised from FCFs with increased area).	Low	Low to negligible

Project component	Associated potential impacts	Applicable mitigation measures	Residual impact	Magnitude of residual impact	Significance of residual impact
WTFs	• Controlled release of treated (and in certain instances untreated) CSG water to surface watercourses (potential adverse effects on surface water quality). • Uncontrolled release of contaminated water to grade and/or watercourses due to spills (from water gathering lines; trucks transporting wastewater and treated water from water transfer stations). • Reduced risk of adverse impacts to water quality, with fewer discharge points (a function of having fewer WTFs).	• Mitigation measures outlined in Sections 9.2.1.1 to 9.1.2.4, and 9.2.2 of the Surface Water Technical Report (Appendix N) of the EIS still apply. • Section 9.2.2.4 of the Surface Water Technical Report (Appendix N) of the EIS specifically applies to any releases from WTFs to the receiving environment, along with information outlined in Section 7.1 of this report.	• Potential impact to surface water hydrology in the event of uncontrolled releases (where it is not possible to control the volume released, such as in an emergency). • The impact to surface water quality, hydrology and geomorphology is dependent on actual rate and quality of CSG water discharge and flow in the Isaac River main channel. The likelihood of this event occurring is very low.	Moderate	Moderate
Linear infrastructure (e.g. roads and pipelines)	• Alteration of flows and flow paths. • Erosion and sediment mobilisation.	• Mitigation measures outlined in the Surface Water Technical Report (Appendix N, Sections 9.2.2.1, 9.2.2.2 and 9.2.2.3) of the EIS still apply.	• Potential localised impact to surface water quality if engineering/management control options fail.	Low	Low to negligible

9 CUMULATIVE IMPACTS

The results of impact assessments undertaken for both the EIS (Cumulative Impacts chapter (Section 31)) and SREIS indicated that surface water resources within the Project area had been impacted by different historic and current land uses such as agriculture, mining and urban development. The EIS determined that through the implementation of appropriate mitigation measures, the potential impacts on surface water quality could be minimised. In addition, the set of principles for CSG water discharges developed in the Surface Water Technical Report (Appendix F) of the SREIS will allow for CSG water to be discharged should this option be required, without having any significant impacts to the receiving environment. Providing that all planned developments are managed with sufficient mitigation measures and appropriate discharge strategies are implemented, significant impacts on surface water quality should not occur. It should be noted that in context of the large volumes of mine affected water that are discharged into the Isaac River by coal mines operating in the region, any CSG water that may be released into the Isaac River by this Project will have an insignificant effect on the receiving environment.

10 MONITORING PROGRAMS

A monitoring program is recommended to assess the effectiveness of management strategies designed to protect the EVs identified within this report. It is noted that these programs will be revised to target specific areas of the Project once infrastructure plans and operations have been updated and finalised.

In general, monitoring will involve the following:

- For any discharges of CSG water into the receiving waters, a surface water monitoring program shall be established to monitor water quality at sites upstream and downstream of the proposed activity to identify potential impacts. For these sites sufficient baseline water quality data shall be collected during the EA approval process to derive site-specific guideline values in accordance with relevant guidelines (EHP, 2009a and ANZECC and ARMCANZ, 2000). Water quality data shall be sufficient to characterise water quality at low and high flow.
  A surface water sampling program should be considered for the duration of construction periods for each key infrastructure such as CGPFs and WTFs, in the event that existing control measures (e.g. erosion and sediment controls) do not adequately eliminate surface water body exposure pathways.
  The water quality parameters to be considered include:
  - pH;
  - Alkalinity;
  - Total suspended solids and/or EC;
  - Dissolved salts (total dissolved solids, bicarbonate, calcium, chloride, fluoride, magnesium, potassium, sodium, sulphate);
  - Nutrients (total phosphorus, orthophosphate, nitrate plus nitrite and ammonia); and
  - Total and dissolved metals and metalloids (aluminium, arsenic, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel and zinc).
- For construction activities at watercourse crossings undertake inspection and monitoring of streams to quantify potential impacts to the watercourse.
- Samples will be collected in accordance with the Monitoring and Sampling Manual (EHP, 2009b). Laboratory analyses will be conducted by a National Association of Testing Authorities (NATA) certified laboratory services provider and subject to standard quality assurance and quality control procedures.

Monitoring frequencies for specific facilities, events and environmental aspects of the Project will be established and detailed further during the environmental authority approval process.

11 CONCLUSIONS

The assessment undertaken for the SREIS has confirmed the original findings presented in the surface water assessment of the EIS, and has refined and updated these findings to allow for an informed impact assessment to be undertaken for this Project. The key difference in the project description since the EIS has been the identification of preferred localities for the two WTFs and for their respective potential discharge reaches along the Isaac River main channel, and also an update to the strategy for CSG water management (see the Project Description chapter (Section 3.5) of the SREIS). The update includes the option of releasing treated (or in certain instances untreated) CSG water into the Isaac River main channel should this option be required to meet operational needs or under emergency conditions.

Assessment of a large dataset of surface water quality for all the sub-catchments of the Project obtained from local operational mines confirmed the surface water quality findings reported in the EIS, and that the surface water quality for the Isaac River main channel complies with the published WQOs with the exception of turbidity, TSS and dissolved aluminium; local WQOs have been derived in this study. This study also confirms that the surface water environment across the Project area is slightly to moderately impacted as a result of historic and current landuses such as agriculture, mining and urban development.

A detailed Environmental Flow Assessment undertaken as part of the Hydrology and Geomorphology Technical Report (Appendix G) of the SREIS described the Isaac River as a highly ephemeral waterway with flows occurring only for short duration between December and March. For the remainder of the year the river is dry or is limited to a series of isolated pools. The hydrological nature of the receiving environment therefore links releases of CSG water, which are surplus to beneficial use options, to flow conditions. Discharges of CSG water into the receiving environment need to be tailored both in terms of the volumes and quality of water being discharged in order to protect downstream surface water EVs.

This report describes a set of principles that allow Arrow to assess the volume, frequency, duration and quality of CSG water that can be safely discharged under any circumstance. By incorporating knowledge of the quality of the CSG water and that of the receiving environment, this report describes how treated or untreated CSG water can be discharged without impacting the receiving environment (surface water quality, environmental flow objectives, geomorphological EVs).

Carefully managed and using the principles outlined in this study, controlled releases of both treated and untreated CSG water are not expected to have any significant impact on the EVs of the Isaac River main channel. Potential impacts associated with emergency releases of treated and untreated CSG water have also been considered in this study, possibly as a result of dam overtopping during periods of heavy rainfall or as a result of dam failure. The impacts arising from uncontrolled releases will vary depending on a number of variables including flows and water quality in the receiving environment, and volume, discharge rate and quality of the CSG water released.

The implementation of the principles presented herein together with further site-specific baseline assessments during the EA application process, and a robust monitoring program would effectively mitigate potential impacts to surface water.

12 REFERENCES

ANZECC and ARMCANZ 2000. *Australian and New Zealand guidelines for fresh and marine water quality*, National Water Quality Management Strategy Paper No 4. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand. Canberra, Australian Capital Territory.

CCME 1999. *Canadian Water Quality Guidelines for the Protection of Aquatic Life: Summary Table*, Canadian Environmental Quality Guidelines Summary Table, Canadian Council of Ministers of the Environment, Winnipeg, 9pp

Department of Environment and Heritage Protection 2009a. *Monitoring and Sampling Manual*. Version 2. Re-published July 2013.

Department of Environment and Heritage Protection 2009b. *Queensland Water Quality Guidelines,* Version 3. Re-published July 2013.

Harvey, F. and Jones, H. 2003. *Maximising the information from discrete electrical conductivity samples in third order catchments*. Department of Infrastructure, Planning and Natural Resources, September 2003.

URS 2011. *Ecological Risk Assessment – Intermittent Permeate Discharge Isaac River*, report prepared for Arrow Energy, 31 October 2011, 100pp.

13 LIMITATIONS

URS Australia Pty Ltd (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of Arrow Energy Pty Ltd and only those third parties who have been authorised in writing by URS to rely on this Report.

It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this Report.

It is prepared in accordance with the scope of work and for the purpose outlined in the contract dated January 2012.

Where this Report indicates that information has been provided to URS by third parties, URS has made no independent verification of this information except as expressly stated in the Report. URS assumes no liability for any inaccuracies in or omissions to that information.

This Report was prepared between January and April 2014 and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This Report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This Report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

Except as required by law, no third party, other than a government or regulatory authority under applicable government or regulatory controls, may use or rely on this Report unless otherwise agreed by URS in writing. Where such agreement is provided, URS will provide a letter of reliance to the agreed third party in the form required by URS.

To the extent permitted by law, URS expressly disclaims and excludes liability for any loss, damage, cost or expenses suffered by any third party relating to or resulting from the use of, or reliance on, any information contained in this Report. URS does not admit that any action, liability or claim may exist or be available to any third party.

Except as specifically stated in this section, URS does not authorise the use of this Report by any third party.

It is the responsibility of third parties to independently make inquiries or seek advice in relation to their particular requirements and proposed use of the site.

Any estimates of potential costs which have been provided are presented as estimates only as at the date of the Report. Any cost estimates that have been provided may therefore vary from actual costs at the time of expenditure.

APPENDIX A SURFACE WATER QUALITY DATA

Parameter	IsaacMainChannel		IsaacNthTribs		IsaacWesternTribs	
	Median	80th percentile	Median	80th percentile	Median	80th percentile
pH	7.8	8.1	7.59	8.048	7.94	8.22
EC (µS/cm)	244.5	428.44	227	567.6	287	535
DO (%Sat)	95	98.5	0	92.3		
DO (mg/L)	8.605	9.21	7.53	7.968	7.775	7.958
Turbidity (NTU)	491	1030	210	470	119	490
Temp	21	24.716	28	30.56	27.4	31.3
TSS (mg/L)	340	594	75	271.8	125	636.4
Hardness (mg/L)	71	87	69	131.4	110	159.6
SO4 (mg/L)	5	21	13	55	13	22
Fluoride (µg/L)	100	120	50	100	100	194
Total Cyanide (mg/L)			0	0		
Ammonia (µg/L)	15	40	20	50	30	60
Nitrate (µg/L)	50	170	30	130	60	188
Nitrogen as N (µg/L)	300	360	200	200		
Nitrite + Nitrate (µg/L)	10	90	90	114		
Alkalinity - hydroxide (mg/L)	0.5	0.5	0.5	0.5		
Alkalinity - carbonate (mg/L)	0.5	0.5	0.5	0.5		
Alkalinity - bicarbonate (mg/L)	188	220.8	83.5	197		
Total Alkalinity (mg/L)	188	225	83.5	197		
TOC (mg/L)	25	25	25	25		
TPH C6-C9 (µg/L)	25	25	10	19	20	20
TPH C10-C14 (µg/L)	25	25	25	25	50	50
TPH C15-C28 (µg/L)	100	100	100	100		
TPH C29-C36 (µg/L)	90	100	100	100		
TPH C10-C36 (µg/L)	100	590	50	646	50	50
Dissolved Al (µg/L)	0.5	350	35	640	150	388
Dissolved As (µg/L)	30	50	0.5	40	1	1
Dissolved B (µg/L)	40	60	50	60	50	60
Dissolved Ba (µg/L)	79	107.2	34	54		
Dissolved Be (µg/L)	0.05	0.1	0.05	0.1		
Dissolved Cd (µg/L)	0.5	1	0.05	1	0.1	0.1
Dissolved Cr (µg/L)	0.5	0.5	0.5	1	1	1
Dissolved Co (µg/L)	2	3	0.5	2	1	1
Dissolved Cu (µg/L)	5	218	2.35	410	2	3
Dissolved Fe (µg/L)	0.5	248	130	700	240	490
Dissolved Pb (µg/L)	0.5	2.5	0.5	3	1	1
Dissolved Mn (µg/L)	0.05	2.5	1	6	2	3
Dissolved Hg (µg/L)	0.5	1	0.05	0.5	0.1	0.1
Dissolved Mo (µg/L)	2	3	0.5	3	1	1
Dissolved Ni (µg/L)	2.5	2.5	2.5	3	3	4.4
Dissolved Se (µg/L)	0.05	2.5	0.3	2.5	10	10
Dissolved Ag (µg/L)	0	0	0	0	1	1
Dissolved U (µg/L)	2.5	2.5	0.5	2.5	1	1
Dissolved V (µg/L)	2.5	5	2.1	3.82	10	10
Dissolved Zn (µg/L)	2.5	2.9	2.5	5	5	5
Total Al (µg/L)	9100	17000	4100	8512	8430	24920
Total As (µg/L)	30	60	2.5	50	2	3
Total B (µg/L)	50	70	60	80	50	60
Total Ba (µg/L)	146	188.8	67	113		
Total Be (µg/L)	0.25	0.25	0.25	0.25		
Total Cd (µg/L)	7	21	0.2	14	0.1	0.1
Total Cr (µg/L)	8	18	2.5	10	6	43
Total Co (µg/L)	9	16	2.5	7	8	22
Total Cu (µg/L)	5100	15920	7	7430	9	24
Total Fe (µg/L)	11	9892	1695	6630	10200	32080
Total Pb (µg/L)	130	340	4	65.6	4	13
Total Mn (µg/L)	0.05	224	29	102.4	240	616
Total Hg (µg/L)	2.5	2.5	0.05	2.5	0.1	0.1
Total Mo (µg/L)	8	21	2.5	10	1	1
Total Ni (µg/L)	2.5	16	4	9	23	66.6
Total Se (µg/L)	0.4	2.5	0.4	2.5	10	10
Total Ag (µg/L)	0.5	0.8	0.25	0.5	1	1
Total U (µg/L)	17.5	40	0.79	20	1	1.032
Total V (µg/L)	20.5	37	6.75	15	24.5	60
Total Zn (µg/L)	24	39	10	20	25	57.8

Parameters assessed against WQOs

	MackenzieMainChannel		MackenzieNWTribs		MackenzieSouthernTribs	
Parameter	Median	80th percentile	Median	80th percentile	Median	80th percentile
pH	8.135	8.222	7.965	8.06	7.79	8
EC (µS/cm)	440	476	951	1130.6	223.5	371.8
DO (%Sat)	101.25	103.08	102.55	107.08	62.9	73.64
DO (mg/L)	8.84	9.194	8.87	9.14	6.63	7.776
Turbidity (NTU)	27.75	39.84	0.775	0.838	185	319.8
Temp	21.96	23.124	23.2	24.96	24.6	26.3
TSS (mg/L)	17.5	20.8	8	13.4	200	650.8
Hardness (mg/L)	139	157	280.5	300.8	54	82.8
SO4 (mg/L)	13	14.8	30	89.4	7	35.2
Fluoride (µg/L)	200	200	250	300	200	300
Total Cyanide (mg/L)						
Ammonia (µg/L)	35	38	30	96	30	60
Nitrate (µg/L)	80	116	5	11	80	200
Nitrogen as N (µg/L)	450	540	400	500	1000	1060
Nitrite + Nitrate (µg/L)	80	116	5	11	60	114
Alkalinity - hydroxide (mg/L)	0.5	0.5	0.5	0.5	0.5	0.5
Alkalinity - carbonate (mg/L)	0.5	0.5	0.5	0.5	0.5	0.5
Alkalinity - bicarbonate (mg/L)	144.5	159.8	174	231.2	139	155.2
Total Alkalinity (mg/L)	144.5	159.8	174	231.2	139	155.2
TOC (mg/L)					9	14.6
TPH C6-C9 (µg/L)	10	10	10	10	10	10
TPH C10-C14 (µg/L)	25	25	25	25	25	25
TPH C15-C28 (µg/L)	50	50	50	50	50	50
TPH C29-C36 (µg/L)	25	25	25	25	25	25
TPH C10-C36 (µg/L)	25	25	25	25	25	25
Dissolved Al (µg/L)					220	620
Dissolved As (µg/L)	0.75	0.9	1	1	1	2
Dissolved B (µg/L)	42.5	53	70	80	25	60
Dissolved Ba (µg/L)	126	171	150	182.8	82	83.2
Dissolved Be (µg/L)	0.5	0.5	0.5	0.5	0.5	0.5
Dissolved Cd (µg/L)	0.05	0.05	0.05	0.05	0.05	0.05
Dissolved Cr (µg/L)	0.5	0.5	0.5	0.5	0.5	1
Dissolved Co (µg/L)	0.5	0.5	0.5	0.5	0.5	0.5
Dissolved Cu (µg/L)	0.5	0.5	0.75	1.4	3	4
Dissolved Fe (µg/L)	25	25	42.5	104	250	490
Dissolved Pb (µg/L)	0.5	0.5	0.5	0.5	0.5	0.5
Dissolved Mn (µg/L)	315	496.8	61.5	148.8	2.5	217.6
Dissolved Hg (µg/L)	0.05	0.05	0.05	0.05	0.05	0.05
Dissolved Mo (µg/L)	0.5	0.5	0.5	0.5	0.5	2
Dissolved Ni (µg/L)	1.5	1.8	1.5	2	2	3
Dissolved Se (µg/L)	5	5	5	5	5	5
Dissolved Ag (µg/L)	0	0	0	0	0	0
Dissolved U (µg/L)	0.5	0.5	0.5	0.5	0.5	0.5
Dissolved V (µg/L)	5	5	5	5	5	5
Dissolved Zn (µg/L)	2.5	2.5	2.5	2.5	2.5	7
Total Al (µg/L)					5360	11700
Total As (µg/L)	2	2	1.25	2.4	2	3
Total B (µg/L)	57.5	77	42.5	84	25	70
Total Ba (µg/L)	140.5	184	173.5	205	102	110.4
Total Be (µg/L)	0.5	0.5	0.5	0.5	0.5	0.5
Total Cd (µg/L)	0.05	0.05	0.05	0.05	0.05	0.05
Total Cr (µg/L)	0.5	0.5	0.5	0.5	6	14
Total Co (µg/L)	0.75	0.9	0.5	0.7	3	8
Total Cu (µg/L)	0.75	0.9	1.25	2	7	16
Total Fe (µg/L)	565	646	365	1156	5975	12900
Total Pb (µg/L)	0.5	0.5	0.5	0.5	2	6
Total Mn (µg/L)	406.5	625.8	125.5	230.2	377	766.6
Total Hg (µg/L)	0.05	0.05	0.05	0.05	0.05	0.05
Total Mo (µg/L)	0.5	0.5	0.5	0.5	0.5	0.5
Total Ni (µg/L)	2	2	2	2.4	8	17
Total Se (µg/L)	5	5	5	5	5	5
Total Ag (µg/L)	0.5	0.5	0.5	0.5	0.5	0.5
Total U (µg/L)	0.5	0.5	0.5	0.5	0.5	0.5
Total V (µg/L)	5	5	5	5	20	30
Total Zn (µg/L)	2.5	2.5	7.75	17.8	15	34

Parameters assessed against WQOs

	ConnorsCentralTribs		SuttorTribs		BowenRiverTribs	
Parameter	Median	80th percentile	Median	80th percentile	Median	80th percentile
pH	8.12	8.556	8.135	8.144	8.355	8.54
EC (µS/cm)	1504	1739.4	2578.5	2630.4	1810.5	3771
DO (%Sat)	121.1	124.48	90.3	92.16	105.95	108
DO (mg/L)	10.23	11.418	8.14	8.176	8.33	10.05
Turbidity (NTU)	11.72	11.72			27.7	63.4
Temp	22.9	23.92	19.99	21.316	23.125	28.2
TSS (mg/L)	5	9	2.5	2.5	4.25	44
Hardness (mg/L)	393	568.4	612	616.8	514	540
SO4 (mg/L)	53	104	13	14.2	69	316
Fluoride (µg/L)	300	620	300	300	300	300
Total Cyanide (mg/L)						
Ammonia (µg/L)	20	44	35	50	20	20
Nitrate (µg/L)	30	4220	12.5	17	12.5	140
Nitrogen as N (µg/L)	100	5400	150	180	200	300
Nitrite + Nitrate (µg/L)	30	4244	12.5	17	12.5	140
Alkalinity - hydroxide (mg/L)	0.5	0.5	0.5	0.5	0.5	0.5
Alkalinity - carbonate (mg/L)	0.5	21.6	0.5	0.5	8.5	16
Alkalinity - bicarbonate (mg/L)	342	379	371	381.8	429.5	456
Total Alkalinity (mg/L)	342	386.2	371	381.8	437.5	472
TOC (mg/L)						
TPH C6-C9 (µg/L)	10	10	10	10	10	10
TPH C10-C14 (µg/L)	25	25	25	25	25	25
TPH C15-C28 (µg/L)	50	50	50	50	50	50
TPH C29-C36 (µg/L)	25	25	25	25	25	25
TPH C10-C36 (µg/L)	25	25	25	25	25	25
Dissolved Al (µg/L)						
Dissolved As (µg/L)	0.5	0.5	1.25	1.7	0.5	0.5
Dissolved B (µg/L)	25	44	110	128	25	50
Dissolved Ba (µg/L)	148	251.6	340.5	460.2	58.5	72
Dissolved Be (µg/L)	0.5	0.5	0.5	0.5	0.5	0.5
Dissolved Cd (µg/L)	0.05	0.05	0.05	0.05	0.05	0.05
Dissolved Cr (µg/L)	0.5	0.5	0.5	0.5	0.5	0.5
Dissolved Co (µg/L)	0.5	0.5	0.5	0.5	0.5	0.5
Dissolved Cu (µg/L)	0.5	0.6	0.5	0.5	0.5	0.5
Dissolved Fe (µg/L)	25	30	25	25	25	25
Dissolved Pb (µg/L)	0.5	0.5	0.5	0.5	0.5	0.5
Dissolved Mn (µg/L)	40	82.6	44.5	70	10.5	12
Dissolved Hg (µg/L)	0.05	0.05	0.05	0.05	0.05	0.05
Dissolved Mo (µg/L)	0.5	2.8	14.75	23.3	1	1
Dissolved Ni (µg/L)	0.5	0.6	0.5	0.5	0.5	0.5
Dissolved Se (µg/L)	5	5	5	5	5	5
Dissolved Ag (µg/L)	0	0	0	0	0	0
Dissolved U (µg/L)	1	2	2.5	2.8	0.5	1
Dissolved V (µg/L)	5	5	5	5	5	5
Dissolved Zn (µg/L)	2.5	2.5	2.5	2.5	2.5	2.5
Total Al (µg/L)						
Total As (µg/L)	0.5	1	1.25	1.7	0.5	0.5
Total B (µg/L)	25	78	135	150	25	50
Total Ba (µg/L)	187	257.2	403	557.8	60.5	76
Total Be (µg/L)	0.5	0.5	0.5	0.5	0.5	0.5
Total Cd (µg/L)	0.05	0.05	0.05	0.05	0.05	0.05
Total Cr (µg/L)	0.5	0.5	0.5	0.5	0.5	0.5
Total Co (µg/L)	0.5	0.5	0.5	0.5	0.5	0.5
Total Cu (µg/L)	0.5	1	3	3.6	0.75	1
Total Fe (µg/L)	60	88	112.5	165	25	25
Total Pb (µg/L)	0.5	0.5	0.5	0.5	0.5	0.5
Total Mn (µg/L)	57	119.8	72	101.4	14.5	87
Total Hg (µg/L)	0.05	0.05	0.05	0.05	0.05	0.05
Total Mo (µg/L)	0.5	3.2	16.25	25.7	0.75	1
Total Ni (µg/L)	0.5	0.8	0.75	0.9	0.5	1
Total Se (µg/L)	5	5	5	5	5	5
Total Ag (µg/L)	0.5	0.5	0.5	0.5	0.5	0.5
Total U (µg/L)	2	2	3	3.6	0.75	1
Total V (µg/L)	5	5	5	5	5	5
Total Zn (µg/L)	2.5	2.5	5.75	7.7	2.5	2.5

Parameters assessed against WQOs

APPENDIX B SUB-REGIONAL WQO - CALCULATIONS

Location	Turbidity (NTU)				TSS (mg/L)			
	n	20th%ile *(z)*	Median *(x)*	80th%ile *(y)*	*n*	20th%ile *(z)*	Median *(x)*	80th%ile *(y)*
Isaac River U/S Hwy	0	N/A	N/A	N/A	17	134.2	232	423
Seloh Nolem U/S	0	N/A	N/A	N/A	16	244	366	460
Isaac D/S Cherwell	0	N/A	N/A	N/A	11	180	281	432
Seloh Nolem D/S	0	N/A	N/A	N/A	16	234	378	448
Isaac River Peak Downs Hwy (MP20)	0	N/A	N/A	N/A	12	231.8	267	577
Isaac River DS Cherwell Ck (MP15)	1	N/A	N/A	N/A	3	235.4	350	603.2
Isaac River Seloh Nolem DS (MP18)	0	N/A	N/A	N/A	1	620	620	620
Isaac River US Burton Gorge	1	73.5	73.5	73.5	3	2.5	2.5	18.4
Isaac River Mid	2	2.04	3.3	4.56	2	5.2	5.5	5.8
Isaac River at Scott Ck junction	2	N/A	N/A	N/A	2	2.5	2.5	2.5
Isaac River DS	1	N/A	N/A	N/A	1	2.5	2.5	2.5
Isaac River Drop Structure MP3	87	236	453	774.8	87	209.2	340	531.6
Isaac River D/S Railway Bridge MP4	99	303.2	548	1238	99	243.6	362	730
Lower Isaac	51	290	597	1270	51	251	380	650
Upper Isaac	31	226	450	864.8	45	218	340	498
n	275	6	6	6	366	15	15	15

Location	Dissolved Aluminium (µg/L)				Dissolved Copper (µg/L)			
	n	20th%ile *(z)*	Median *(x)*	80th%ile *(y)*	*n*	20th%ile *(z)*	Median *(x)*	80th%ile *(y)*
Isaac River U/S Hwy	2	184	280	376	2	3.4	4	4.6
Seloh Nolem U/S	6	40	75	270	6	1.4	2.35	2.8
Isaac D/S Cherwell	6	180	375	460	6	1.7	2.05	2.6
Seloh Nolem D/S	6	130	170	360	6	2	2.5	3
Isaac River Peak Downs Hwy (MP20)	5	440	1480	2440	5	1.8	3	4
Isaac River DS Cherwell Ck (MP15)	3	374	560	1466	3	2.4	3	3.6
Isaac River Seloh Nolem DS (MP18)	1	360	360	360	1	2	2	2
Isaac River US Burton Gorge	0	N/A	N/A	N/A	3	0.5	0.5	1.4
Isaac River Mid	0	N/A	N/A	N/A	2	0.6	0.75	0.9
Isaac River at Scott Ck junction	0	N/A	N/A	N/A	2	0.5	0.5	0.5
Isaac River DS	0	N/A	N/A	N/A	1	1	1	1
Isaac River Drop Structure MP3	88	0.5	0.5	0.5	18	25	80	260
Isaac River D/S Railway Bridge MP4	99	0.5	0.5	0.5	99	80	200	540
Lower Isaac	41	120	420	3200	51	2	3	5
Upper Isaac	38	128	405	3440	45	2	2	3.2
n	295	11	11	11	250	15	15	15

Location	Dissolved Arsenic (µg/L)				Dissolved Uranium (µg/L)			
	n	20th%ile *(z)*	Median *(x)*	80th%ile *(y)*	*n*	20th%ile *(z)*	Median *(x)*	80th%ile *(y)*
Isaac River U/S Hwy	2	0.5	0.5	0.5	2	0.5	0.5	0.5
Seloh Nolem U/S	6	0.5	0.5	0.6	6	0.098	0.345	0.46
Isaac D/S Cherwell	6	0.5	0.5	0.5	6	0.12	0.285	0.5
Seloh Nolem D/S	6	0.5	0.5	0.5	6	0.118	0.315	0.5
Isaac River Peak Downs Hwy (MP20)	5	0.5	0.5	0.5	5	0.5	0.5	0.5
Isaac River DS Cherwell Ck (MP15)	3	N/A	0.5	N/A	3	N/A	0.5	N/A
Isaac River Seloh Nolem DS (MP18)	1	N/A	0.5	N/A	1	N/A	0.5	N/A
Isaac River US Burton Gorge	3	N/A	0.5	N/A	3	N/A	1	N/A
Isaac River Mid	2	0.5	0.5	0.5	2	0.5	0.5	0.5
Isaac River at Scott Ck junction	2	0.5	0.5	0.5	2	0.5	0.75	0.5
Isaac River DS	1	0.5	0.5	0.5	1	0.5	0.5	0.5
Isaac River Drop Structure MP3	87	25	40	60	88	2.5	2.5	4.2
Isaac River D/S Railway Bridge MP4	98	30	50	60	99	2.5	2.5	2.5
Lower Isaac	41	0.5	0.5	40	41	0.1	0.2	2.5
Upper Isaac	38	0.5	0.5	0.5	37	0.05	0.05	0.2
n	301	12	15	12	302	12	15	12

Parameter	z mean	z SE (±)	x mean	x SE (±)	y mean	y SE (±)	Existing WQO	Proposed WQO
Turbidity (NTU)	188.5	50.0	354.1	102.9	704.3	225.3	50.0	354.0
TSS (mg/L)	187.6	40.5	261.9	47.1	400.1	67.0	55.0	262.0
Dissolved Aluminium (µg/L)	177.9	45.8	375.1	123.6	818.9	392.5	55.0	375.0
Dissolved Copper (µg/L)	8.4	5.3	20.4	13.8	55.6	38.6	3.5	N/A
Dissolved Arsenic (µg/L)	5.0	3.0	6.4	4.1	13.7	7.0	24.0	N/A
Dissolved Uranium (µg/L)	0.7	0.3	0.7	0.2	1.1	0.4	0.5	N/A

G O V E R N M E N T   O I L & G A S   I N F R A S T R U C T U R E   P O W E R   I N D U S T R I A L

URS is a leading provider of engineering, construction, technical and environmental services for public agencies and private sector companies around the world. We offer a full range of program management; planning, design and engineering; systems engineering and technical assistance; construction and construction management; operations and maintenance; and decommissioning and closure services for power, infrastructure, industrial and commercial, and government projects and programs.

URS Australia Pty Ltd
Level 17, 240 Queen Street
Brisbane, QLD 4000
GPO Box 302, QLD 4001
Australia

T: +61 7 3243 2111
F: +61 7 3243 2199

www.urs.com.au