LOWER FITZROY RIVER
INFRASTRUCTURE PROJECT

Appendix X

Fish passage technical report

SunWater
MAKING WATER WORK

Gladstone Area Water Board

SunWater and Gladstone Area Water Board

Lower Fitzroy River Infrastructure Project

Eden Bann Weir and Rookwood Weir - assessment and planned provisions for fish passage

June 2015

Executive summary

The Lower Fitzroy River Infrastructure Project (Project) is the construction and operation of a raised Eden Bann Weir and a new weir at Rookwood on the Fitzroy River, Central Queensland.

Key Project components include the following:

- Eden Bann Weir (EB1) (an existing structure):
  - Eden Bann Weir Stage 2 (EB2) – a raise of the existing EB1 to a full supply level (FSL) 18.2 m Australian Height Datum (AHD) and associated impoundment of the Fitzroy River
  - Eden Bann Weir Stage 3 (EB3) – raising EB1 to EB2 and include the addition of 2 m high flap gates to achieve FSL 20.2 m AHD and associated impoundment of the Fitzroy River
- The proposed Rookwood Weir:
  - Rookwood Weir Stage 1 (RW1) – a new build to FSL 45.5 m AHD, saddle dams and associated impoundment of the Fitzroy, Mackenzie and Dawson rivers
  - Rookwood Weir Stage 2 (RW2) – a new build to RW1 and including the addition of 3.5 m high flap gates to achieve FSL 49.0 m AHD and associated impoundment of the Fitzroy, Mackenzie and Dawson rivers
- Any combination of the above (development scenarios)
- Fish passage infrastructure and turtle passage infrastructure, namely fish locks and a turtle bypass, respectively, at each weir.

Other infrastructure components associated with the Project include:

- Augmentation to and construction of access roads.
- Construction of low level bridges in areas upstream of weir infrastructure.
- Installation of culverts at Hanrahan Crossing downstream of Rookwood Weir.

Aquatic ecology assessments undertaken for the Project conclude that no *Environment Protection and Biodiversity Conservation Act 1999* (Cth) listed-threatened fish species have been previously recorded or are predicted to occur in the Project area. Further no *Nature Conservation Act 1992* (Qld) listed-threatened fish species have been previously recorded or are predicted to occur in the study area. Endemic species are present.

The raising of an existing weir and the development of a new weir is however a waterway barrier works, and is assessable development under the *Sustainable Planning Act 2009* (SP Act). Development approval is required to raise Eden Bann Weir and construct Rookwood Weir.

The purpose of this report is to provide a summary document that consolidates material in support of the required waterway barrier works development application for weir construction and operation and in particular the fish passage design process and outcomes such that stated conditions can be achieved through the environmental impact statement (EIS).

It is recognise that one of the key potential risks requiring consideration and management during the design, construction and operation of the Project is the maintenance of upstream and downstream passage of fish species.

To address this, a fishway design process was undertaken in accordance with Queensland Fisheries (then as the Department of Employment, Economic Development and Innovation (DEEDI)) Design Process criteria). This process involved the selection of fishway design

specifications and success criteria and the development of preliminary fishway designs for both Eden Bann Weir and Rookwood Weir. Members of the fishway design team were selected such that a range of engineering and scientific disciplines necessary for fish passage design were present and that representation from the range of key stakeholders, including DEEDI fish biologists, an independent freshwater fish biologist and an independent fishway engineering specialist, were involved in the design process.

Fish passage infrastructure has been designed to preliminary level as follows:

- Eden Bann Weir fish passage infrastructure:
  - An upgraded fish lock on the left bank
  - A new fish lock located on the right bank for high and low reservoir levels to cater for flows from about 500 m^3/s to 2700 m^3/s. This provides for normal operating conditions as well as low spillway flow conditions at the weir.
- Rookwood Weir fish passage infrastructure:
  - A right bank fish lock to cover low and high reservoir levels to cater for flows from a minimum operating level up to 500 m^3/s.

The lock arrangements proposed are considered suitable for the purpose of fish passage as:

- The lock is in a configuration known to work (although physical model studies are required to assist with refinement of entry / exit conditions and sedimentation management).
- The addition of a right bank fish lock will improve on current passage efficiency above spilling flows (Table 8-1). Currently fish are attracted to the right bank spillway section of the weir, and as there is no passage become stranded as tailwater levels drop.
- The lock would provide passage for 87 out of 123 flood events as well as ongoing 'normal flows' at Eden Bann Weir and it provides for between 89.4 per cent and 99.8 per cent of flows across the seasons at Rookwood Weir.
- It reduces average wait days per occurrence from 11 to seven at Eden Bann Weir. At Rookwood Weir the average number of waiting days per event is estimated at ten.
- The lock arrangement is capable of providing continuous attraction flows when the fishway is operating and allows for variable attraction flows between phases of the cycle. Attraction flow velocities can be varied between: 0.15 m/s and 1.8 m/s.
- It caters for small and large-bodied fish.
- It provides upstream and downstream passage.
- It can be shut down in large floods to maximize operation following flood

A Fish Monitoring Program will be designed and implemented to monitor the effectiveness of fish passage infrastructure during both the construction and operation phases.

A detailed construction plan will be developed during detailed design for a determined build scenario. Fish passage will not be inhibited during construction as flow is maintained instream and the existing fish lock at Eden Bann Weir would remain operational. Further, downstream works will only occur during the dry season when flows have ceased.

Detailed design will include the provision for CFD and physical model studies.

It is considered that assessment, analysis, mitigation, management and monitoring proposed in relation to fish passage infrastructure at a raised Eden Bann Weir and a new weir at Rookwood satisfies performance objectives as defined in the State Development Assessment Provisions Module 5 Fisheries resources (V1.5) 5.2: Constructing or raising waterway barrier works in fish habitats state code.

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Acronyms

Abbreviation/acronym	Full term
AMTD	Adopted Middle Thread Distance
FSL	full supply level
LFRIP	Lower Fitzroy River Infrastructure Project
ML	mega litres
NC Act	*Nature Conservation Act 1992*
pers. comm.	personal communication
RL	reduced level
SDAP	State Development Assessment Provisions
SP Act	*Sustainable Planning Act 2009*
SPP	State Planning Policy

1. Introduction

1.1 Project overview

The Lower Fitzroy River Infrastructure Project (Project) is the construction and operation of a raised Eden Bann Weir and a new weir at Rookwood on the Fitzroy River, Central Queensland. The Fitzroy River forms at the confluence of the Mackenzie (flowing from the north) and Dawson (flowing from the south) rivers flowing out into Keppel Bay, some 300 km downstream. The Fitzroy River passes through the city of Rockhampton which lies approximately 59 km upstream from the river mouth.

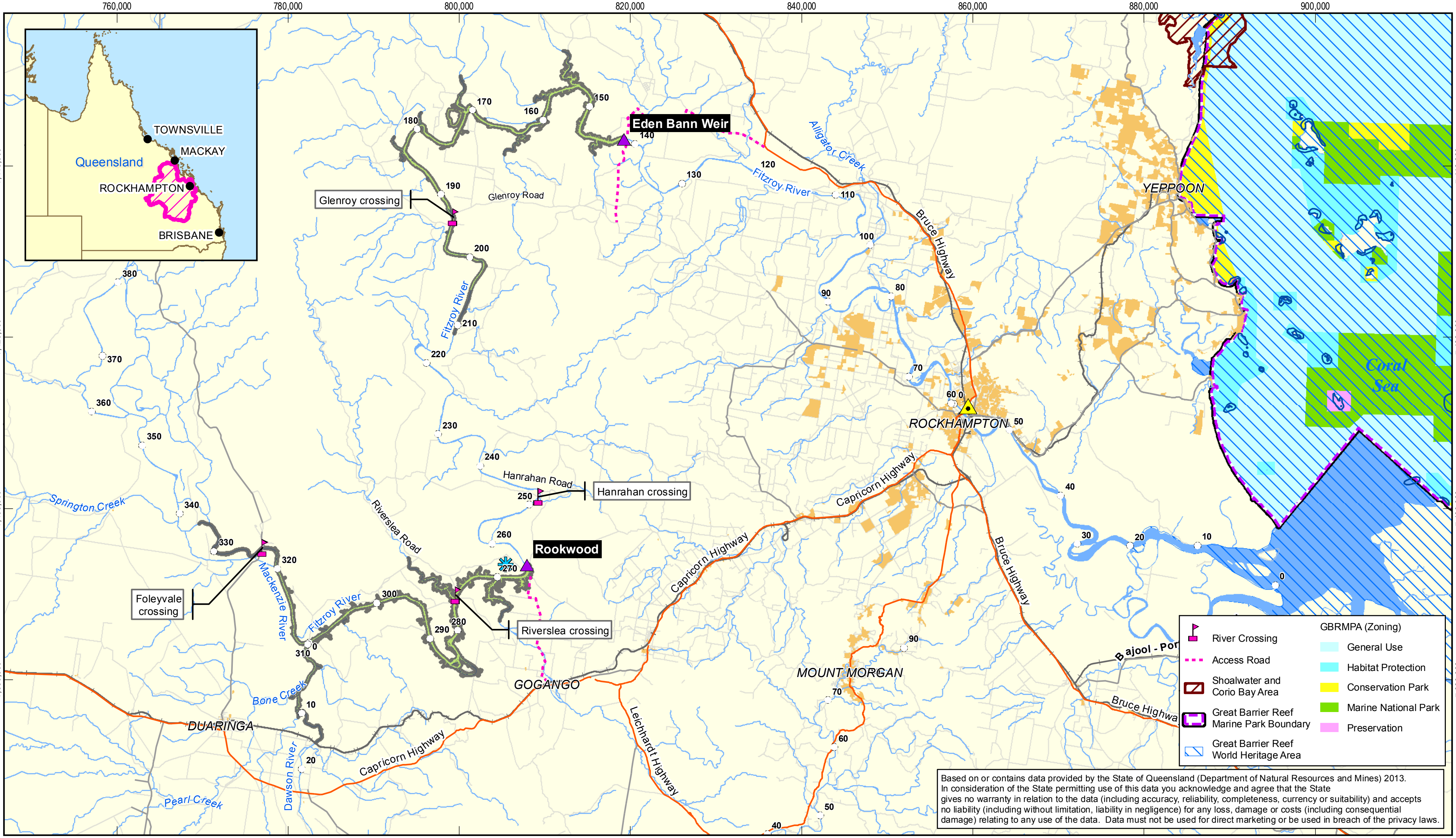
Key Project components include the following:

- Eden Bann Weir (EB1) is an existing structure, built in 1994, approximately 62 km north-west of Rockhampton in central Queensland on the Fitzroy River at 141.2 km adopted middle thread distance (AMTD):
  - Eden Bann Weir Stage 2 (EB2) – a raise of the existing EB1 to a full supply level (FSL) 18.2 m Australian Height Datum (AHD) and associated impoundment of the Fitzroy River
  - Eden Bann Weir Stage 3 (EB3) – raising EB1 to EB2 and include the addition of 2 m high flap gates to achieve FSL 20.2 m AHD and associated impoundment of the Fitzroy River
- The proposed Rookwood Weir located on the Fitzroy River at 265.3 km AMTD approximately 10 km downstream from the Riverslea Road river crossing:
  - Rookwood Weir Stage 1 (RW1) – a new build to FSL 45.5 m AHD, saddle dams and associated impoundment of the Fitzroy, Mackenzie and Dawson rivers
  - Rookwood Weir Stage 2 (RW2) – a new build to RW1 and including the addition of 3.5 m high flap gates to achieve FSL 49.0 m AHD and associated impoundment of the Fitzroy, Mackenzie and Dawson rivers
- Any combination of the above (development scenarios)
- Fish passage infrastructure and turtle passage infrastructure, namely fish locks and a turtle bypass, respectively, at each weir.

Other infrastructure components associated with the Project include:

- Augmentation to and construction of access roads (public and private) to and from the weir sites for construction and operations and upgrades to intersections.
- Construction of low level bridges in areas upstream of weir infrastructure impacted by the impoundments, specifically at Glenroy, Riverslea and Foleyvale crossings.
- Installation of culverts at Hanrahan Crossing downstream of Rookwood Weir to facilitate access during operation releases.
- Removal and decommissioning of existing low level causeways and culverts at river crossings described above.
- Relocation of existing and/or installation of new gauging stations.
- Water supply for construction will be sourced directly from nearby rivers and creeks and will not require the construction of additional water supply infrastructure.

The location of the Project and its key components is shown in Figure 1-1.



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Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA94)
Grid: Map Grid of Australia 1994, Zone 55

LEGEND

- AMTD (km)
- Weir Location
- Fitzroy Barrage
- Saddle dams
- Highway
- Major Road
- Streets (Local)
- Access Road
- Fitzroy Basin
- Urbanised Area
- Rookwood Weir Stage 1 impoundment
- Rookwood Weir Stage 2 impoundment
- Eden Bann Weir Stage 2 impoundment
- Eden Bann Weir Stage 3 impoundment

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Lower Fitzroy River Infrastructure Project

Job Number 41-20736
Revision J
Date 26 Sep 2014

Project locality plan

Figure 1-1

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Figure 1-2 shows the location of Eden Bann Weir infrastructure and impoundment extents at full supply levels. The Eden Bann Weir construction area is shown on Figure 1-3. Figure 1-4 shows the location of Rookwood Weir infrastructure and impoundment extents at full supply levels. The Rookwood Weir construction area is shown on Figure 1-5.

A detailed project description is provided in the environmental impact statement (EIS) at Volume 1 Chapter 2 Project description and Volume 2 Chapter 2 Project description.

Operationally the Project comprises the maintenance and management of the weir infrastructure, private access roads and impoundments, inclusive of a flood buffer. Water releases will be made through 'run of river' methods and no water distribution infrastructure is required. Water releases will be made to satisfy environmental and water security objectives in accordance with the *Water Resource (Fitzroy Basin) Plan 2011* (Fitzroy WRP). Operating regimes will be developed and implemented through the Fitzroy Basin Resource Operations Plan (Fitzroy ROP) (as augmented).

The development of weir infrastructure (and associated works), the resultant storage of water (inundation of the river bed and banks) and the transfer of water between storages through 'run of river' methods on the Fitzroy River comprise the scope of the Project. Abstraction, transmission and distribution to end users are not considered as part of the proposed Project, and are subject to the users own environmental investigations.

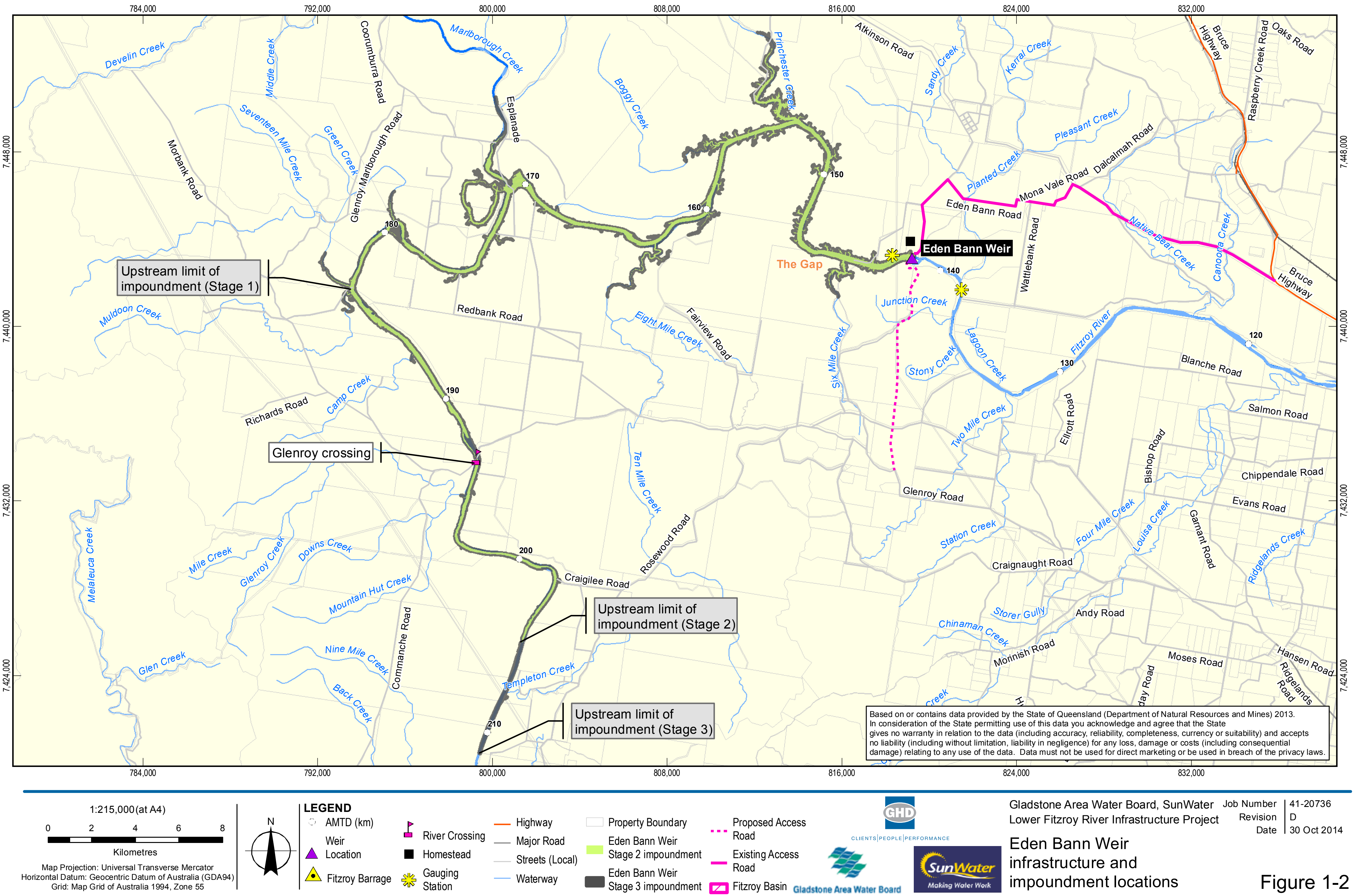
The Project is likely to be staged, with sequencing and timing dependant on a number of demand triggers including existing and new consumers, drought conditions and security of supply requirements. The Project will be implemented by way of a flexible strategy to allow the rapid delivery of water to meet anticipated future demands, when triggered. There is yet to be a decision on the order in which the proposed developments will proceed. The Project will only proceed to development after full project evaluation and impact assessment studies have been satisfactorily completed, all necessary regulatory approvals obtained and a development proponent identified.

Construction (per stage) is programmed to occur over at least two dry seasons (Section 6). A contract start time for EIS reporting purposes has been set so that site activities, particularly those related to the riverbed construction activities can commence at the end of the wet season (Q1 Year 1) due to the unpredictability and magnitude of the flows during the wet season. Further detail with regard to Project timeframe in relation to triggers is provided in Volume 1 Chapter 1 Introduction.

The milestones and timeframes for the Project are as follows, noting that an actual start date will be determined by a demand trigger coinciding with seasonal factors as explained above:

- Preparatory and early works (15 to 18 months prior to Q1 Year 1). The early works phase includes further investigations such as survey, geotechnical investigations and hydraulic studies (for example physical model studies for spillway and fishways) to inform the delivery of the detailed design; detailed design, procurement development approval applications, including waterway barrier works, land acquisition and cultural heritage surveys.
- Contract award (Q1 Year 1)
- Commencement of construction (start-Q1 Year 1)
- Spillway concrete complete (start-Q4 Year 2)
- Commencement of impounding (mid-Q4 Year 2)
- Weir construction practically complete (end-Q4 Year 2)

Impoundment is expected to occur within a single wet season during which commissioning will take place (Chapter 9 Surface water resources).



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Revision D
Date 30 Oct 2014

Eden Bann Weir infrastructure and impoundment locations

Figure 1-2

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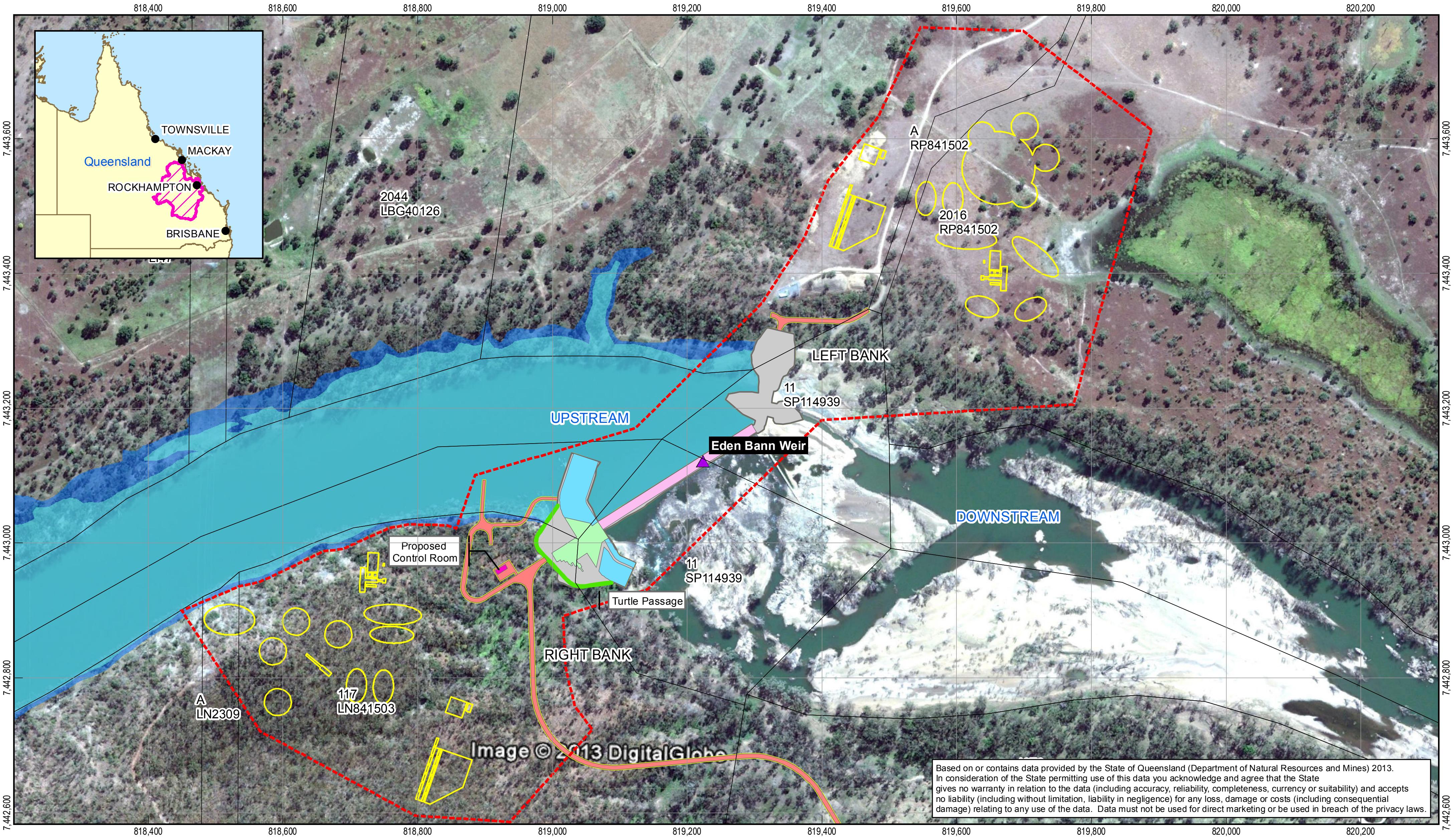

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Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA94)
Grid: Map Grid of Australia 1994, Zone 55

N

LEGEND

- Weir Location
- Fitzroy Basin
- Access Roads
- Channel
- Outlet works and fishway
- Proposed Control Room
- Proposed Spillway
- Turtle Passage
- Eden Bann Weir Proposed Structure
- Construction Footprints
- Construction Area
- Eden Bann Weir Stage 2 impoundment
- Eden Bann Weir Stage 3 impoundment

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Eden Bann Weir construction area

Figure 1-3

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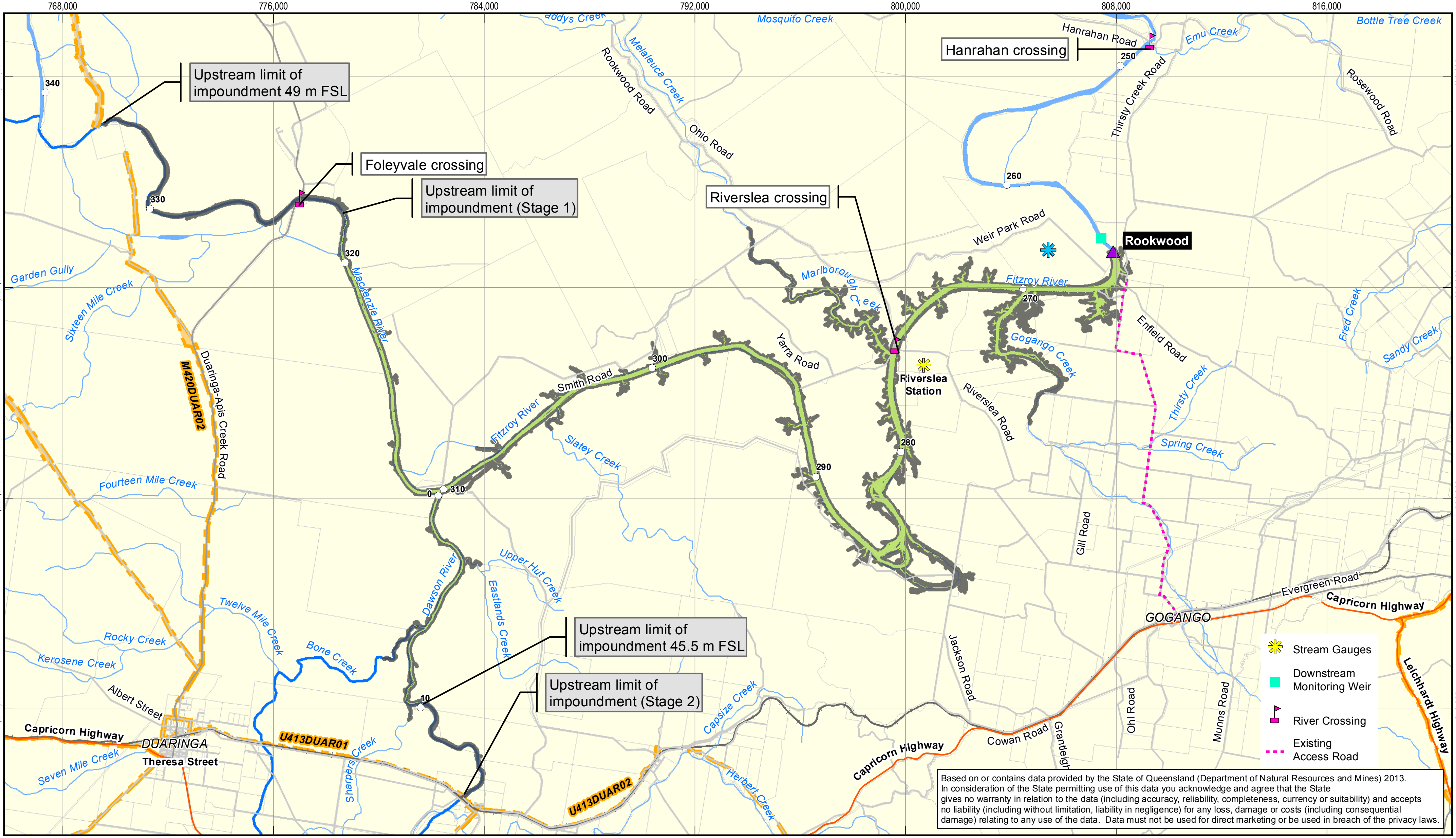

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Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA94)
Grid: Map Grid of Australia 1994, Zone 55

LEGEND

- AMTD (km)
- Weir Location
- Fitzroy Barrage
- Saddle dams
- Highway
- Major Road
- Streets (Local)
- Railway
- Waterway
- Fitzroy Basin
- Property Boundary
- Stock Routes
- Rookwood Weir Stage 1 impoundment
- Rookwood Weir Stage 2 impoundment

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Rookwood Weir infrastructure and impoundment location

Figure 1-4

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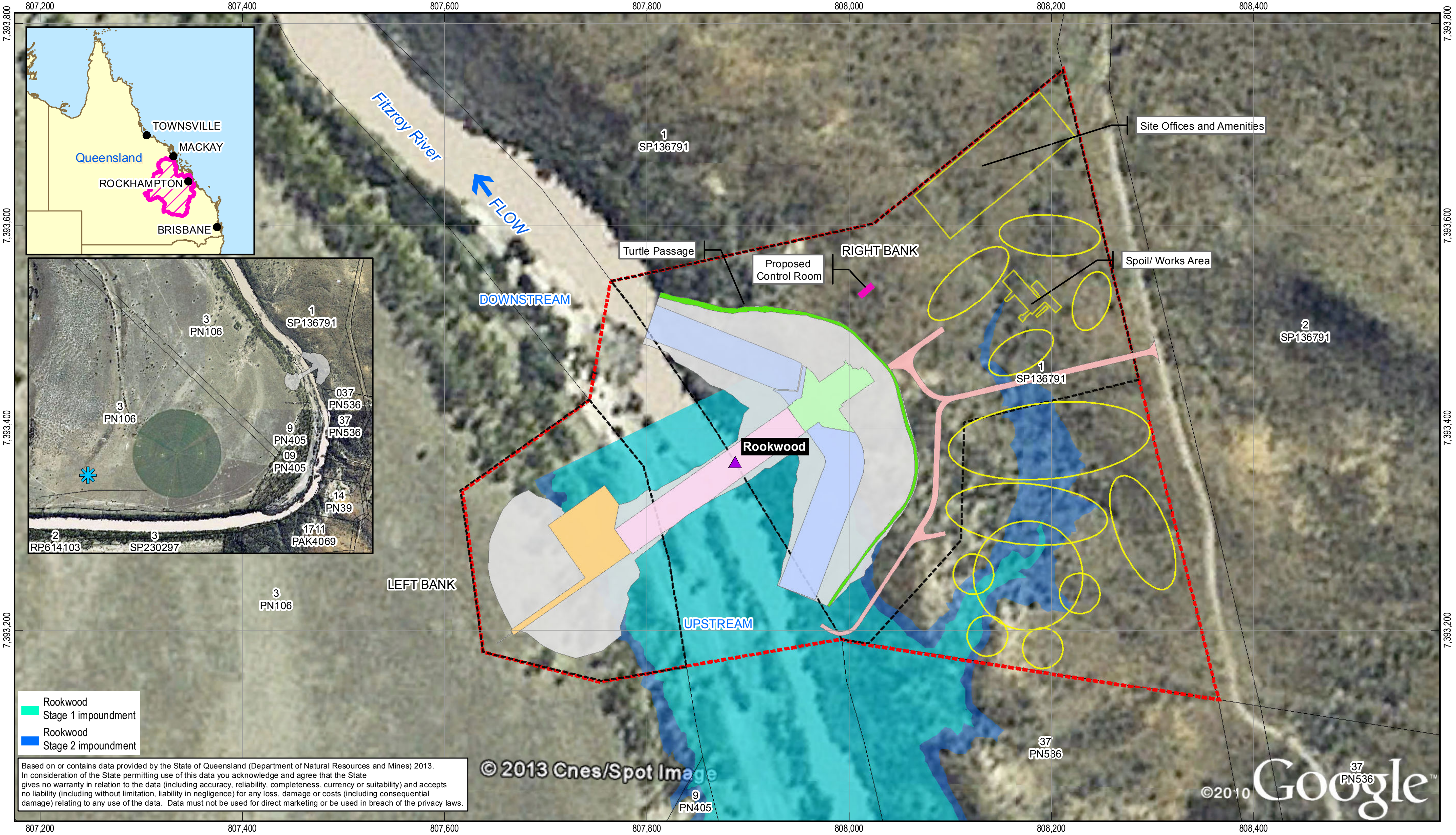

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Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA94)
Grid: Map Grid of Australia 1994, Zone 55

N

LEGEND

- Weir Location
- Fitzroy Basin
- Construction Area
- Proposed Property Acquisition Boundary
- Rookwood Weir proposed structure
- Construction Site Facilities
- Abutement, Wide Rock filled mattress
- Access Roads
- Channel
- Outlet works and fishway
- Proposed Control Room
- Spillway
- Turtle Passage
- Saddle Dam

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Rookwood Weir construction area

Figure 1-5

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1.2 Purpose of this report

The raising of an existing weir and the development of a new weir is a waterway barrier works, and is assessable development under the *Sustainable Planning Act 2009* (SP Act) (Section 2). Therefore, development approval is required to raise Eden Bann Weir and construct Rookwood Weir.

The purpose of this report is to provide a summary document that consolidates material in support of the required waterway barrier works development application for weir construction and operation and in particular the fish passage design process and outcomes (Section 2.2.2) such that stated conditions can be achieved through the EIS.

2. Regulatory framework

The EIS provides a detailed description of relevant legislation at Volume 1 Chapter 3 Legislation and project approvals and Volume 2 Chapter 3 Planning and approvals. Water resource planning and its regulatory framework is described in Volume 1 Chapter 9 Surface water resources. With particular reference to fish and fish passage the following legislation applies.

2.1 Commonwealth

2.1.1 Environment Protection and Biodiversity Conservation Act 1999

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is the primary Commonwealth legislation for environmental protection of the Australian environment, and its flora and fauna (including aquatic communities).

No EPBC Act listed-threatened fish species have been previously recorded or are predicted to occur in the Project area.

2.2 Queensland

2.2.1 Fisheries Act 1994

The *Fisheries Act 1994* (Fisheries Act) details mechanisms for the management and sustainable use of fisheries resources within Queensland. The Fisheries Act provides legislative guidance for the maintenance of fish movement through waterways. Section 76G of the Fisheries Act requires that where a new waterway barrier is constructed, or where an existing waterway barrier is raised, adequate provisions must be made for fish passage. A barrier (culverts, crossings, weirs and dams) may be created by construction; raising; replacement and/or maintenance works.

The construction and/or raising of a waterway barrier is classed as operational works and requires a development approval under the *Sustainable Planning Act 2009* (SP Act) (Section 2.2.1). Included in the development approval process is an assessment under the Fisheries Act.

The Project has engaged with the Department of Agriculture and Fisheries (DAF) to establish a fish passage design process in this regard (Section 2.2.2).

The DAF spatial data layer '*Queensland waterways for waterway barrier works*' identifies the expected impacts to fish movement arising from development of a barrier. The spatial layer provides a colour-coded rating of the potential impacts for each waterway in Queensland as described in Table 2-1 for dams and weirs.

Table 2-1 Waterway barrier works assessment requirements for weirs

Category	Waterway zone	Risk of impact	Assessment level
One	Green	Low	Self-assessable
Two	Amber	Moderate	Development approval
Three	Red	High	Development approval
Four	Purple	Major	Development approval
Five	Grey	Major	Development approval

Eden Bann Weir and Rookwood Weir fall within Category 4 (the purple waterway zone) (Figure 2-1; Figure 2-2) and are considered to comprise a major risk of impact and as such construction of the weirs will require development approval.

The provision of fish passage is an integral part of the waterway barrier works approval and has been and will be considered during Project design.

Where applicable (for example on Thirsty Creek) minor works associated with road upgrades and the installation of culvert crossings will be undertaken in accordance with the Code for self-assessable development - Minor waterway barrier works Part 3: culvert crossings (code number WWBW01) and/or the Code for self-assessable development Minor waterway barrier works Part 4: bed level crossings (code number: WWBW01), as applicable (Fisheries Queensland 2013a). Construction of coffer dams on the Fitzroy River will be undertaken in accordance with the Code for self-assessable development – Temporary waterway barrier works (code number WWBW02) (Fisheries Queensland 2013b).

Hanrahan Road, comprising an existing track across the bed of the river, with an existing concrete causeway and pipe culvert at the low flow channel, may be impacted as a result of operational releases from Rookwood Weir. It is proposed that the crossing upgrade will comprise the installation of a new bank of culverts designed to accommodate flows up to 50 m^3/s and provide for fish passage. Such culverts are large and will facilitate fish passage. Preliminary design for the bridges was undertaken in accordance with the Australian Standard for Bridge Design (AS 5100). During the early works phase waterway crossings will be detailed designed to meet the requirements of the Fisheries Act 1994 and in consultation with DAF. These elements are not addressed further in this report and separate development approvals and or self-assessments will be undertaken. Detailed descriptions of the proposed works are provided in Volume 1 Chapter 2 Project description and impacts assessed in Volume 1 Chapter 7 Aquatic ecology with regard to aquatic fauna.

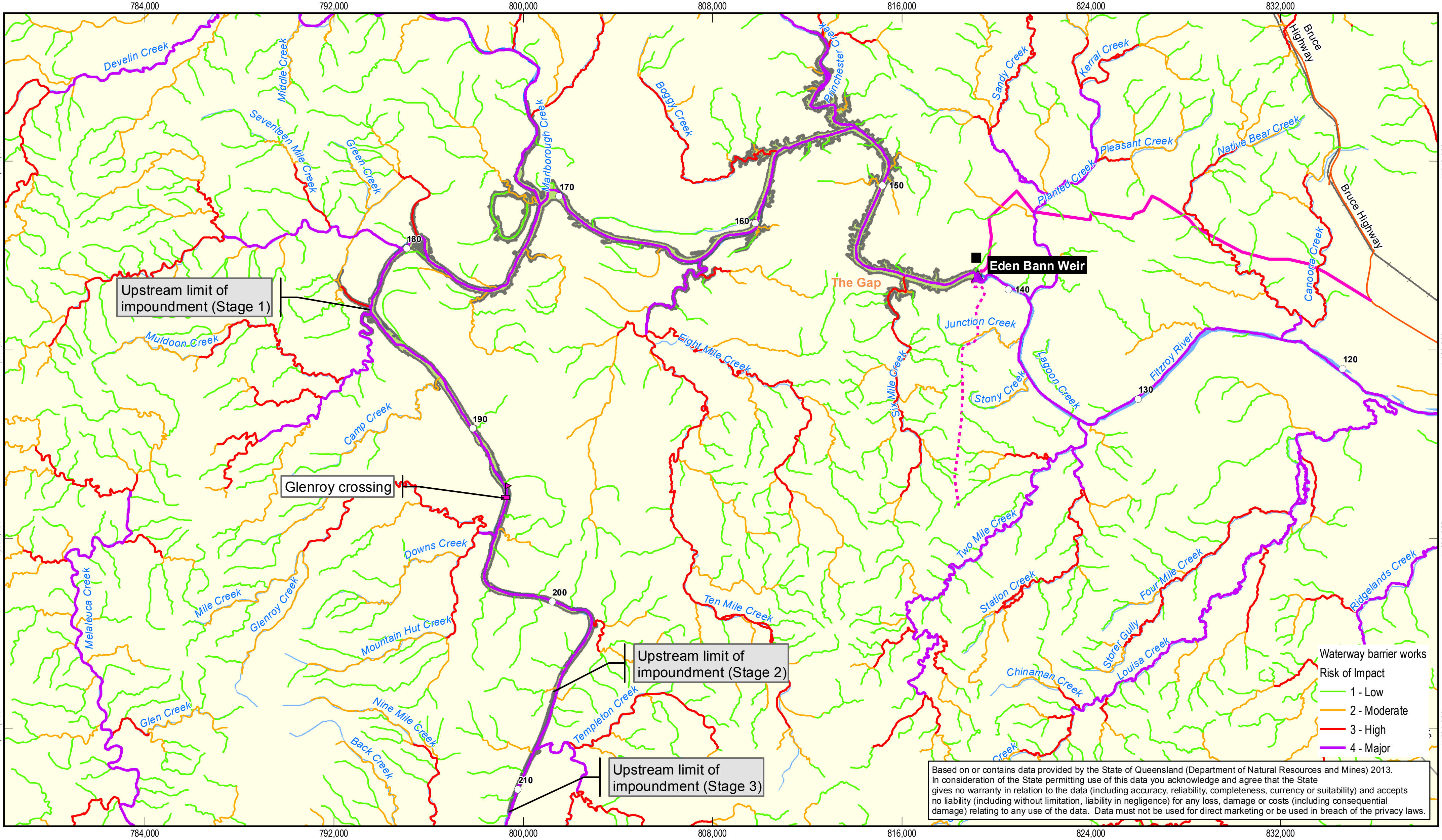
2.2.2 Nature Conservation Act 1992

Under the *Nature Conservation Act 1992* (Qld) (NC Act), any activity that has or may have the potential to impact on wildlife in an area, may be seen as a threatening process and will be referred to the Department of Environment and Heritage Protection (DEHP) as part of the development approval process. In particular, the effect of the Project on endangered, vulnerable, or rare wildlife, or the habitat on which that wildlife depends, will be of interest. No NC Act listed-threatened fish species have been previously recorded or are predicted to occur in the study area. Endemic species are present and discussed in Section 5.4.

2.2.1 Sustainable Planning Act 2009

The SP Act provides a streamlined approach to development assessment in Queensland. The State Development Assessment Provisions (SDAP) are prescribed in the Sustainable Planning Regulation 2009 and is a statutory instrument made under the SP Act. The SDAP contains the matters the chief executive may have in regard to assessing a development application as either an assessment manager or a referral agency. Applicants are required to prepare a response to the relevant state codes contained within the SDAP.

The state code relevant to the Project with regard to operational work for waterway barrier works (constructing or raising) is Code 5.2 Constructing or raising waterway barrier works in fish habitats state code under SDAP Module 5: Fisheries resources included at Appendix A.



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0 2 4 6 8

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA94)
Grid: Map Grid of Australia 1994, Zone 55

N

LEGEND

- AMTD (km)
- Weir Location
- River Crossing
- Homestead
- Highway
- Major Road
- Waterway
- Eden Bann Weir Stage 2 impoundment
- Eden Bann Weir Stage 3 impoundment
- Proposed Access Road
- Existing Access Road

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Date	06 Feb 2015

Queensland waterways for waterway barrier works mapping categories for Eden Bann Weir

Figure 2-1

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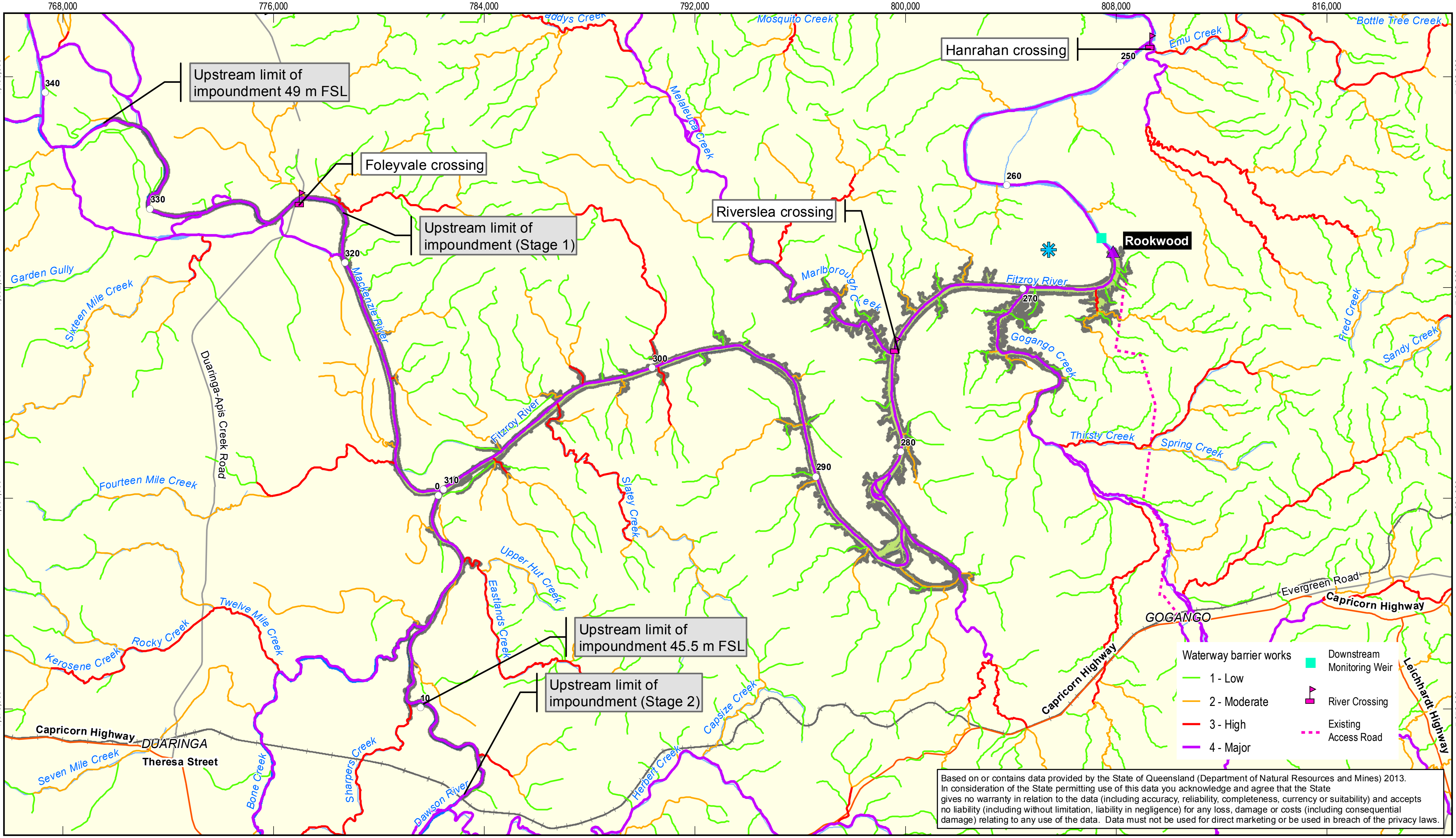

1:195,000 (at A4)

0 2 4 6 8

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA94)
Grid: Map Grid of Australia 1994, Zone 55

LEGEND

- AMTD (km)
- Weir Location
- Saddle dams
- Highway
- Major Road
- Railway
- Waterway
- Rookwood Weir Stage 1 impoundment
- Rookwood Weir Stage 2 impoundment

Gladstone Area Water Board, SunWater
Lower Fitzroy River Infrastructure Project

Job Number	41-20736
Revision	A
Date	06 Feb 2015

Queensland waterways for waterway barrier works mapping categories for Rookwood Weir

Figure 2-2

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2.2.2 Water Resource (Fitzroy Basin) Plan 2011

The Fitzroy WRP seeks to achieve general and specific outcomes for the sustainable management of water (Volume 3 Appendix P). The outcomes relate to providing:

- Security for water users and licence holders through the establishment of water allocation security objectives (WASOs).
- Environmental water for aquatic ecosystems through the establishment of environmental flow objectives (EFOs). EFOs are the flows considered necessary to sustain a healthy environment. The Fitzroy WRP defines EFOs that specifically relate to flow-based performance indicators.

2.2.3 Fitzroy Basin Resource Operations Plan

The Fitzroy ROP implements the Fitzroy WRP and defines the rules for allocation and management of water in order to achieve WASOs and EFOs. In this regard, the Fitzroy ROP specifically deals with the management arrangements for supplemented water supply schemes and associated infrastructure, and those for unsupplemented water in water management areas:

- Supplemented water is managed through water supply schemes. Relative to the Project, the Lower Fitzroy (supported by the existing Eden Bann Weir storage) and the Fitzroy Barrage (supported by the Fitzroy Barrage storage) water supply schemes are applicable
- Unsupplemented water is managed by the State in water management areas. The Fitzroy Water, Nogoa Mackenzie and Dawson Valley management areas are applicable to the Project

The Fitzroy WRP identifies unallocated water held as strategic water infrastructure reserve; a nominal volume of 76,000 ML (for supplemented water allocations) is reserved for water infrastructure on the Fitzroy River, within which the Project is included. The Fitzroy ROP specifies that the chief executive may accept submissions for making unallocated water available from the strategic infrastructure reserve on the Fitzroy River as follows:

- Gladstone Area Water Board: up to 30,000 ML of the reserve for urban and industrial water supplies
- Local government authority: up to 4,000 ML of the reserve for urban water supplies for the Capricorn Coast
- Person or entity: up to the remaining 42,000 ML of the reserve.

Further detail regarding the Fitzroy WRP and Fitzroy ROP is provided in Volume 3 Appendix P.

3. Fish passage design process

3.1 Approach

One of the key potential risks requiring consideration and management during the design, construction and operation of the Project is the maintenance of upstream and downstream passage of fish species. Provision of fish passage will be an integral part of the conditions relevant to the waterway barrier works approval. To address this, a fishway design process was undertaken in accordance with Queensland Fisheries (then as the Department of Employment, Economic Development and Innovation (DEEDI)) Design Process criteria (Appendix B). This process involved the selection of fishway design specifications and success criteria and the development of preliminary fishway designs for both Eden Bann Weir and Rookwood Weir.

The fishway design process undertaken for the Project was based on the processes previously used in Queensland for both Paradise Dam and Wyaralong Dam. This process was recommended by DEEDI due to the high level of consultation that occurs between stakeholders.

The key stages in the fishway design process included:

- Data collection and review
- Development of a fish passage issues register
- Inception meeting
- Site visit
- Development of design specifications and success criteria
- Development of a preliminary Project fishway design.

3.2 Roles and responsibilities

3.2.1 Project Control Group

The Project Control Group (PCG) is the primary internal decision-making body for the Project. During the fishway design process the PCG consisted of the Chief Executive Officers of the Gladstone Area Water Board (GAWB) and SunWater Limited (SunWater) with representation from (the then) Department of Infrastructure and Planning – Regional Development Group and (the then) Department of Environment and Resource Management, with input from GHD as necessary and applicable.

The PCG met approximately monthly during the fishway design process.

3.2.2 Project Technical Committee

The Project Technical Committee (PTC) consists of representatives of SunWater, GAWB and GHD. The key role of the PTC is to guide the development of the Project.

The PTC's involvement in the fishway design process was specifically as follows:

- Review, comment and endorse success criteria and design specifications
- Review, comment and endorse fishway design elements
- Report progress to the PCG.

The PTC met fortnightly during the fishway design process.

3.2.3 Design team

The fishway design team was responsible for developing the fishway design.

Members of the fishway design team were selected such that a range of engineering and scientific disciplines necessary for fish passage design were present and that representation from the range of key stakeholders, including DEEDI fish biologists, an independent freshwater fish biologist and an independent fishway engineering specialist, were involved in the design process as shown in Table 3-1. Members of the fishway design team were supported by a broader GHD project team who undertook investigations, evaluations and design tasks as required.

Table 3-1 Fishway design team

Role	Name	Organisation
Team facilitator Overall coordination of design process; approvals process; meeting minutes and notes; workshop development and logistics; present outcomes	Claire Gronow / Natasha Witting Natalie Clark (assistant)	GHD
Proponent representative Operational considerations; fishway design considerations; PTC representative	Errol Beitz Simone Gillespie	SunWater
Proponent representative Operational considerations; fishway design considerations; PTC representative	Richard West Penny Fiddes	GAWB
Fishway engineering design Technical input on engineering aspects	Jon Williams Lesa Delaere	GHD
Fishway engineering design Fish passage design, hydraulic engineering	Brian Cooper	Brian Cooper Consulting
Ecology - team leader Coordinate ecological studies; technical input on ecological aspects	Natasha Witting	GHD
Freshwater fish biologist Technical input on fish behaviour	Ivor Stuart	Kingfisher Research
Aquatic ecologist Technical input on ecological aspects	Natalie Clark	GHD
DEEDI fish biologists Technical input on fish behaviour; technical input on fishway design; input into DEEDI Policy	Claire Peterken Tim Marsden Andrew Berghuis	DEEDI

3.3 Methodology

3.3.1 Data collection and review

The objective of the task was to collate existing information relevant to fish passage design and operation and comprised:

- Desktop literature review
- Creation of a Fishway Design Background Report (report number 20736-D-RP-025; as provided to DEEDI as 'commercial in confidence') detailing:

- Fish assemblages at, up and downstream of the Project sites and any relevant behavioural data for species including: movement biology (for example, time of the year that upstream and downstream migration takes place, triggers for migration), breeding ecology, swimming ability (depth and velocity required for upstream and downstream migration)
- Fish habitat at, up and downstream of the Project sites
- Project site hydrology including the existing and projected headwater / tailwater levels at a range of flows (flow duration curves, annual exceedance probabilities, flow event curves)
- Relevant water management arrangements impacting on the Project sites (for example environmental flow release requirements, water resource and resource operation plan requirements)
- Any other constraints such as upstream and downstream conditions and impediments
- Likely weir operation scenarios.

Data collection was facilitated by GHD with team meetings and briefings held to facilitate reporting.

3.3.2 Fish passage issues register

A register of issues that required resolution in relation to fish passage was established and maintained for Eden Bann Weir and Rookwood Weir.

Ongoing updates of the issues register were provided during all team interactions. Updates included:

- New issues and/or risks
- Additional information on issues on the register
- Updates and close-out where issues were addressed and/or resolved.

3.3.3 Inception and site visit

At inception the fishway design process was formally commenced and team members introduced and roles and responsibilities assigned.

At inception a field visit to both Eden Bann Weir and the proposed Rookwood Weir site was undertaken by the fishway design team in order to gain a general understanding of the physical and ecological conditions upstream and downstream of the Project sites and to review the design and operation of the existing Eden Bann Weir fish lock.

The field visit also included a site visit by the fishway design team to the Fitzroy Barrage (at Rockhampton) and the Wattlebank gauging station (immediately downstream of the existing Eden Bann Weir) to gain an understanding of the design and operation of these existing fish passage and monitoring facilities.

3.3.4 Design specifications and success criteria

Workshops were held to establish design specifications and success criteria for fish passage; and to establish a framework for the evaluation of design concepts and included consideration of the following:

- The operating range and conditions for operation - upstream passage and downstream passage
- Target species and particular passage requirements

- Performance during spilling/spill events
- Entry and exit conditions including flow velocities, turbulence, interference etc.
- Interaction with outlet works and attraction flows
- Construction aspects
- Cost
- Safety in design and engineering design considerations
- Energy requirements and power supply options
- Operational requirements, flow availability.

Agreed design specifications and success criteria are presented in Table 3-2. The criteria are based on the DEEDI Design Principles for Fishways (Appendix B) as refined during four fishway design team workshops. Criteria have not been tested for practicability and in some instances require computational fluid dynamics (CFD) and physical model studies to determine and/or refine criteria. That is some criteria may later be deleted or modified if shown to be impractical, excessively expensive or to compromise structural integrity, hydraulic performance or health / safety. It is not expected that the final fishway design will meet all criteria absolutely but rather that there will be some trade-offs between criteria. There is scope for the further development and optimisation of the design specifications and success criteria during detailed design.

3.3.5 Preliminary fishway design

Based on the agreed design specifications and success criteria the fishway design team identified and evaluated a range of potentially suitable fish passage concepts through various workshops.

Concept designs were considered in terms of:

- Mechanisms for conveying fish across the structure in the upstream and downstream direction
- Entry and exit design
- Spillway and dissipater design
- Fish exclusion from outlet works
- Operating rules requirements for particular concepts.

Shortlisted designs were evaluated including consideration of preliminary cost estimates; preliminary engineering design of overall structures and evaluation against design specifications and success criteria. This included development of preliminary design drawings, undertaking hydrological and hydraulic analysis, undertaking flow data analysis and an ecological risk assessment and evaluation.

Stream flow and flood flow analysis was undertaken using outflow ‘release’ data from each weir (upper limit development stages EB3 and RW2) from the IQQM model as simulated flows. This facilitated assessment of the time periods that daily flows where in or out of range for use by fish passage infrastructure thereby providing quantification of whether the fish passage infrastructure was passing or not passing fish. Further this facilitated quantification and assessment of potential waiting periods experienced by fish species during periods that passage was not able to be provided.

Table 3-2 Fishway design specifications and success criteria

Issue	Criteria – Eden Bann Weir	Criteria – Rookwood Weir site
Design life for fishway structure and components does not compromise operational time	Mechanical/electrical 10-20 years. Structural 100 years.	Mechanical/electrical 10-20 years. Structural 100 years.
Fishway does not compromise structural integrity or hydraulic performance of weir	New fish lock is located on right the right bank. High flow fish passage subject to geotechnical conditions on either bank. Structures do not protrude above abutment height (or other height to be determined after resolving siltation versus afflux issues) – *to be resolved during detailed design process*. Structures do not limit spillway capacity.	Fish passage structures are located on right bank. Structures do not protrude above abutment height (or other height to be determined after resolving siltation vs afflux issues) -– to be resolved during detailed design process. Structures do not limit spillway capacity.
Procurement and construction costs are minimised	Optimal costs without sacrificing other criteria.	Optimal costs without sacrificing other criteria.
Operational costs are minimised	Optimal costs without sacrificing other criteria.	Optimal costs without sacrificing other criteria.
Health and Safety is not compromised	Operation and maintenance requirements do not introduce Health and Safety risk. Confined space entry requirements are minimised.	Operation and maintenance requirements do not introduce Health and Safety risk. Confined space entry requirements are minimised.
Upstream and downstream passage for small, medium and large fish (15-800 mm long) is provided	Able to operate at flow velocities from 0.15 m/s to 1.8 m/s. Provides protection from predation for small fish. Holding chamber dimensions are the same as in the current fish lock at Eden Bann Weir.	Able to operate at flow velocities from 0.15 m/s to 1.8 m/s. Provides protection from predation for small fish. Holding chamber dimensions are the same as in the current fish lock at Eden Bann Weir.
Larval mortality is minimised	Undershot crest gates are not used on the spillway or close to the surface. Late summer flood flows are passed over the weir (if consistent with Resource Operations Plan requirements - to be determined).	Undershot crest gates are not used on the spillway or close to the surface. Late summer flood flows are passed over the weir (if consistent with Resource Operations Plan requirements - to be determined).
Fish mortality is minimised	Downstream spillway face is largely a "smooth formed surface finish" (allow for roughness on bank edges/abutments for turtles). Fish screens are provided on outlet works (20 mm screens, 0.3 m/s velocity). Avoid strong transverse flows as tailwater rises. Energy dissipater and stilling basin/plunge pool design to minimise injury and mortality to fish. Avoid spilling directly onto rocks downstream of Eden Bann Weir. Features that may become downstream barriers to fish movement under low flow regimes to be modified (features to be identified).	Avoid creating pools downstream of spillway where fish get trapped as flows recede. Provide fish passage across tailwater control structures. Downstream spillway face is largely a "smooth formed surface finish" (allow for roughness on bank edges/abutments for turtles). Fish screens are provided on outlet works (20 mm screens, 0.3 m/s velocity). Provide deeper stilling basin floor levels. Avoid strong transverse flows as tailwater rises. Energy dissipater and stilling basin/plunge pool design to minimise injury and mortality to fish.

Issue	Criteria – Eden Bann Weir	Criteria – Rookwood Weir site
		Features (such as road crossings) that may become downstream barriers to fish movement under low flow regimes to be modified (features to be identified).
Period of operation is maximised	Routine maintenance is not required during fish migration season. Maximum likely downtime due to unplanned maintenance requirements is minimised. Capable of operating at all times when there is a release. Capable of operating on an inflow/outflow basis if required under Resource Operations Plan. Can operate at lower end of regular release levels. Time that fishway is not operational due to siltation and debris is minimised by location and upstream design treatments to minimise silt and debris entering. Access to fishway is available as soon as possible after a flood event, subject to external road network. Mechanism for flushing/scouring of fishway is provided. High level fishway (as necessary and applicable) is not rendered inoperable by debris during flood flows.	Routine maintenance is not required during fish migration season. Maximum likely downtime due to unplanned maintenance requirements is minimised. Capable of operating at all times when there is a release. Capable of operating on an inflow/outflow basis if required under Resource Operations Plan. Can operate at lower end of regular release levels Time that fishway is not operational due to siltation and debris is minimised by location and upstream design treatments to minimise silt and debris entering. Access to fishway is available as soon as possible after a flood event, subject to external road network. Mechanism for flushing/scouring of fishway is provided. High level fishway (as necessary and applicable) is not rendered inoperable by debris during flood flows.
Downstream operating range is maximised	Fish passage is provided from elevation level 7 to drown out (subject to determining fish movements and downstream hydraulic conditions on high flows). Upper operating limit of fish lock to result in no more than x-x consecutive days (to be resolved) of non-operation in high flow conditions (percent exceedance to be determined from flow duration curves, ability of fish to swim against flows).	Fish passage is provided from dead storage to drown out (subject to determining fish movements and downstream hydraulic conditions on high flows). Upper operating limit of fish lock to result in no more than x –x consecutive days (to be resolved) of non-operation in high flow conditions (percent exceedance to be determined from flow duration curves, ability of fish to swim against flows).
Upstream operating range is maximised	Fish passage is provided from EL 7 m to drown out (subject to downstream operating range, downstream hydraulic conditions and fish swimming ability). Upper operating limit of fish lock to result in no more than x-x consecutive days (to be resolved) of non-operation in high flow conditions (percent exceedance to be determined from flow duration curves).	Fish passage is provided from dead storage (level to be determined) to drown out (level to be determined) (subject to downstream operating range, downstream hydraulic conditions and fish swimming ability). Upper operating limit of fish lock to result in no more than x-x consecutive days (to be resolved) of non-operation in high flow conditions (percent exceedance to be determined from flow duration curves).
Upstream exit/entrance optimises fish passage	Exit/entrance is accessible at all water levels (within operating range to be determined). Fish can exit at or below water level throughout operating range. Fish exiting do not become entrained in outlet works. Fish exiting are not carried back over spillway (when spilling). Exit is close to bank or cover is provided to facilitate fish moving close to	Exit/entrance is accessible at all water levels (within operating range to be determined). Fish can exit at or below water level throughout operating range. Fish exiting do not become entrained in outlet works. Fish exiting are not carried back over spillway (when spilling). Exit is close to bank or cover is provided to facilitate fish moving close

Issue	Criteria – Eden Bann Weir	Criteria – Rookwood Weir site
	bank. Weed assemblage is avoided at exit.	to bank. Weed assemblage is avoided at exit.
Downstream entrance/exit optimises fish passage	Exit/entrance is accessible at all water levels (within specified operating range). Fish can get to the entrance no matter which way they approach without returning downstream. Refugium for small fish is provided in entrance channel.	Exit/entrance is accessible at all water levels (within specified operating range). Fish can get to the entrance no matter which way they approach without returning downstream. Refugium for small fish is provided in entrance channel.
Upstream passage requirements of fish species are met	Upstream passage to be provided as follows: • Specify flow conditions under which upstream passage is critical.	Upstream passage to be provided as follows. • Specify flow conditions under which upstream passage is critical.
Downstream passage requirements of fish species are met	Downstream passage to be provided as follows: • Specify flow conditions under which downstream passage is critical.	Downstream passage to be provided as follows: • Specify flow conditions under which downstream passage is critical.
Water releases (other than spilling) optimise fish movement	Releases in the following range are via fishway: • Lower limit of flow to be specified; and • Upper limit of flow to be specified. Flows are directed through the fishway in preference to the outlet works. Water releases through the fishway are of surface water quality. Water quality of releases from outlet to fishway entrance area: (water quality in Eden Bann Weir to be reviewed). • Dissolved oxygen > 5 milligrams per litre; • Temperature change is -1 °C to +2 °C from ambient; and • Water releases are drawn from 2 m below surface during late summer/high flow events to minimise larval entrainment.	Releases in the following range are via fishway: • Lower limit of flow to be specified; and • Upper limit of flow to be specified. Flows are directed through the fishway in preference to the outlet works Water releases through the fishway are of surface water quality Water quality of releases from outlet to fishway entrance area: • Dissolved oxygen > 5 milligrams per litre; • Temperature change is -1 °C to +2 °C from ambient; and • Water releases are drawn from 2 m below surface during late summer/high flow events to minimise larval entrainment.
Outlet works are located to complement fishway operation	Adjacent to fishway. Outlet works do not interfere with or mask attraction flows. Outlet flows enhance attraction to the fishway. Able to balance releases through fishway and outlet works. Allow for selective withdrawal to manage water quality.	Adjacent to fishway. Outlet works do not interfere with or mask attraction flows. Outlet flows enhance attraction to the fishway. Able to balance releases through fishway and outlet works. Allow for selective withdrawal to manage water quality.
Disruption to fish passage during spilling conditions is minimised	As levels fall, flows can be transferred to fishway and outlet works to reduce low level spilling. Spilling flows do not confuse fish and prevent them from entering fishway. Fishway operation ceases when level above spillway reaches threshold (threshold to be determined, maximum would be drown out).	As levels fall, flows can be transferred to fishway and outlet works to reduce low level spilling. Spilling flows do not confuse fish and prevent them from entering fishway. Fishway operation ceases when level above spillway reaches threshold (threshold to be determined, maximum would be drown out).

Issue	Criteria – Eden Bann Weir	Criteria – Rookwood Weir site
Attraction flows maximise fish passage	Turbulence is minimised even at high attraction flows. Attraction flows are parallel to lock walls/entrance axis. Diffusers create air bubbles and water noise (noise is an attractor). Capable of providing continuous attraction flows when fishway is operating, *i.e.* including on the emptying cycle. Attraction flow velocities can be varied between: 0.15-1.8 m/s – for the fish lock. 250 mm slots for vertical slot – 350 mm slots for the fish locks. Allow for variable attraction flows between phases of the cycle.	Turbulence is minimised even at high attraction flows. Attraction flows are parallel to lock walls/entrance axis. Diffusers create air bubbles and water noise (noise is an attractor). Capable of providing continuous attraction flows when fishway is operating, *i.e.* including on the emptying cycle. Attraction flow velocities can be varied between: 0.15-1.8 m/s – for the fish lock. 250 mm slots for vertical slot – 350 mm slots for the fish locks. Allow for variable attraction flows between phases of the cycle.
Fish can pass readily from entrance to exit	Avoid overcrowding in any holding chambers (area to be based on Eden Bann Weir). Refugium for small fish is provided. Flows within structure are suitable for fish likely to be present. Low turbulence.	Avoid overcrowding in any holding chambers (area to be based on Eden Bann Weir). Refugium for small fish is provided. Low velocity flows. Low turbulence.
Effect of construction works on fish passage is minimised	Continue to operate existing fish lock during construction (practicality of this to be determined – otherwise alternative arrangements to be identified). Provide fish passage under (or over) any temporary roads *etc.* used for construction. Pipes used in diversion and under temporary road crossings must be suitable for fish passage particularly in relation to light levels.	Provide temporary fish passage during construction (method to be developed along with diversion strategy). Provide fish passage under (or over) any temporary roads *etc.* used for construction. Pipes used in diversion and under temporary road crossings must be suitable for fish passage particularly in relation to light levels.
Commissioning and post commissioning allows for ongoing management and maintenance	Allow for handover from construction to operator. Allow for adjustments to be made in commissioning and post commissioning including entrance/exit slot, diffuser orientation and velocity. Allow for monitoring and response in first 3 years of operation (assuming these are not very low flow years). Embed fishway operation, management and maintenance requirements in operations and maintenance manual.	Allow for handover from construction to operator. Allow for adjustments to be made in commissioning and post commissioning including entrance/exit slot, diffuser orientation and velocity. Allow for monitoring and response in first 3 years of operation (assuming these are not very low flow years). Embed fishway operation, management and maintenance requirements in operations and maintenance manual.

Daily data from the IQQM was used to undertake the following:

- Analyse the percent of time that the fish passage infrastructure could pass fish
- Analyse the days passing and days wait for flows greater than 500 m^3/s
- Analyse the days passing and days of success assuming either a four day or seven day wait time
- Graph the flood hydrographs for floods greater than 500 m^3/s.

The outputs of the fishway design process resulted in the proposed fishway design for the Project, namely:

- Eden Bann Weir: a modified existing left bank fish lock and a new right bank fish lock
- Rookwood Weir: construction of a fish lock on the right bank.

Fish passage design is detailed further in Section 8.

4. Ecological understanding for the provision of fish passage

4.1 Movement, dispersal and migration

Based on migration patterns, fish are classified as either diadromous or potamodromous. Diadromous fish migrate between freshwater and marine environments and can be categorised into three distinct groups, as follows:

- Catadromous – species that reside in freshwater, and migrate to the sea to breed
- Amphidromous – species that migrate between freshwater and the sea not for breeding purposes, but as part of the species life cycle
- Anadromous – reside in saltwater, and migrate to freshwater to breed.

Potamodromous fish migrate wholly within freshwater for the purpose of breeding or otherwise (Marsden and Power 2007).

Worldwide, tropical freshwater fish regularly move among spawning, feeding and refuge habitats (Lowe-McConnell 1987; Lucas and Baras 2001). The influence of seasonal flows on fish migration is profound and fish movements are often associated with flooding in the wet season (Winemiller and Jepsen 1998; Agostinho *et al.* 2004). Some fish undertake long-distance migrations, while others are more localised. Several species coincide movement with the peak of flows, when new habitats are available, while others move on the ascending or descending flow limbs (Baran 2006) or as waters recedes from the floodplain (Bishop *et al.* 1995). In many tropical rivers, there is fish movement all year round.

4.2 Impact of barriers to movement

Restriction and prevention of natural fish migrations due to dams and weirs has been implicated in the decline of many native species in Australia (Stuart and Mallen-Cooper, 1999). Impediments to movement impact upon the ability of species to breed, disperse and recruit, potentially altering population structures, gene flow, species assemblages and trophic interactions.

When a migrating fish approaches a dam or weir there is often a short interruption or delay before finding and ascending a fishway. This delay would not usually have negative consequences. However, if fish passage is not provided for throughout the full range of the hydrograph, then fish may experience delays in the ability to move, having to wait until fish passage infrastructure becomes accessible. For example delayed migration on small-bodied fish can lead to increased mortality below weirs from larger predators.

The maximum extent of an “allowable delay” depends on the timing, the flow cue and the motivation of the migration. The allowable delay also depends on the position of the weir within the catchment and the habitat upstream and downstream. In the United States of America, delays to migrating fish (salmon) of over 3 consecutive days, for a 1-in-10 year flow event, between cessation of fishway operation to the drown-out of the weir may negatively impact upstream spawners (Katapodis 1992). In Australia, there are no published criteria for allowable delays to fish migration and it is likely to vary for each fish species and river system.

Amphidromous and some potamodromous fish might be able to tolerate short delays while delays of days or weeks to catadromous fish appear more directly detrimental. For example, some downstream migrations of catadromous fish (for example eels) involve considerable physical changes, including depletion of fat or muscle and physico-chemical readiness to enter salt water. Hence, there can be physical and stress damages as well as reduction in spawning success for these fishes. It is also likely that impoundments on coastal rivers increase the travel time for downstream migrating catadromous fish. For example in the United States of America, Chinook salmon take an extra 40 days to reach the estuary than what they did prior to dams being in place. In the Fitzroy River catchment, delays to downstream migration might be exacerbated by the long travel distances (hundreds of kilometres), especially during the extended periods of zero flow over spillways.

Catadromous fish, such as barramundi, can be adults and juveniles and this often includes dispersal migrations from nursery areas of high abundance (Russell and Garrett 1985). Delays at tidal barriers can be highly detrimental where small fish are prone to high levels of predation from larger con-specifics (*e.g.* barramundi), from other piscivorous fish and birds and also heightened levels of disease, physical damage and physiological stress due to elevated salinity (Harris 1984, Sheaves *et al.* 2007). The delay caused by a tidal barrier can be compounded by low river flows and highlight the importance of understanding the position of the barrier within the catchment.

For potamodromous fish, there might also be a reduction in spawning success with ‘flood ready’ males and females unable to reach their preferred spawning habitat at the appropriate time. It appears that there are a specific set of conditions that contribute to successful spawning and recruitment (rising flow in late spring or early summer) in the upper Fitzroy River catchment (Roberts *et al.* 2008). Fish caught below dams will either resorb their eggs or spawn in secondary habitats downstream of the dam. Golden perch which accumulate below weirs and dams can also be subject to increased mortality from anglers and stranding after rapid decreases in tailwater.

There are also behavioural impacts with radio-tagged golden perch being reluctant to approach large weirs during downstream migration, displaying local avoidance behaviour, and most fish eventually returning upstream (O’Connor *et al.* 2005). Hence, some fish might not complete their spawning or become isolated from their home area. In the Murray system of southern Australia, pre-spawning adult golden perch delayed beneath stream barriers appear to accumulate for several weeks in spring before dispersing and a higher biomass is apparent during elevated flow conditions. The impact on the spawning success of the fish is unknown and a subject for further research (L. Baumgartner, pers. comm.)

The impact of migration delay on small-bodied fish is primarily due to increased mortality below weirs from larger predators. For some small fish below tidal barriers the majority of that year’s recruitment can be subject to heightened levels of mortality. In the freshwater reaches of rivers there are major migrations of thousands of small-bodied fish such as empire gudgeons, hardyheads and rainbowfish and some of these fish are dispersing and some are pre-spawning (Bishop *et al.* 1995, Hogan *et al.* 1997, Renfree and Marsden 2006; Stuart *et al.* 2008). Delays to small fish migration can be costly in terms of mortality but the effects on recruitment success are unknown.

5. Existing environment and ecological values of the Fitzroy River

5.1 Aquatic habitat values

Aquatic habitats within the Fitzroy River are dynamic and vary over a temporal and spatial scale in association with catchment climatic conditions. The Fitzroy River catchment is influenced by both temperate and tropical climatic patterns with highly variable summer dominated rainfall. River flows are directly correlated to rainfall events and discharge flows can range from as low as <100, 000 ML per annum in dry years to over 23 million ML per annum (Queensland Department of Natural Resources and Water, 2008).

During these periods of high rainfall, the river primarily exists as a deep fast-flowing pool in which many of the in-stream aquatic habitats are inundated as a result of the increase in water depth and velocity. Normally isolated off-stream billabong and wetland habitats become connected to the main river channel when river levels rise above bank height. As water levels recede, the river channel is transformed into a series of pool-riffle-run sequences and the off-stream habitats again become separated. It is during this period that aquatic habitat diversity is at its greatest with each section of the river providing a diverse combination of habitat conditions for aquatic fauna. During the dry season, the riffle and run habitats dry out and the river exists as a series of isolated non-flowing pools. These isolated pools act as refugia for aquatic fauna during the dry season however the pools are often highly competitive systems with limited foraging resources for aquatic fauna and often exhibit reduced water quality conditions.

The construction of the Fitzroy Barrage, Wattlebank Gauging Station and Eden Bann Weir has altered the aquatic habitat availability within the lower Fitzroy River. All riverine habitats within the barrage and weir inundation zones have been converted to large, deep, slow-moving pools. All three structures have fish passage devices installed.

Aquatic habitat is described and discussed further in Volume 1 Chapter 7 Aquatic ecology and Volume 1 Chapter 22 Offsets.

5.1.1 Eden Bann Weir

The terrestrial environment upstream of Eden Bann Weir contains the highest proportion of remnant vegetation cover along the Fitzroy River. The landscape is a mix of rugged ranges, low undulating hills and alluvial plains. Lowland areas are predominantly cleared for grazing. However large areas of woodland vegetation persist on low rocky hills. The river is wide and slow-flowing within the impoundment, with a series of sand banks that are vegetated with *Melaleuca* spp. The riparian fringe is narrow adjacent to grazing areas and wider and more extensively vegetated adjacent to rocky hills. A series of small creeks join the river between the Eden Bann Weir and Glenroy Crossing. These generally have more natural, complex riparian vegetation.

The Fitzroy River currently impounded upstream of the existing Eden Bann Weir (to 184 km AMTD) is deep, wide and slow-flowing. The river bed substrate is generally clay/slit with smaller amounts of gravel and sand. The abundance and diversity of macrophytes is reduced and those that do occur are generally restricted to the shallow margins. The river banks are generally stable to moderately stable and on average approximately 7 m high. The riparian zone has been partially inundated and in many cases the river connects directly to the terrestrial vegetation on the flood plain. The inundated riparian vegetation that remains along the margins appears in relatively good condition in the upstream reaches but deteriorates in health downstream, with only dead woody remnants/debris remaining adjacent to the spillway at the weir itself.

Approximately 270 ha of natural (not impounded) aquatic habitat occurs within the Eden Bann Weir Project footprint. Aquatic habitat types within the Eden Bann Weir Project footprint are described in Table 5-1.

Table 5-1 Summary of aquatic habitat types upstream of Eden Bann Weir

Habitat type	Characteristics	Representative photograph
Impounded pool	• Deep, wide river channel • Generally low to zero flow • Generally poor quality clay/slit substrate • Small areas of gravel and sand • Temperature stratification • Low oxygen levels • Low density of macrophytes • Low density of overhanging riparian vegetation • Generally low density of in-stream debris • Areas of inundated vegetation increase in-stream debris in places	
Natural pool	• Deep, narrow river channel • Generally low-medium flow • Medium oxygen levels (maybe reduced in dry season) • Medium density of macrophytes • Some overhanging riparian vegetation • Some in-stream debris	
Run	• Narrow river channel • Medium depth (not as shallow as riffle) • Substrate variable (can be soft or rocky) • Medium oxygen levels • Medium density of macrophytes on margins • Some overhanging riparian vegetation • Some in-stream debris	
Riffle	• Narrow river channel • Shallow water depth (< 1 m) • High velocity • Rocky substrate • High oxygen levels • High diversity and abundance of aquatic vegetation (macrophytes and algae) • High diversity and abundance of benthic invertebrates • May dry out completely in dry season	
Creek	• Narrow, shallow river channel • Medium-low flows • Medium-low oxygen levels • High density of macrophytes • High density of overhanging vegetation • High density of in-stream debris	

Habitat type	Characteristics	Representative photograph
Billabong	• Isolated water body • No water flow (seasonally, or only occasionally, connected to main river system by floodwaters) • Low oxygen levels except during flood events • High diversity and abundance of macrophytes • High density of overhanging vegetation • High abundance of in-stream debris	

5.1.2 Rookwood Weir

The proposed Rookwood Weir is located at a 'greenfield' site at AMTD 265.3 km on the Fitzroy River, approximately 85 km south-west of Rockhampton.

The river at this location is deeply incised with 25 m high banks (SunWater, 2008). Landuse adjacent to the Rookwood Weir Project footprint is dominated by low density pastoral grazing land including cattle grazing, and cropping.

The impoundment associated with the proposed Rookwood Weir Stage 2 extends approximately 337 km AMTD into the Mackenzie River and approximately 15 km AMTD into the Dawson River. The Fitzroy River in the Rookwood Weir Project footprint is generally more narrow and dynamic than areas further downstream which have been altered as a result of impoundments (namely, Eden Bann Weir and the Fitzroy Barrage). There are no existing weirs or other water storage infrastructure within the Rookwood Weir Project footprint. Consequently, it retains many of the features of a natural riverine system and contains a greater diversity of lotic habitats.

The river banks within the Rookwood Weir Project footprint are generally moderately stable and contain a relatively larger amount of overhanging vegetation. The riparian zone ranges in width from narrow highly degraded strips to wide sections of well-developed large growth vegetation that joins directly to the terrestrial vegetation extending out onto the floodplain. Land use adjacent to the Rookwood Weir Project footprint is dominated by low density pastoral grazing land and cropping. The landscape is predominantly flat and has been extensively cleared for grazing. However, low undulating rocky hills and uncleared alluvial plains occur in places and retain remnants of native woodland vegetation.

The river channel is less defined than areas downstream, with greater seasonal changes in river flow attributable to the lack of anthropogenic regulation of the system. Open riverine sections (natural pools) are interspersed with more confined sections of riffles and runs. Water depth and velocity vary from deep, slow-moving conditions in the natural pools to shallow and fast-flowing conditions in the riffle zones. Substrates are predominately gravel, pebble, cobble with smaller areas of clay/slits, sands and bedrock. Macrophyte abundance and diversity is greatest within the creeks, riffle zones and off-stream billabongs. Attached, filamentous and floating algae occur occasionally throughout the Rookwood Weir Project footprint.

Approximately 647 ha of aquatic habitat occurs within the Rookwood Weir Project footprint. Aquatic habitat types within the Rookwood Weir Project footprint are described in Table 5-2. The natural pool habitat is the most extensive aquatic habitat type, covering a total stream length of approximately 46 km (approximately 47 per cent of the main river channel within the Rookwood Weir Project footprint). The riffle and run habitats that connect the natural pools cover a total length of approximately 21 km (approximately 22 per cent) and approximately 29 km (approximately 30 per cent), respectively. Off-stream billabongs occur in linear depressions within the riparian zone, typically 20 – 50 m from the rivers' edge. Billabongs are relatively abundant and vary in size from small ephemeral ponds to large permanent to semi-permanent water bodies.

Table 5-2 Aquatic habitat types upstream of proposed Rookwood Weir site

Habitat type	Characteristics	Representative photograph
Natural pool	• Deep, narrow river channel • Generally low-medium flow • Medium oxygen levels (maybe reduced in dry season) • Medium density of macrophytes • Some overhanging riparian vegetation • Some in-stream debris	
Run	• Narrow river channel • Medium depth (not as shallow as riffle) • Substrate variable (can be soft or rocky) • Medium oxygen levels • Medium density of macrophytes on margins • Some overhanging riparian vegetation • Some in-stream debris	
Riffle	• Narrow river channel • Shallow water depth (< 1 m) • High velocity • Rocky substrate • High oxygen levels • High diversity and abundance of aquatic vegetation (macrophytes and algae) • High diversity and abundance of benthic invertebrates • May dry out completely in dry season	
Creek	• Narrow, shallow river channel • Medium-low flows • Medium-low oxygen levels • High density of macrophytes • High density of overhanging vegetation • High density of in-stream debris	
Billabong	• Isolated water body • No water flow (seasonally, or only occasionally, connected to main river system by floodwaters) • Low oxygen levels except during flood events • High diversity and abundance of macrophytes • High density of overhanging vegetation • High abundance of in-stream debris	

5.2 Water quality

Desktop assessments were undertaken to determine general surface water quality characteristics and potential impacts on surface water quality as a result of the Project area. Detailed analysis is presented in Volume 1 Chapter 11 Water quality. The Fitzroy Basin has a large agricultural production base, accounting for almost 90 per cent of land use in the Basin area. These activities, combined with point source inputs from mining operations, reduced or altered flows from weirs and the natural climatic variability of the region, have the potential to affect water quality in the lower Fitzroy, Dawson and Mackenzie rivers.

Existing physio-chemical water quality characteristics of the Fitzroy River are summarised as follows:

- The median pH recorded was within guideline values and the pH recorded within the impoundment indicates a largely alkaline environment; a reflection of the fact that most Fitzroy soils are alkaline (DERM, 2008)
- The Fitzroy River is known to be a highly saline system (DERM, 2009; Hart, 2008; Noble et al., 1997); however median electrical conductivity (EC) was below guideline values. It was however, noted that cumulative impacts from mining in the Fitzroy River catchment have contributed to recent increases in in-stream salinity (DERM, 2009; Hart, 2008)
- The long-term median water temperature at 25.35 ºC at The Gap (within the existing Eden Bann Weir impoundment) and 25 ºC at Riverslea (276 km AMTD). Trend analysis shows only a slight reduction in temperature over depth within the weir, as expected within a shallow impoundment resulting in little to no stratification.
- The median concentration of dissolved oxygen (DO) at The Gap was greater than guideline values. There is a trend for the concentration of DO to decrease with depth (albeit slightly) within the Eden Bann Weir impoundment suggesting a low level of stratification within the water column. The median concentration of DO at Riverslea was within guideline values.
- Median turbidity levels were greater than guideline values consistent with generally high turbidity levels observed within the Fitzroy, Mackenzie and Dawson rivers.
- The concentrations of nutrients, total nitrogen (TN) and total phosphorous (TP) within the Eden Bann Weir impoundment and upstream at Riverslea are greater than guideline values. The concentration of nutrients in waters within the Fitzroy Basin are influenced by land use practices and derived from runoff from croplands and pasturelands, and sourced from agricultural fertilisers and manure, together with high erosion and sedimentation during flood events (Johnston et al. 2008).
- The median concentration of dissolved copper and zinc recorded were greater than guideline values. The concentration of dissolved metals in the Fitzroy River may be associated with naturally mineral-rich soils which occur throughout the Fitzroy Basin (Taylor and Jones 2000). The concentration of dissolved metals in the waterways of the catchment may contribute to the observed results (Taylor and Jones 2000).
- Median chlorophyll a (as an indicator of algal growth) recorded within the Eden Bann Weir impoundment was less than guideline values.

Existing physio-chemical water quality characteristics of the lower Dawson River are summarised as follows:

- The median pH recorded was within guideline values and indicates an alkaline environment
- The median EC recorded was less than guideline values under baseflow conditions
- The long-term dataset recorded a median temperature of 26.7 ºC whereas the short-term data indicates cooler temperatures with a median of 20.5 ºC
- The median concentration of DO was within guideline values

- The long term median turbidity within the fresh water reach was greater than guideline values, however the median short-term turbidity data indicates a reduction in turbidity in more recent times.
- The median concentration of nutrients (TN and TP), copper and zinc were greater than the WQO.

Existing physio-chemical water quality characteristics of the lower Mackenzie River are summarised as follows:

- The median pH recorded was within guideline values and indicates an alkaline environment
- The long term median EC recorded was less than guideline values under baseflow conditions. However, the short term median EC was greater than guideline values under baseflow conditions
- Median water temperature is approximately 26 ^{o}C
- The median concentration of DO was within guideline values in the Mackenzie River
- The long term median turbidity within the fresh water reach was greater than guideline values. However, the median short-term turbidity data indicates a reduction in turbidity in more recent times
- The concentration of nutrients (TN and TP) was less than guideline values
- The median concentration of copper and zinc were greater than the WQO which is similar to the Fitzroy and Dawson Rivers.

5.3 Fish habitat areas

The Fitzroy River Fish Habitat Area (FHA) (FHA-072) is located downstream of the Fitzroy Barrage, more than 60 km downstream of the existing Eden Bann Weir.

5.4 Fish species

5.4.1 Species composition

Thirty-four species of fish have been previously recorded in the study area as listed in Table 5-3. No EPBC Act or NC Act listed-threatened species have been previously recorded or are predicted to occur in the study area. Species considered to have local conservation value due to their restricted geographic range include: southern saratoga (*Scleropages leichardti*); leathery grunter (*Scortum hillii*); and golden perch (*Macquaria ambigua oriens*). These species, while not recorded during field surveys within the Project footprints, have previously been recorded in the study area (Stuart 1997, Berghuis and Long 1999, Long and Meager 2000, Heindenreich and Broadfoot 2001, Marsden and Power 2007 and Stuart et al 2007).

Table 5-3 Fish species previously recorded within the study area

Family	Species – scientific name	Species - common name
Catadromous		
Anguillidae	*Anguilla reinhardtii*	Long-finned eel
Centropomidae	*Lates calcarifer*	Barramundi
Scorpaenidae	*Notesthes robusta*	Bullrout
Synbranchidae	*Ophisternon spp.*	Swamp eel
Amphidromous		
Ariidae	*Arius graeffei*	Blue catfish
Belonidae	*Strongylura krefftii*	Freshwater longtom
Gobiidae	*Redigobius bikolanus*	Speckled goby
Hemiramphidae	*Arrhamphys sclerolepis*	Snub-nosed garfish
Megalopidae	*Megalops cyprinoides*	Oxeye herring
Mugilidae	*Mugil cephalus*	Sea mullet
Potamodromous		
Apogonidae	*Glossamia aprion*	Mouth almighty
Atherinidae	*Craterocephalus stercusmuscarum*	Fly-specked hardyhead
Chandidae	*Ambassis agassizii*	Agassiz's glassfish
Clupeidae	*Nematalosa erebi*	Bony bream
Cyprinidae	*Carassius auratus*	Goldfish[3]
Cyprinidae	*Cprinus caripio*	European carp[3]
Eleotridae	*Hypseleotris compressa*	Empire gudgeon
Eleotridae	*Philypnodon grandiceps*	Flathead gudgeon
Eleotridae	*Hypseleotris species 1*	Midgley's carp gudgeon
Eleotridae	*Mogurnda adspersa*	Purple-spotted gudgeon
Eleotridae	*Oxyeleotris lineolata*	Sleepy cod
Eleotridae	*Hypseleotris klunzingeri*	Western carp gudgeon
Melanotaeniidae	*Melanotaenia splendida splendida*	Eastern rainbow fish
Osteoglossidae	*Scleropages leichardti*	Southern saratoga[1]
Percichthyidae	*Macquaria ambigua oriens*	Golden perch[2]
Plotosidae	*Neosilurus ater*	Black catfish
Plotosidae	*Tandanus tandanus*	Freshwater catfish
Plotosidae	*Neosilurus hyrtlii*	Hyrtl's tandan
Plotosidae	*Porochilus rendahli*	Rendahl's catfish
Poeciliidaee	*Gambusia holbrooki*	Mosquitofish[3]
Poeciliidaee	*Poecilia reticulata*	Guppy[34]
Pseudomugilidae	*Pseudomugil signifer*	Pacific blue-eye
Terapontidae	*Amniataba percoides*	Barred grunter
Terapontidae	*Bidyanus bidyanus*	Silver perch[4]
Terapontidae	*Scortum hillii*	Leathery grunter[1]
Terapontidae	*Hephaestus fuliginosus*	Sooty grunter
Terapontidae	*Leiopotherapon unicolor*	Spangled perch

[1] endemic species; [2] endemic sub-species; [3] introduced species [4] translocated species
Source: Stuart et al. 2007; Marsden and Power 2007; Long and Meager 2000; Berghuis and Long 1999; Stuart 1997.

The fish community within the Project area is dominated by potamodromous species; however, several diadromous species (specifically catadromous and amphidromous species) are represented (Table 5-3). Potamodromous fish migrate wholly within freshwater for the purpose of breeding or otherwise, while diadromous fish migrate between freshwater and marine environments as follows:

- Catadromous species reside in freshwater and migrate to the sea to breed
- Amphidromous species migrate between freshwater and the sea as part of the species life cycle, but not for breeding purposes (Marsden and Power 2007).

The Fitzroy Basin catchment has a relatively low diversity of introduced and noxious fish species, with the mosquitofish (*Gambusia holbrooki*), goldfish (*Carassius auratus*) and guppy (*Poecilia reticulata*) known to occur. The highly invasive and destructive European carp (*Cprinus caripio*) has been recorded in a lagoon adjacent to Tartrus Weir on the Mackenzie River (Limpus et al. 2007) upstream of the Project area.

Table 5-4 lists the catch composition from season field surveys. Ten species were recorded during field surveys within the Eden Bann Weir Project footprint (Volume 3 Appendix J), and 18 species were recorded within the Rookwood Weir Project footprint (Volume 3 Appendix K). No listed threatened species or species of local conservation value were encountered during the field survey program. All fish species recorded are relatively common species.

The most abundant fish species within the Eden Bann Weir Project footprint was the western carp gudgeon (*Hypseleotris klunzingeri*). The most commonly encountered fish within the Rookwood Weir Project footprint was the Agassiz's glassfish (*Ambassis agassizii*). The blue catfish (*Arius graeffei*) was the most commonly encountered large-bodied (>100 mm) fish species captured within both Project footprints.

Table 5-4 Catch composition from seasonal field surveys

Species	Number of individuals				
	Eden Bann Weir		Rookwood Weir		Total abundance
	Wet	Dry	Wet	Dry	
Agassiz's glassfish	-	-	-	137	137
Barred grunter	-	-	-	1	1
Blue catfish	86	3	4	-	93
Bony bream	5	-	-	-	5
Eastern rainbow fish	-	-	1	10	11
Flathead gudgeon	6	-	1	2	9
Fly-speckled hardyhead	-	-	-	40	40
Freshwater catfish	6	-	-	1	7
Freshwater longtom	-	-	-	1	1
Golden perch	-	-	2	7	9
Hyrtl's tandan	5	-	1	1	7
Leathery grunter	-	-	-	1	1
Long-finned eel	1	1	-	-	2
Midgley's carp gudgeon	-	2	-	79	81
Mosquitofish	-	-	2	-	2
Mouth almighty	-	-	3	6	9
Purple-spotted gudgeon	-	-	-	4	4
Sleepy cod	2	1	2	7	12

Species	Number of individuals				
	Eden Bann Weir		Rookwood Weir		Total abundance
	Wet	Dry	Wet	Dry	
Snub-nosed garfish	-	-	-	1	1
Speckled goby	1	-	-	-	1
Western carp gudgeon	-	28	-	102	130

Species with significant fisheries values previously recorded within the Project footprints include the barramundi, a catadromous species that is a key target of the Queensland East Coast Inshore Fin Fish Fishery (DEEDI 2009). Whilst commercial fishing does not occur upstream of, or within, the Project footprints, the life-history traits of the barramundi include the use of both freshwater and saltwater habitats. As such, barramundi occurring in the Project footprints areas are considered to be a potential component of the downstream commercial fishery. Other commercially important species known to occur include sea mullet (Eden Bann Weir Project footprint only) and the long-finned eel (both Project footprints).

Recreational target species previously recorded in the study area include barramundi, southern saratoga, golden perch, blue catfish, freshwater catfish, sleepy cod, oxeye herring and snub-nosed garfish (DERM 2010).

Department of Agriculture, Fisheries and Forestry (DAFF) (Queensland Fisheries) stocking records for the period January 2009 to February 2013 indicate that barramundi and golden perch are stocked within dams and weirs throughout the Fitzroy catchment. With reference to the Project, barramundi in particular is stocked within the Fitzroy River Barrage impoundment and within the lower reaches of the Fitzroy River. Golden perch stocking occurs further upstream on the Dawson and Mackenzie rivers outside of the Project areas (with Neville Hewitt Weir and Bedford Weir being the closest stocking locations, respectively). Saratoga is stocked at a single location (Theresa Creek Dam) upstream of Project areas.

5.4.2 Habitat occupancy

Species of fish in the Fitzroy Basin catchment have adapted to the highly dynamic and variable nature of this system (Long 2000). These adaptations are represented by the specific foraging, breeding and sheltering preferences of the species within the system. Most species occur in (or are tolerant of) the still or slow flowing conditions that are present in pool habitats (Pusey et al. 2004; Allen et al. 2003; Marsden and Power 2007). The relatively deep water areas of large pools provide habitat for larger-bodied species that occur in the water column (for example, southern saratoga and golden perch) and benthic habitats (for example, freshwater catfish and Rendahl's catfish). Within the shallow water areas, smaller bodied species such as western carp gudgeon, eastern rainbowfish and fly-specked hardyhead are more common. Whilst widely distributed species such as the long-finned eel and barred grunter are known to inhabit the fast-flowing conditions of riffles and runs, few species in the Fitzroy Basin catchment are specifically adapted to these habitats. Species previously recorded in the study (but not recorded during field surveys) that are known to prefer flowing conditions include silver perch and sooty grunter.

The foraging and breeding habits in the majority of riverine species of fish are associated with in-stream microhabitats in the form of fallen logs, undercut banks, root masses and macrophytes. Creeks and off-stream habitats such as floodplains and billabongs generally contain a high diversity of in-stream microhabitats. As a result, such areas provide habitat for a wide range of species. Off-stream water bodies also provide breeding and nursery habitat for an array of fish species. The breeding season of a number of species (such as barramundi, long-finned eel, oxeye herring, spangled perch, eastern rainbowfish and empire gudgeon) is known to occur during the wet season when flows within the river are high and off-stream water bodies are connected to the river system (Reynolds 1983; Pusey et al. 2004; Stuart 1999; Stuart and Berghuis 1997).

Field surveys conducted within the Project footprints confirmed the general habitat occupancy detailed from the literature review. The relatively deep, slow-flowing habitat in natural pools housed species such as the blue catfish, golden perch, Hyrtl's tandan and freshwater catfish. Flowing water habitats including runs and upstream and downstream of riffles, supported sleepy cod and mouth almighty. Along the margins of wide natural pools small native species dominated catches, including the Agassiz's glassfish, western carp gudgeon, Midgley's carp gudgeon, fly-speckled hardyhead, purple-spotted gudgeon, and eastern rainbow fish. Whilst off-stream water bodies were not sampled within the Project footprints, surveys of these habitats within the study area (downstream of Eden Bann Weir) demonstrated that these habitats support predominantly small-bodied native fish, such as Agassiz's glassfish, Midgley's carp gudgeon, fly-speckled hardyhead, purple-spotted gudgeon, spangled perch and eastern rainbow fish.

5.4.3 Fish migrations

The Fitzroy Basin catchment is typical of many dry tropical rivers in northern Australia where fish migrations are strongly cued with hydrology (Hogan et al. 1997; Renfree and Marsden 2006). Other factors, or combinations of environmental factors, which stimulate migration include water temperature, length of day, food availability, fish biomass and water chemistry. The hydrology cue, however, is recognised as one of the most important for influencing tropical river fish communities and their migrations (Baran 2006; Sheaves et al. 2007; DERM 2010).

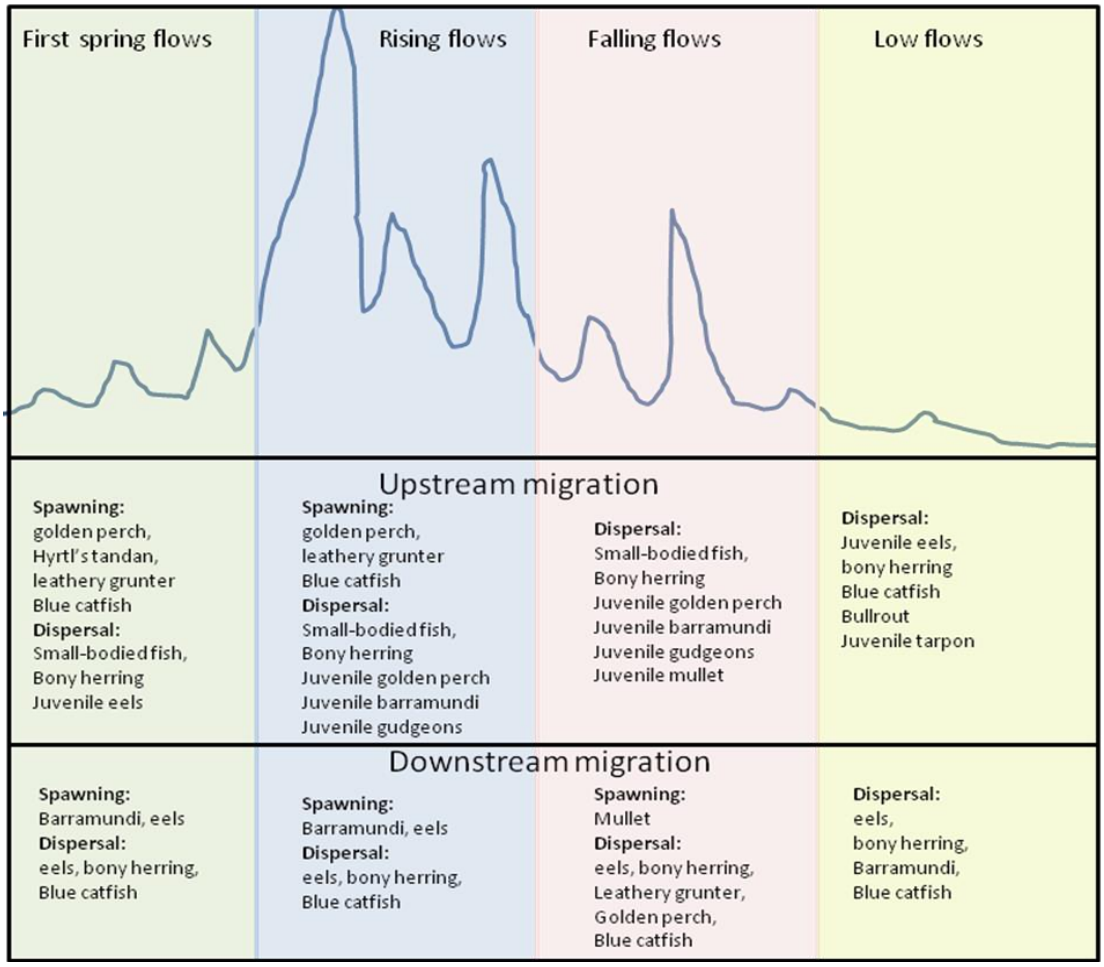
In the Fitzroy Basin catchment, a general model of migration includes the first spring flows (for migration of leathery grunter, Rendahl's catfish and golden perch in particular), flood flows associated with the wet season (for migration of golden perch, Rendahl's catfish, spangled perch, barramundi and empire gudgeons), flow recession (for migration of juvenile fish) and low flows (for migration of blue catfish and eels) (DERM 2010).

Figure 5-1 depicts the relationship between fish migration and flow in the Fitzroy Basin catchment. The ecology of freshwater fish in the Fitzroy River is one of migration during flooding.

The first post winter flood is likely to trigger spawning and dispersal migrations for a number of species and these are likely to continue during summer flows (Marsden and Power 2007). For catadromous fish (such as barramundi and eels), high flows and floods are especially important for spawning migrations to downstream estuarine and marine waters (DERM 2010). Barramundi have shown increased recruitment and strong year-classes associated with high flows when fish can migrate laterally into off-stream water bodies (Staunton-Smith *et al*., 2004). Low flow events are important for the upstream dispersal migrations of the juvenile stage of several species including sea mullet, juvenile leathery grunter, juvenile Hyrtl's tandan and juvenile empire gudgeon (Marsden and Power 2007; DERM 2010).

Taxonomically, golden perch appears to be the species most sensitive to high flow and flood migration triggers. However in the order of 30 per cent of species in the Fitzroy River migrate strongly on large floods (defined as being more than 120,000 ML/d) and many others respond to increasing flows as described in Table 5-5. In the Fitzroy River, a general model of migration includes the first spring flows (e.g. leathery grunter, Rendahl's catfish and golden perch), flood flows associated with the wet season (golden perch, Rendahl's catfish, spangled perch, barramundi and empire gudgeon), flow recession (bony herring, juvenile fish) and low flows (blue-catfish, eels and oxeye herring).

Figure 5-1 Relationship between fish migration and flow in the Fitzroy Basin catchment



Source: modified from Marsden and Power 2007

Table 5-5 Sensitivity of native fish migration to hydrological cues for movement (where known)

Fish species	Flood migration	First spring flow migration	Maximum discharge when observed (where available)
Diadromous			
Long-finned eel	✓	✓	+195,757 ML/d (+2265 m^3/s)[1, 3]
Swamp eel			127,457 ML/d (1475 m^3/s)[1]
Bullrout			6,937 ML/d (80 m^3/s)[3]
Barramundi	✓	✓	127,457 ML/d (1475 m^3/s)[1]
Blue catfish	✓	✓	195,757 ML/d (2265 m^3/s)[1]
Striped mullet	✓		127,457 ML/d (1475 m^3/s)[1]
Oxeye herring			127,457 ML/d (1475 m^3/s)[1]
Freshwater longtom			660 ML/d (8 m^3/s)[1]
Snub-nosed garfish			660 ML/d (8 m^3/s)[1]
Potamodromous			
Spangled perch	✓	✓	127,457 ML/d (1475 m^3/s)[1]
Sooty grunter			660 ML/d (8 m^3/s)[1]
Banded grunter	✓	✓	127,457 ML/d (1475 m^3/s)[1]
Leathery grunter	✓	✓	+195,757 ML/d* (+2265 m^3/s)[3, 5]
Golden perch	✓	✓	119,581 ML/d (1384 m^3/s)[2, 3, 5]
Bony herring	✓	✓	127,457 ML/d (1475 m^3/s)[1, 3, 5]
Fly-specked hardyhead			65,466 ML/d (758 m^3/s)[1]
Olive perchlet			65,466 ML/d (758 m^3/s)[1]
Rendahl's catfish		✓	
Hyrtl's tandan	✓	✓	195,757 ML/d (2265 m^3/s)[3]
Black catfish	✓		127,457 ML/d (1475 m^3/s)[1]
Mouth almighty			65,466 ML/d (758 m^3/s)[1]
Eastern rainbowfish			119,581 ML/d (1384 m^3/s)[1, 3, 5]
Sleepy cod			127,457 ML/d (1475 m^3/s)[1, 5]
Empire gudgeon			127,457 ML/d (1475 m^3/s)[1, 4]
Purple-spotted gudgeon			65,466 ML/d (758 m^3/s)[1]
Midgley's carp gudgeon		✓	
Western carp gudgeon		✓	
Eel-tail catfish		✓	

*=small numbers

References: [1] Hogan et al. 1997; [2] Mallen-Cooper and Edwards 1991; [3] Stuart and Mallen-Cooper 1999; [4] Renfree and Marsden 2006; [5] Marsden and Power 2007.

The first post winter flood is likely to trigger spawning migrations for a number of species. During this event and on all other flows during the summer there will be continued dispersal migrations of adults and juveniles and some spawning migrations of fish not triggered by the first flow (Marsden and Power 2007).

Low flow events are equally as important for some migration of some fish species. Large numbers of fish have been found accumulating below weirs on the Fitzroy River during small water releases of <18 ML/d (Stuart and Mallen-Cooper 1999). Low flow events are important for the upstream dispersal migrations of the juvenile stage of several species including striped mullet, juvenile leathery grunter, juvenile Hyrtl's tandan and juvenile empire gudgeons (Marsden and Power 2007). Passage for small fish during these small flows is necessary as they are vulnerable to predation when accumulating below obstacles. Predation has been witnessed by schools of forked-tail catfish, pelican and cormorants downstream of the Tartrus Weir (Marsden and Power 2007).

Fish migration at high flows is well known to the Aboriginal people who constructed the Brewarrina fish traps to collect migratory golden perch and other fishes during flow events on the Darling system (Dargin 1976). These observations are supported by state fisheries agency surveys of the Darling and Murray systems during flooding when large numbers of golden perch were migrating upstream at weirs (Mallen-Cooper and Edwards 1991, Harris *et al.* 1992, Mallen-Cooper 1996). In the Australian tropics, state fisheries agency studies that have also collected large numbers of fish at high flows include Hogan *et al.* (1997) (>127,000 ML/d) and Renfree and Marsden (2006) in the fishway on the Burdekin system at Clare Weir where large numbers of fish of 27 species were collected during the study(60,000 ML/d).

On the Fitzroy River at Eden Bann Weir, large numbers of fish were collected migrating at flows of 35,000+ ML/d but higher flows could not be sampled (Stuart et al. 2007) due to safety considerations. Observations of considerable numbers of fish in the rock pools below the weir, after high flow events, indicated that there had been migration during the flood events (Stuart et al. 2007). The major fish which migrated on high flows were golden perch, blue catfish and leathery grunter.

At the Fitzroy Barrage, fish (primarily several catfish species and long-finned eels) were collected at major floods of >197, 000 ML/d (exceeded 0.5 percent of the time) before the fishway drowned-out and sampling was suspended (Stuart and Mallen-Cooper 1999). These represent some of the highest flows ever sampled because these conditions usually present insurmountable safety hazards to field staff.

For catadromous fish (barramundi and eels), high flows and floods are especially important for downstream migration, often over weirs on their journey to estuarine and marine waters for spawning. Barramundi have shown increased recruitment and strong year-classes associated with high flows when fish migrate laterally into connected floodplains (Staunton-Smith et al. 2004). Hence, catadromous fish have also evolved a migration strategy to take advantage of flooding.

In summary, the ecology of freshwater fish in the Fitzroy River is one of migration during flooding.

Volume 3 Appendix J and Volume 3 Appendix K provide further detail on movement behaviour and hydrological requirements of fish species.

5.4.4 Hydrological requirements

Hydrological requirements for large bodied fish, namely golden perch, barramundi, long-finned eel, sea mullet, fork-tailed catfish, leathery grunter, oxeye herring, sleepy cod and saratoga are described below and summarised in Table 5-6.

Table 5-6 Summary of movement characteristics and conditions for large-bodied fish

Species	Movement type	Flow conditions	Season
Golden perch	Potamodromous	Variety of flows	Summer (but all year)
Barramundi	Catadromous	Juvenile: tail of high flow Up to 8,000 ML/d and drawn-out 93 m^3/s*	Spring/summer
Long-finned eel	Catadromous	Variety of flows	Autumn/spring/ summer
Sea mullet	Amphidromous	Variety of flows	Autumn/spring/ summer
Blue catfish	Amphidromous	Top of flow events 1 per cent exceedance 18-757 ML/d 1-9 m^3/s * 5,500 ML/d at Kolan River barrage	Summer
Leathery grunter	Potamodromous	First flood of spring	Spring
Oxeye herring	Catadromous	65,466-127,467 ML/d at Clare Weir, Burdekin 758 – 1475 m^3/s *	N/A
Sleepy cod	Not migratory	N/A	N/A
Saratoga	Not migratory	N/A	N/A

** Values in ML/d were converted to m^3/s (cubic metres per second) for comparison (1 m^3/s = 86.4 ML/d).*

Golden perch

Golden perch from the Fitzroy River basin are a genetically and morphologically distinct sub-species from the southern population. The species is distributed widely throughout the sub-catchments and has been observed moving through fishways at the Fitzroy Barrage on the Fitzroy River (Stuart 1997), Eden Bann Weir (Stuart *et al.* 2007) and other weirs (Marsden and Power 2007). Past and recent research into the migratory requirements of golden perch has identified a need for this species to migrate upstream and downstream to breed (Reynolds 1983; Pusey *et al.* 2004; O'Çonnor *et al.* 2005).The flood recruitment model has been proposed in the past as the main mechanism for recruitment for golden perch in the Murray-Darling Basin but they can also recruit during rising flows within the river channel (Lake 1967; Mallen-Cooper and Stuart 2003).In the Fitzroy River catchment, there is strong recruitment in years associated with high flows and floods in late spring and summer (Roberts *et al.* 2008). The degree of river regulation can also apparently depress recruitment patterns. This strategy potentially allows larvae to benefit from the floodplain at times of maximum inundation, and maximum exposure to larval food supplies (O'Connor *et al.* 2003). Return movements of spent golden perch have been observed in the Murray River.

Migration often occurs in the spring and summer months but has also been recorded after flow events in autumn and winter (Stuart and Berghuis 1999; Dawson River Fish Stocking Group, pers. comm.). This indicates that golden perch migrations are most likely temperature independent and more driven by opportunistic flow events (Marsden and Power 2007). Migration is triggered by environmental cues such as temperature and flow events but is not necessarily restricted to initial or periods of high flow (Marsden and Power 2007). The species have been witnessed moving through the Fitzroy Barrage over a wide range of flows (Stuart 1997). It has been determined that 1.83 m/s is an appropriate water velocity in fishways for an adult golden perch (Mallen-Cooper 1994).

Barramundi

The Fitzroy River basin is an important source of catadromous fish colonists, such as barramundi, to rivers in the south (Sawynok 1998). Tagged individuals have been found as far south as Hervey Bay. Barramundi spawn in saltwater and the juveniles often migrate upstream into freshwater (Mallen-Cooper 1992). Juveniles move upstream on high flow events preferably on the tail of the hydrograph, at least three days after the peak flow but they can also move upstream opportunistically at lower flows (Marsden and Power 2007).

Barramundi generally move during spring and summer with sub-adult fish (100-400 mm) forming the majority of migrating fish (Stuart 1999, Renfree and Marsden 2006). Individuals will still continue migrations throughout the cooler months but in lower numbers (Marsden and Power 2007). There is limited fish movement when water temperature is below 22.5 degrees Celsius (°C). In other rivers, upstream movement has not been recorded at low flows. In the Fitzroy River movement has been observed at a range of flows up to about 8,000 ML/d (Pusey *et al.* 2004). Juvenile barramundi (43 mm) have been recorded moving through laboratory fishways with a swimming speed of 0.66 m/s (Mallen-Cooper 1992). This is thought to be a conservative estimate of barramundi swimming speed due to the low water temperature used in the experiment. Within the Fitzroy River, barramundi were observed negotiating a fishway with a maximum water velocity of 1.4 m/s (Stuart 1997). Barramundi can also pass barriers and obstacles during a period of drown-out (Marsden and Power 2007). In some areas where barriers are present the species has become extinct in upstream areas due to its requirement to spawn in saltwater.

Long-finned eel

Long-finned eels are catadromous with adults migrating downstream on a variety of flows in order to breed at sea. Migration downstream occurs in autumn with the onset of cooler weather. As movement occurs under a variety of flow conditions, this movement is most likely temperature dependent (Stuart and Berghuis 1999). Elvers (50-100 mm) migrate upstream during high flow events in spring and summer. This movement is protracted as individuals must allow time to acclimate to reduced salinity upstream (Pusey *et al.* 2004). Within the freshwater environment, fish are thought to exhibit limited local movement (Pusey *et al.* 2004).

Long-finned eels have been recorded above the Tartrus Weir, on which no fishway is present. This occurrence might be explained by the fact long-finned eels have been demonstrated to migrate past barriers of a similar size to Tartrus Weir (Marsden and Power 2007). This species has been observed climbing obstacles and travelling short distances over damp ground. Several researchers have advocated the inclusion of roughened substrate on fishways in order to enable climbing (friction with substrate) (Langdon and Collins 2000; Stuart and Berghuis 2002). The swimming ability of this species (0.32-0.75 m/s) may be below that necessary to negotiate the high velocities frequently observed in fishways (Langdon and Collins 2000).

Sea mullet

Sea mullet are amphidromous moving downstream during autumn as part of their annual migration to spawning grounds in the sea (Stuart and Berghuis 1999, Stuart 1999). These downstream migrations are triggered by specific water temperature conditions. They migrate downstream in the autumn with the onset of cooler weather and on a variety of flows (Stuart and Berghuis 1999). The juveniles then disperse upstream during spring and summer (Marsden and Power 2007). The juveniles utilise low flows to undertake dispersal migrations and have been recorded migrating on low flows through a fishway on Raglan Creek, indicating the importance of passage at that time (Marsden and Power 2007). Fish under 40 mm have been observed negotiating the Fitzroy Barrage and Burnett vertical-slot fishways which have a maximum water velocity of 1.4 m/s (Stuart and Mallen-Cooper 1999; Stuart and Berghuis 2002).

Saratoga

The saratoga is endemic to the Fitzroy River catchment. There is limited knowledge of the movement biology of this species. It is present throughout the upper Fitzroy, Dawson and Mackenzie rivers and is not considered to be migratory (Merrick and Schmida 1984). However, local anglers have reported large numbers of saratoga congregating below the Neville Hewitt Weir during flow events (Dawson River Fish Stocking Group, pers. comm.). This anecdotal evidence may indicate this species may undertake facultative migrations. One saratoga has been collected in the Eden Bann fish lock (Stuart et al. 2007).

Fork-tailed catfish

Fork-tailed catfish are an amphidromous species. They reproduce in freshwater and in estuarine waters and movement may be stimulated by various conditions (Pusey et al. 2004). Individuals have been recorded moving through the Eden Bann Weir fishlock, reaching peak numbers at the top of each flow event throughout the summer months (Stuart and Berghuis 1997), while lower numbers occur on flow peaks throughout the rest of the year (Stuart 1999; Marsden and Power 2007). At the Kolan River barrage, the species has been observed migrating upstream in flows up to 5500 ML/d (Broadfoot *et al.* 2000). Movement at high flows has also been observed at the Fitzroy Barrage. Movement is greatly reduced in the colder winter months.

Leathery grunter

The leathery grunter is endemic to the Fitzroy River basin. Upstream migration has been documented prior to spawning suggesting the species is potamodromous (Merrick and Schmida 1984). Sampling at barriers within the Fitzroy River catchment indicate the first flood of spring as being a major migration cue for the leathery grunter (Stuart et al. 2007).This species undertakes upstream migrations coinciding with summer rainfall prior to spawning. Anecdotal reports suggest that the numerous barriers on the Fitzroy-Dawson river system prevent upstream migration necessary for reproduction (Marsden and Power 2007).

Sleepy cod

It does not appear as though this species undertakes substantial migrations (Pusey *et al.* 2004). Only 5 and 21 individuals have been observed moving through the Fitzroy Barrage and Eden Bann Weir fishway, respectively. A small number have also been recorded at the Clare Weir fishway in the Burdekin system (Renfree and Marsden 2006). It is expected that this species moves in response to changing abundance of prey fish rather than a need to migrate.

Oxeye herring

A small number of oxeye herring have been detected ascending the Fitzroy Barrage during March and April only (Kowarsky and Ross 1981) and they have also been found in the Burnett barrage fishway. It is believed that this species undertakes downstream spawning migrations. There is debate as to whether adults return upstream after spawning (Pusey *et al.* 2004). This species has been recorded attempting to ascend Clare Weir fishway on the Burdekin River under flow conditions (65,466 – 127,467 ML/d).

Hydrological requirements for small-bodied fish, namely fly-specked hardyhead, eastern rainbow fish, Hyrtl's tandan, Midgley's carp gudgeon and empire gudgeon are described below and summarised in Table 5-7.

Table 5-7 Summary of movement characteristics and conditions for small-bodied fish

Species	Movement type	Flow conditions	Season
Fly-specked hardyhead	Potamodromous	Up to 18, 305 ML/d 212 m^3/s* 10 percent exceedance	Summer
Eastern rainbow fish	Potamodromous	Observed at low flows	Nov -March
Hyrtl's tandan	Potamodromous	Juveniles at 18 ML/d 1 m^3/s *	Nov –March
Midgley's carp gudgeon	N/A	N/A	N/A
Empire gudgeon	Facultative potamodromy or semi-amphidromy	18 – 18, 305 ML/d 1-212 m^3/s * 8-92 percent exceedance	Spring/summer

** Values in ML/d were converted to m^3/s (cubic metres per second) for comparison (1 m^3/s = 86.4 ML/d).*

Fly-specked hardyhead

The movement pattern of the fly-specked hardyhead is described as facultative potamodromy. Access to estuarine areas is not a necessary component of the life cycle. The species is abundant in streams that are periodically disconnected during low flow. Therefore the species has the ability to survive in isolated pools and rapidly recolonise previously dry stretches (Pusey et al. 2004). Within the Fitzroy River, upstream migration peaks in early summer with low fish movement occurring for the remainder of the year. There are few records of this species undertaking downstream movement (Stuart 1997). The environmental cue for movement is unknown however elevated flows are a likely stimulus (Table 5-7; Pusey et al. 2004). The fly-specked hardyhead has been recorded moving through a fishway at flows of 18,305ML/d. This figure is exceeded 10 percent of the time in the Fitzroy River (Stuart 1997). The species has difficulty ascending pool-weir type fishways and has been observed in large numbers immediately downstream of obstructions (Pusey et al. 2004).

Eastern rainbowfish

The eastern rainbowfish is a potamodromous species. The adults migrate upstream in order to spawn. During high flow events the species undertakes dispersal migration (Pusey et al. 2004). Eastern rainbowfish have been observed in low numbers moving through fishways on the Fitzroy River at low flows (Stuart 1997). The highest rate of movement has been recorded from November to April.

Hyrtl's tandan

The Hyrtl's tandan is a potamodromous species. Adults migrate upstream to spawn, and then disperse downstream (Pusey et al. 2004). Individuals have been observed moving upstream through fishways on the Fitzroy River. Movement occurs between November and March under most flow conditions. Small fish (<150 mm) only moved upstream during low flow conditions (18 ML/d) (Stuart 1997). At Eden Bann Weir, there has been a strong migration response of Hyrtl's tandan to the first rising flows of spring and this has also been observed elsewhere (A. Berghuis, pers. comm.).

Midgley's carp gudgeon

Midgley's carp gudgeon has been observed moving upstream in a tributary of the Fitzroy River (Wager 1997). Upstream migration may occur after being displaced from a flow event or as dispersal movements when flow conditions allow.

Empire gudgeon

The empire gudgeon is described as facultative potamodromous or semi-amphidromous. The species engage in a facultative mass dispersal phase and mass upstream migrations (Renfree and Marsden 2006). It is unclear whether empire gudgeon undertake migration for spawning or simply recolonising freshwater (Pusey et al. 2004). They have the ability to breed in freshwater. They have been observed entering the Fitzroy Barrage fishway on a wide variety of flows (18 – 18,305 ML/d) these flows are exceeded about 82 percent to eight percent of the time respectively (Stuart 1997). Upstream migration usually takes place in spring and summer, particularly on large flow events. They have the ability to swim at a velocity of 1 m/s (Hogan *et al.* 1997).

5.5 Existing barriers to movement

Two existing structures restrict fish passage on the Fitzroy River, the Fitzroy Barrage (at 59.6 km AMTD) and Eden Bann Weir (at 141.2 km AMTD). Both structures impound water for commercial, industrial and residential use in the Rockhampton region, and both structures have fish passage infrastructure.

5.5.1 Fitzroy Barrage

The Fitzroy Barrage was completed in 1970 and is owned and operated by Fitzroy River Water (a business unit of RRC). The storage is used to supply water for urban supply, irrigation and recreation. Water from the impoundment is treated at the Glenmore Water Treatment Plant before being distributed via an existing reticulation system.

Within the lower Fitzroy system, the Lower Fitzroy Water Supply Scheme (Eden Bann Weir) and the Fitzroy Barrage Water Supply Scheme (Fitzroy Barrage) operate in conjunction with each other.

When the Fitzroy Barrage was constructed in 1970, a 'pool-and-weir' fishway was included on the southern bank. The design of this fish passage was based on structures utilised in the northern hemisphere to facilitate the movement of salmonid fishes (of which Australia has no native species). The fishway incorporated 14 pools (2.62 m long x 1.83 m wide) on a 1-in-20 slope, over a total length of 40.85 m (Stuart and Mallen-Cooper, 1999). The head difference between adjacent pools was 0.15 m.

A study of the efficacy of the fishway undertaken by Kowarsky and Ross (1981) revealed that the structure performed poorly, with only sea mullet regularly and successfully moving upstream via the conduit. The ineffectiveness of the fishway was addressed in 1987 through the addition of extra baffles within each pool, although this approach failed to rectify the poor performance of the structure (Stuart and Mallen-Cooper, 1999).

The ‘pool-and-weir’ fishway was replaced in 1994 by a vertical-slot fishway. All horizontal baffles from the existing structure were removed and replaced by 17 vertical slot baffles. Furthermore, the height of the channel was raised. The modifications resulted in the creation of sixteen pools (1.95 m x 1.83 m x 1.3 m (usual operating pool depth)), with a head difference of 0.097 m between pools. Vertical slots separating each pool extended the full depth of the pool, with a width of 0.15 m.

Replacing the horizontal baffles with vertical slots, and reducing the head difference between pools resulted in significant decreases in water velocity (2.5 to 1.4 m/s) and turbulence (250 to 41 watts per cubic metre (Stuart and Mallen-Cooper, 1999). Moreover, the alterations increased the operational capabilities of the fishway with regards to the headwater and tailwater range in which the fishway could effectively facilitate fish movement (Stuart and Mallen-Cooper, 1999).

Stuart and Mallen-Cooper’s (1999) assessment of the modified fishway at the Fitzroy Barrage revealed that it was far more effective in facilitating upstream movement of a wide variety of fish species than the original ‘pool-and-weir’ structure. Notably, over 80 percent of native freshwater fish identified in previous studies from the Fitzroy River basin, including catadromous, amphidromous and potamodromous species were recorded utilising the fishway (a total of 24 species) (Stuart and Mallen-Cooper, 1999). Whilst the study highlighted that large fish such as blue catfish could ascend the fishway in as little as two hours, many juveniles and small fish species (such as Agassiz's glassfish, fly-specked hardyhead and several gudgeon species) were incapable of moving upstream via the passage (Stuart and Mallen-Cooper, 1999). Upstream movement through the fishway was observed to cease in bony bream at the onset of nightfall, with fish moving downstream if they had not ascended the fishway before dark (Stuart and Mallen-Cooper, 1999).

The relative success of the vertical-slot fishway on the Fitzroy Barrage compared with the original ‘pool-and-weir’ structure was largely attributed to reductions in water velocity and turbulence which promoted greater utilisation by native freshwater species. The design of the modified fishway was such that fish species boasting a range of behavioural (that is benthic to pelagic) and physiological (small to large) attributes could successfully move upstream beyond the Fitzroy Barrage (Stuart and Mallen-Cooper, 1999). However, the smallest fish species, and small size-classes (sub-adults and juveniles) of larger species were unable to negotiate the structure, probably as a result of their inability to swim against the water flow at the downstream entrance of the fishway (Stuart and Mallen-Cooper, 1999). Furthermore, macroinvertebrates such as crabs and shrimps were unable to ascend the fishway (Stuart and Mallen-Cooper, 1999).

5.5.2 Eden Bann Weir

The existing Eden Bann Weir (Stage 1) was constructed in 1994 on the Fitzroy River primarily to supply high priority water (in the order of 24,000 ML/a) to Stanwell Power Station. The existing Eden Bann Weir is owned and operated by SunWater under the Lower Fitzroy Water Supply Scheme. Water released from Eden Bann Weir is captured in the Fitzroy Barrage, which is then pumped to various water consumers.

The existing Eden Bann Weir is a conventional concrete weir with an existing FSL of 14.50 m AHD. This Stage 1 construction is approximately 8 m high (river bed to weir crest) and 412 m long, with a total storage volume of 36,000 ML (confined within the river).

The left abutment accommodates the existing outlet works and a fish lock (Section 4.3.2). A diversion channel cut through a rock bar services the outlet works and fish lock. A control weir (and gauging station) at Wattlebank (3 km downstream) maintains tailwater levels.

Access for operations and maintenance purposes is via a gravel road on the left bank

Whilst no specific provision for future raising of Eden Bann Weir was made in the original design, some care was taken to accommodate future expansion through crest design provisions and downstream excavation was extended sufficiently to accommodate a larger structure warranted under a raising (SunWater 2007). This allows for the co-location of the existing weir infrastructure and the proposed raised weir infrastructure

Eden Bann Weir, constructed in 1994, incorporates an automated fish lock to assist upstream movement of fish beyond the 7.6 m high barrier. The fish lock and outlet works are located on the left bank whilst the main river channel and the majority of spillway flows occur adjacent to the right bank. A 110 m long channel (6 m wide x 1 m deep) connects the fish lock and outlet works to the main river channel downstream of the weir. The fish lock comprises an entrance chamber, a vertical lock chamber and an exit channel (for detailed specifications refer to Stuart et al., 2007).

The lock operates through four major phases, with a complete cycle taking approximately 90 minutes. In a typical 24 hour period, 16 cycles take place. The four phases in each cycle are attraction (at the downstream entrance of the fishway), filling of the vertical lock chamber, exit (upstream of the weir) and draining of the vertical lock chamber (Stuart et al., 2007). Originally, the design of the fish lock, and its operational control via a computerized Programmable Logic Controller, only catered for low river flows (up to 6,000 ML/d), thereby limiting upstream movement of fish beyond Eden Bann Weir during periods of increased flow (Stuart et al., 2007). Reprogramming of the Programmable Logic Controller software in the late 1990s increased its operational threshold to a daily river discharge amount of 50,000 ML/d, thus allowing the fish lock to operate under flow conditions that persist for 94 percent of the time (that is all but the highest flow events) (Stuart et al., 2007).

A small fish ladder is also installed on the Wattlebank Gauging Weir immediately downstream of Eden Bann Weir.

Sampling conducted between 1996 and 2000 recorded 17 freshwater fish species entering the fish lock (Stuart et al., 2007). Sampling at the upstream exit of the lock over the same period recorded only 13 species. The freshwater longtom, eastern rainbowfish, barramundi and saratoga were recorded entering the fish lock but did not remain in the structure to complete the transfer cycle (Stuart et al., 2007). Two species constituted 92 percent of total captures: blue catfish (52 percent) and bony bream (40 percent) (Stuart et al., 2007). The actual design of the fish lock (notwithstanding its site-specific application at Eden Bann Weir) was found to successfully facilitate fish passage above the weir, when analysed in the context of the five most commonly caught species (Stuart *et al.*, 2007). Notably, most fish belonging to a variety of size-classes of these five species that were recorded entering the lock chamber, successfully exited the chamber during the exit phase (Stuart et al., 2007).

The life history traits of fish species recorded using the fish lock at Eden Bann Weir indicates that it provides a conduit for a diversity of native fish. Benthic (blue catfish), mid-water (bony bream) and pelagic (snub-nosed garfish) species were captured during surveys by Stuart et al. (2007). A variety of catadromous (long-finned eel), amphidromous (blue catfish) and potamodromous (bony bream) species were identified as using the fish lock (Stuart et al., 2007). Based on a review of studies in other parts of the world, in conjunction with the findings of a study on the migratory biomass ascending the fishway at the Fitzroy Barrage (Stuart and Mallen-Cooper, 1999), Stuart et al. (2007) deduced that the fish lock at Eden Bann Weir has the potential to provide passage for the migratory biomass of freshwater fish in the Fitzroy River. However, the ability of some fish to find the entrance of the fish lock was compromised by the site-specific attributes of the Eden Bann Weir site.

Whilst a diversion weir that was built in the late 1990s to direct fish towards the fish lock entrance increased the number of fish locating the fishway, some species including golden perch and long-finned eel were still found to concentrate below the weir when water was overtopping the structure (Stuart et al., 2007). The relatively low discharge from the fish lock (0.08 percent of total river flow during medium flows of up to 50,000 ML/d) was identified as a flaw limiting its attractiveness to fish (Stuart et al., 2007). The geography of the site further hinders the ability of fish to locate the fishway, with the main river channel (and thus the area of major flow during spillway flows) isolated from the fishway by a rocky ridge of raised bedrock.

Species including blue catfish, leathery grunter, bony bream and Hyrtl's tandan were found to migrate during periods of increased river flow (more than 32,000 ML/d) (Stuart *et al.,* 2007). More generally, high flows are believed to be an important environmental cue for fish movement in many freshwater species in northeast Australia (Stuart *et al.,* 2007). There are difficulties in attracting fish to the fishway at Eden Bann Weir during such high flow periods, when the majority of water flow is concentrated on the opposite (right) bank to the fishway. Stuart et al. (2007) suggested that a second fishway be constructed on the opposite bank, specifically to cater for fish passage during high flows. A vertical-slot fishway incorporating auxiliary attraction flow that would be operational through the upper half of tailwater elevation (when flows exceed 50,000 ML/d) may provide a suitable and cost-effective mechanism to facilitate the movement of larger fish (> 150 millimetres (mm)) during medium to high-flow periods.

A general recommendation for future fishway design is that spillway flows should be considered, such that these can contribute towards guiding fish towards fishway entrances. An assessment of various cycle times of the fish lock at Eden Bann Weir did not return conclusive results regarding which cycle duration was optimal for successful fish passage (Stuart et al., 2007). Stuart et al. (2007) suggested that an observed increase in migratory movements of blue catfish coincident with rising water temperatures may allow for increased cycle durations to be implemented during the cooler winter months when fish migratory biomass is lower.

Downstream passage of fish across Eden Bann Weir may be facilitated by incorporating a downstream mode into the Programmable Logic Controller system that controls the operation of the fish lock (Stuart et al., 2007). However, doing this would reduce the facilitation of upstream passage, as the lock cannot operate in an upstream and downstream mode concurrently. A second fish lock specifically built to allow downstream movement (particularly of catadromous species such as barramundi) was proposed by Stuart et al. (2007) to reconcile this issue.

Whilst site-specific issues relating to the location of the fishway at Eden Bann Weir were identified by Stuart et al. (2007), in general, their study found that the fish lock provides a suitable mechanism by which a wide array of species and fish size-classes can travel upstream beyond Eden Bann Weir during periods of low flow. Potential solutions to the issues of high-flow upstream movements, which is a key attribute of the life history of many native Australian freshwater fish, and downstream passage of catadromous species were provided in a comprehensive review by Stuart et al. (2007) of the Eden Bann Weir fish lock.

6. Weir design and construction

6.1 Preliminary design

6.1.1 Design parameters

Weir design for the Project has been undertaken to a concept/preliminary level informed by studies and concept designs undertaken by SunWater. Commencing in late 2008/2009, in parallel with environmental investigations and assessment, GHD was appointed to further progress the concept/preliminary design stages. This included:

- Aerial laser survey and aerial photography
- Hydrological and hydraulic investigations and modelling, including for flood conditions
- Yield modelling and associated development of Project stages
- Geotechnical reviews and investigations
- Concept/preliminary engineering design

The following Project performance criteria applied:

- The maximum fixed crest level will be set such that the afflux is 300 mm at both Eden Bann Weir and the proposed Rookwood Weir sites at bank full flow
- The maximum gate level was determined as less than bank full level and the level at which upstream impacts are acceptable in terms of acquisitions, crossings and environmental matters
- Environmental flow objectives are as per the Fitzroy WRP
- Fishways performance as per the design specification set by the Fishway Design Process undertaken in conjunction with the Queensland Fisheries (Section 8)
- Turtle passage requirements incorporated into weir design as per design specifications drafted in consultation with the Department of Environment and Heritage Protection (DEHP) as necessary and applicable.

Table 6-1 and Table 6-2 provide summaries of Eden Bann Weir raise and Rookwood Weir design data. Fishway design is detailed in Section 8.

Hydrological and hydraulic analysis undertaken to inform design is presented in Volume 3 Appendix P.

Table 6-1 Summary of Eden Bann Weir raise design data

Criteria	Stage 1 (existing)	Stage 2	Stage 3
Weir infrastructure			
Weir type	Conventional concrete weir with fixed crest and earth embankment at left abutment.	Conventional concrete weir raise with an un-gated concrete gravity ogee spillway section and earth abutment on left bank.	Addition of 18 flap gates (2 m high) with reinforced concrete piers such that development comprises a conventional concrete weir with 2 m high gated gravity spillway section and earth abutment on left bank. An example of a flap gate is provided in Figure 6-1.
Purpose	Water supply		
Catchment area	135,000 km^2		
FSL	RL 14.5 m AHD	RL 18.2 m AHD	RL 20.2 m AHD
Storage at FSL	35,980 ML	67,690 ML	91,450 ML
Yield (per stage) at FSL	Not applicable	35,000 ML/a	50,000 ML/a
Dead storage level	7.25 m		
Dead storage volume	9,650 ML		
Impoundment area at FSL	670 ha	1,170 ha	1,690 ha
Impoundment extent at FSL	184 km AMTD	205 km AMTD	211 km AMTD
Impoundment length (main channel) at FSL (approximate)	43 km	64 km	70 km
Total weir length	427 m	461.70 m	461.70 m
Fauna passage	Fish lock (left bank) The existing weir incorporates a fish lock on the left bank adjacent to the outlet works and a 1.5 m diameter outlet conduit. A diversion channel cut through a rock bar services the outlet works and fish lock	Fish lock (left bank) Fish lock (right bank) Turtle ramp (right bank)	Fish lock left bank) Fish lock (right bank) Turtle ramp (right bank)
Spillway section			
Type	Split level concrete un-gated spillway with a low section over 92 m (at 14.5 m AHD) adjacent to the left abutment and a high level section over the remaining 180 m (at 14.8 m AHD)	Spillway: un-gated concrete ogee spillway (Figure 6-1)	2 m high flap gates with concrete ogee spillway(Figure 6-3)

Criteria	Stage 1 (existing)	Stage 2	Stage 3
Crest level	RL 14.5 m	RL 18.2 m	RL 18.2 m
Crest length	The left abutment is perpendicular to the left bank for about 92 m and then the axis for the spillway and right abutment skews across the river perpendicular to the right bank	Primary spillway: 270 m (Figure 6-4)	
Downstream slope	0.8 H : 1.0 V		
Energy dissipation method	Not required as foundation rock is non-erodible and consists of large boulders and irregular rock outcrops which assist in energy dissipation	Not required given satisfactory performance of existing structure	
Design headwater level (bank full level)	Not applicable	RL 30 m	RL 30 m
Control description	Not applicable	Not applicable	2 m high crest gates with hydraulic controls
Height above riverbed	Approximately 5 m	Approximately 13 m	Approximately 15 m
Other		A crane/pedestrian access bridge over the crest of the weir for maintenance purposes	
Left abutment			
Crest level	RL 18.5 m	RL 26.2 m	
Crest width (non-spillway)	Varies	6 m	
Section type	Earthfill	Zoned earthfill	
Embankment downstream slope	2.5 H : 1.0 V		
Embankment slope protection	Rockfill / rip rap	Reinforced concrete and rip rap	
Right abutment			
Crest level	RL 18.5 m	RL 26.2 m	
Crest width (non-spillway)	4 m	6 m	
Section type	Mass concrete	Conventional concrete	
Embankment downstream slope	0.8 H : 1.0 V	0.8 H : 1.0 V	
Embankment slope protection	Not required	Not required	

Criteria	Stage 1 (existing)	Stage 2	Stage 3
Outlet works (Figure 6-5 and Figure 6-6)			
Provision for selective withdrawal	Manual selection of baulks	Outlet control gates with selective withdrawal capability and trash screens	
Low level outlet conduit	Inlet structure 1200 mm x 1200 mm	1,800 mm diameter inlet to a 1,400 mm outlet	
Low level outlet valve	Sluice gate to 1500 mm x 1500 mm box culvert	Vertical discharge regulating valve	
Low level outlet capacity	Adjacent to fish lock (left bank)	Discharge rate: 15 m^3/s (or a volume of 1,300 ML/day)	
Siting	Approximately 12 m in length	Adjacent to fish locks	
Environmental flow outlet size	Outlet capacity 5.5 m^3/s (maximum volume 500 ML/d)	3 bays of culverts (1.9 m x 2 m) with gated sluice	
Environmental flow outlet length	Concrete overflow stilling basin	Approximately 12 m	
Environmental flow outlet capacity		Discharge rate: 58 m^3/s (or a volume of 5,000 ML/day)	
Environmental flow outlet stilling basin type		USBR impact type basin	
Saddle dam	Not applicable	Not required	

Figure 6-1 Flap gate (example)

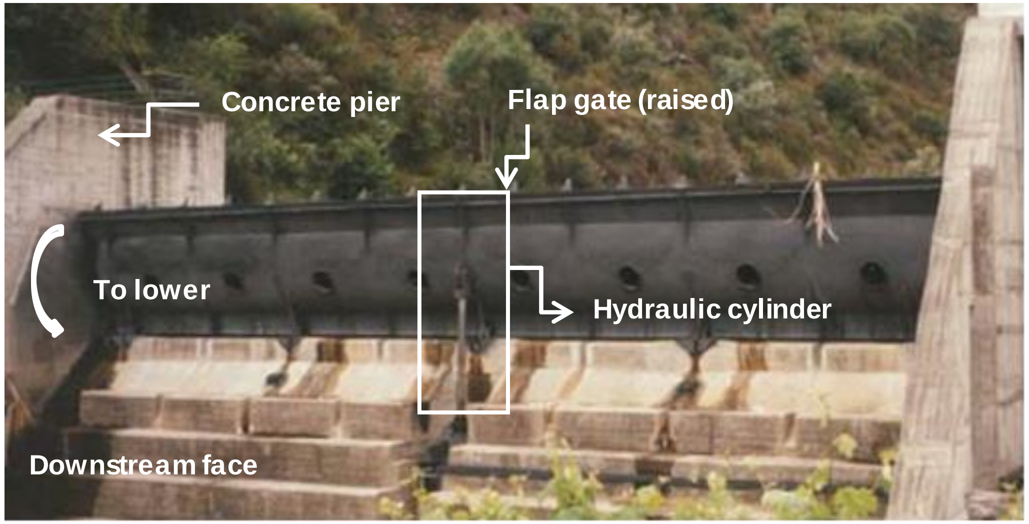


Figure 6-2 Eden Bann Weir Stage 2 ogee spillway section

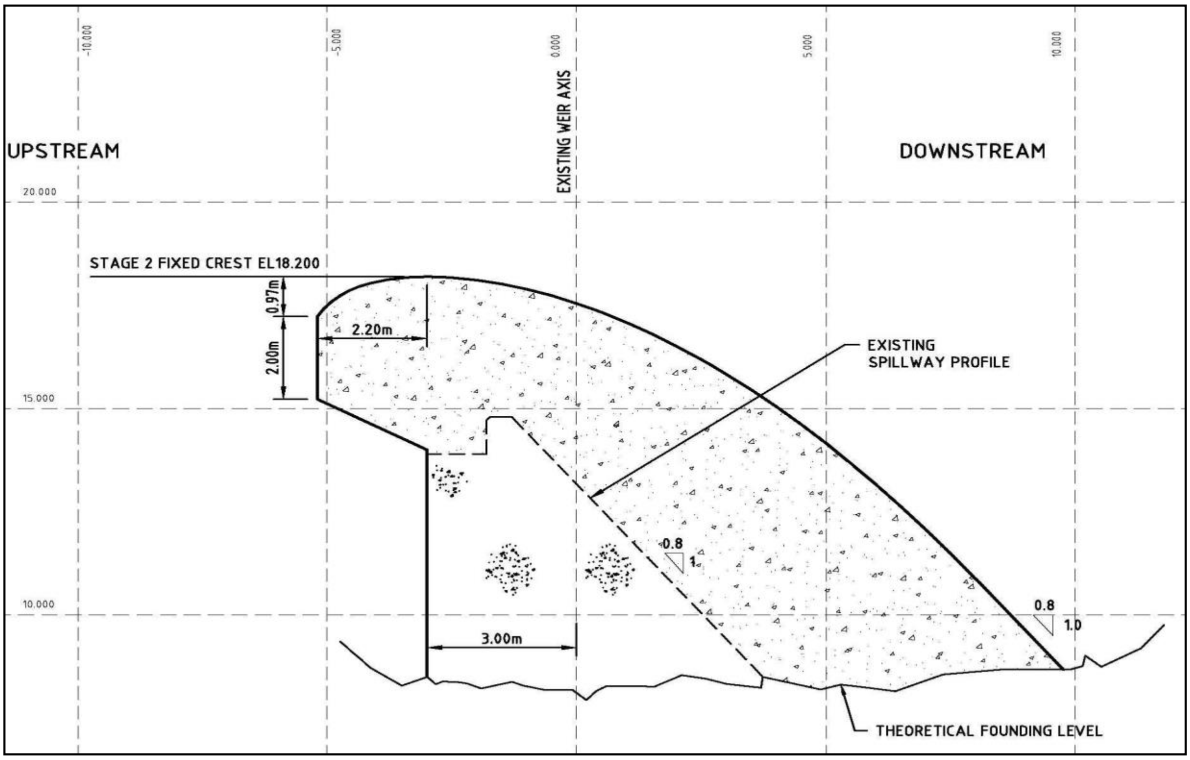
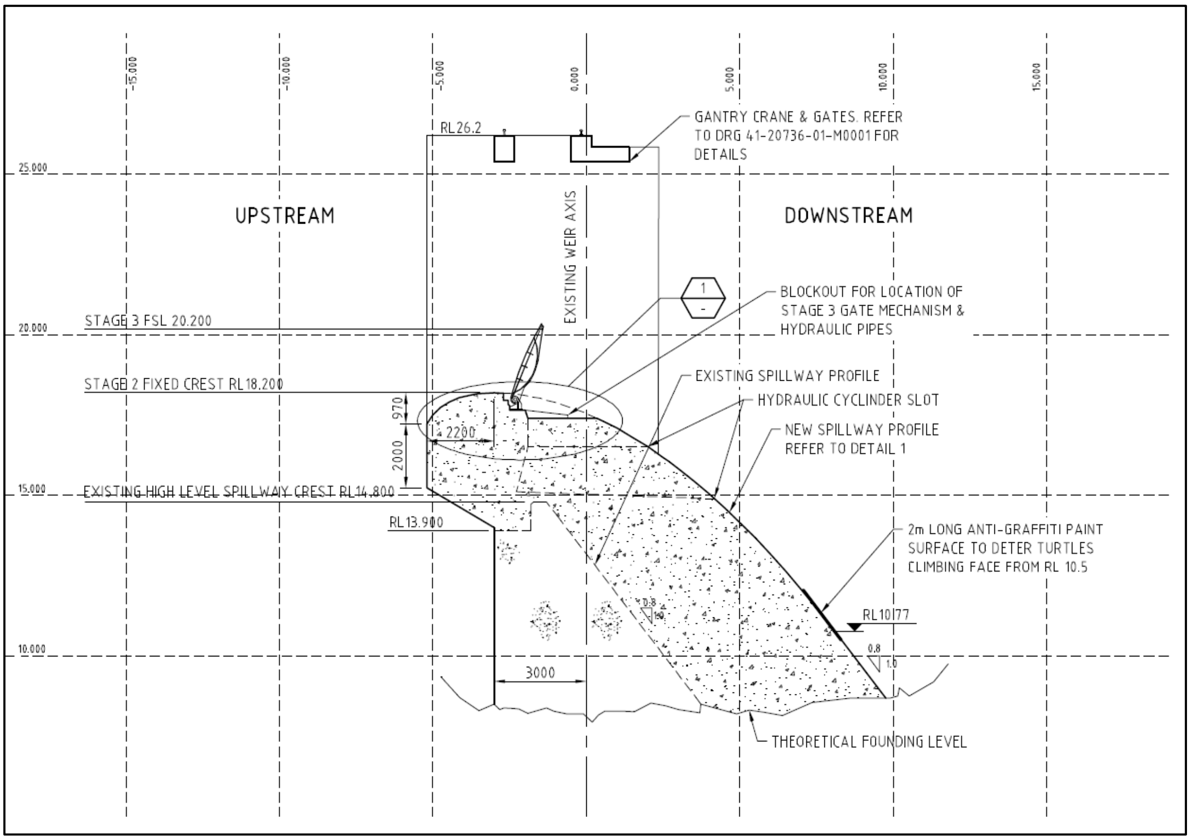
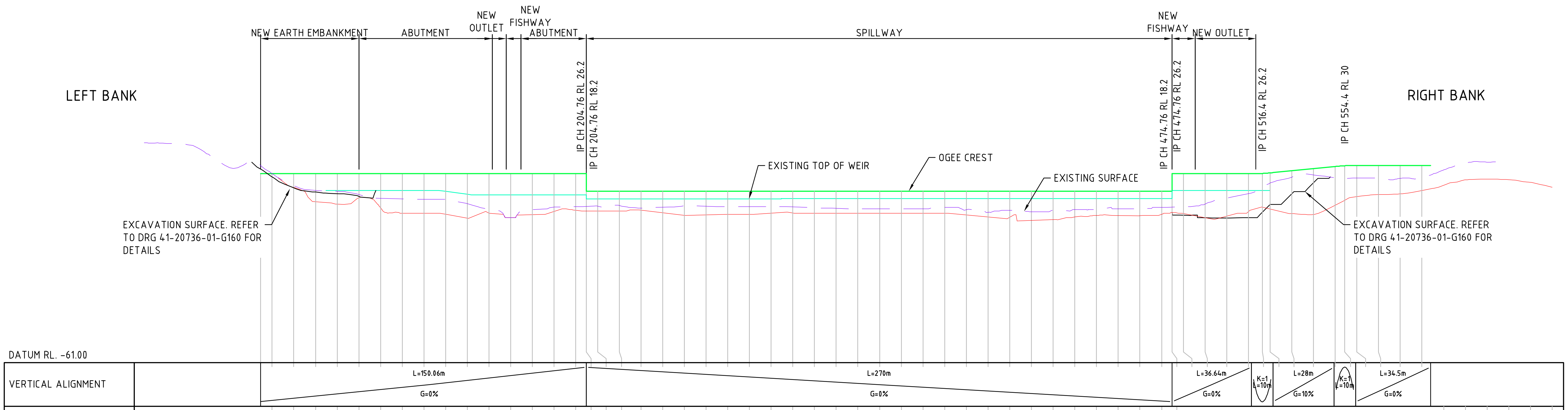


Figure 6-3 Eden Bann Weir Stage 3 ogee spillway section with flap gates





CHAINAGE	EXISTING WEIR LEVEL	THEORETICAL FOUNDING LEVEL	LEVEL DIFFERENCE CUT - / FILL +	DESIGN SURFACE LEVEL	EXISTING SURFACE LEVEL
0.00					40.38
10.00					40.25
20.00					39.75
30.00					35.40
40.00					29.23
50.00					31.50
60.00				26.200	26.25
70.00		19.85	5.62	26.200	20.72
80.00		13.25	7.62	26.200	18.58
90.00	18.50	12.20	8.20	26.200	18.06
100.00	18.50	15.10	9.59	26.200	16.61
110.00	18.50	10.48	11.39	26.200	14.81
120.00	18.50	8.00	11.69	26.200	14.51
130.00	18.50	8.00	11.77	26.200	14.43
140.00	18.07	7.54	11.75	26.200	14.45
150.00	16.74	5.66	13.81	26.200	12.39
160.00	16.50	7.95	16.36	26.200	9.84
170.00	16.50	6.00	20.20	26.200	6.00
180.00	16.50	7.30	16.62	26.200	9.58
190.00	16.50	8.81	15.32	26.200	10.88
200.00	16.50	9.36	15.11	26.200	11.09
204.76		9.00	15.11	26.200	11.09
210.00	14.50	9.00	6.94	18.200	11.26
220.00	14.50	9.00	6.66	18.200	11.54
230.00	14.50	9.47	7.31	18.200	10.89
240.00	14.50	8.27	7.32	18.200	10.88
250.00	14.50	7.06	6.69	18.200	11.51
260.00	14.50	7.23	6.99	18.200	11.21
270.00	14.50	7.42	7.20	18.200	11.00
280.00	14.50	7.51	7.20	18.200	11.00
290.00	14.50	8.07	7.20	18.200	11.00
300.00	14.80	8.10	7.31	18.200	10.89
310.00	14.80	8.00	7.69	18.200	10.51
320.00	14.80	8.00	7.97	18.200	10.23
330.00	14.80	8.00	8.20	18.200	10.00
340.00	14.80	8.00	8.20	18.200	10.00
350.00	14.80	8.00	8.20	18.200	10.00
360.00	14.80	8.00	8.20	18.200	10.00
370.00	14.80	8.00	7.59	18.200	10.61
380.00	14.80	7.23	8.61	18.200	9.59
390.00	14.80	6.32	9.81	18.200	8.39
400.00	14.80	6.11	8.81	18.200	9.39
410.00	14.80	4.68	9.46	18.200	8.74
420.00	14.80	5.02	8.88	18.200	9.32
430.00	14.80	6.29	8.59	18.200	9.61
440.00	14.80	7.00	8.12	18.200	10.08
450.00	14.80	6.98	8.20	18.200	10.00
460.00	14.80	6.86	8.47	18.200	9.73
470.00	14.80	7.50	7.60	18.200	10.60
474.76		8.37	7.42	18.200	10.78
480.00	18.50	7.87	15.20	26.200	11.00
490.00	18.50	5.94	14.05	26.200	12.15
500.00	18.50	6.59	11.24	26.200	14.96
510.00	18.50	8.72	9.19	26.200	17.01
516.40		10.76	6.42	26.325	19.90
520.00		9.92	4.67	26.570	21.90
530.00		7.82	3.04	27.560	24.52
540.00		7.43	2.93	28.560	25.63
550.00		11.64	5.20	29.558	24.36
554.40		13.88	5.77	29.875	24.10
560.00		15.65	5.81	30.000	24.19
570.00		16.54	5.86	30.000	24.14
580.00		16.90	5.95	30.000	24.05
590.00		18.38	5.58	30.000	24.42
600.00		20.91			27.92
610.00		23.35			31.12
620.00		23.70			31.51
630.00		23.45			31.48
640.00		22.18			29.31
650.00		19.99			28.68

LONGITUDINAL SECTION – WEIR

SCALE HORIZ 1:1000 VERT 1:1000

0 10 20 30 40 50m
SCALE 1:1000 AT ORIGINAL SIZE

NOTES:

1. WEIR AXIS IS OFFSET 3m FROM UPSTREAM FACE OF WEIR.
2. EXISTING WEIR CHAINAGES RUN IN OPPOSITE DIRECTION (FROM RIGHT TO LEFT BANK) WITH BEND AT CH 334.777.
3. GATES, PIERS & DECKS HAVE BEEN OMITTED FOR CLARITY.

Figure 6-4 Eden Bann Weir spillway longitudinal section including founding levels

Figure 6-5 Eden Bann Weir right bank outlets and fish lock design

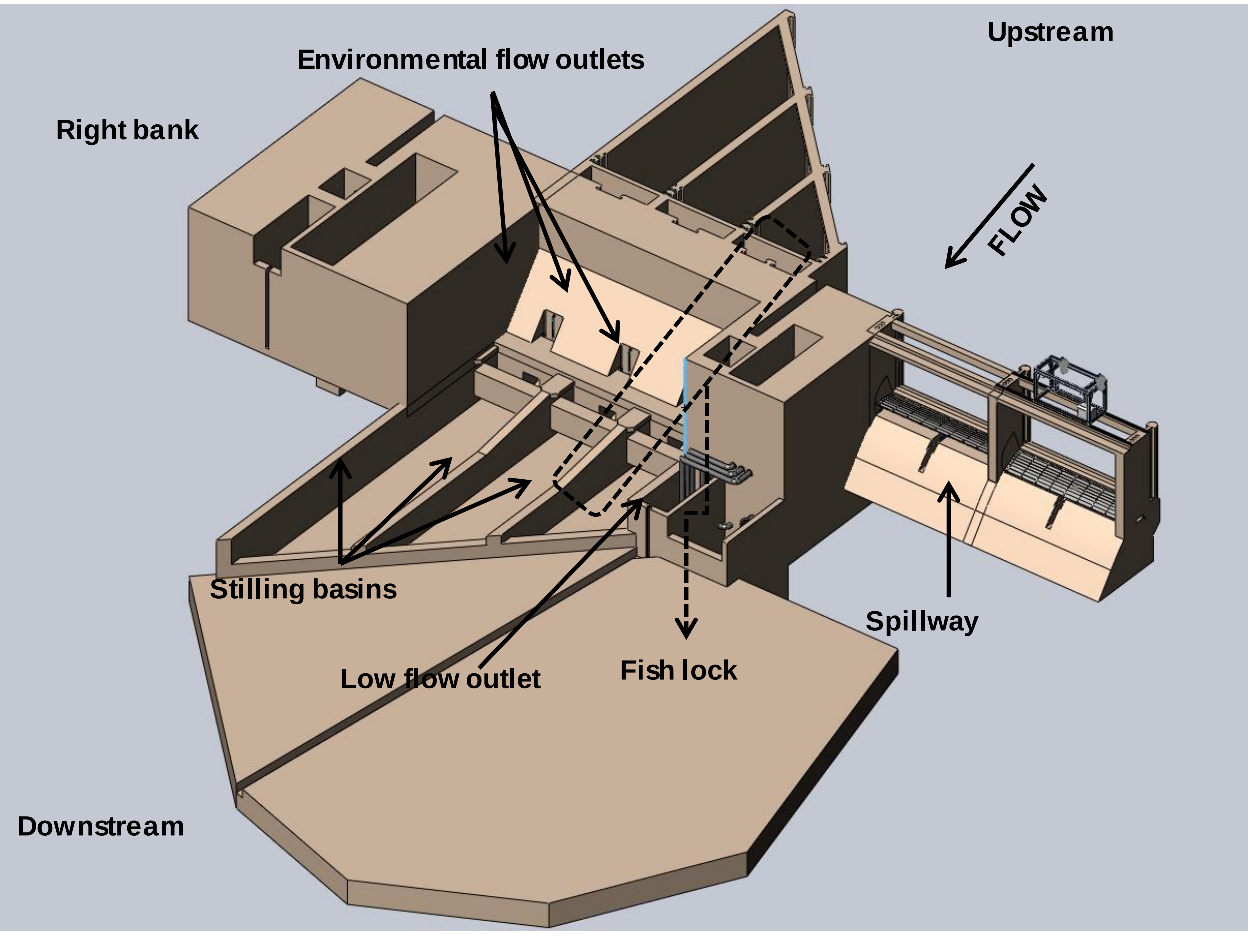


Figure 6-6 Section through Eden Bann Weir environmental flow outlets

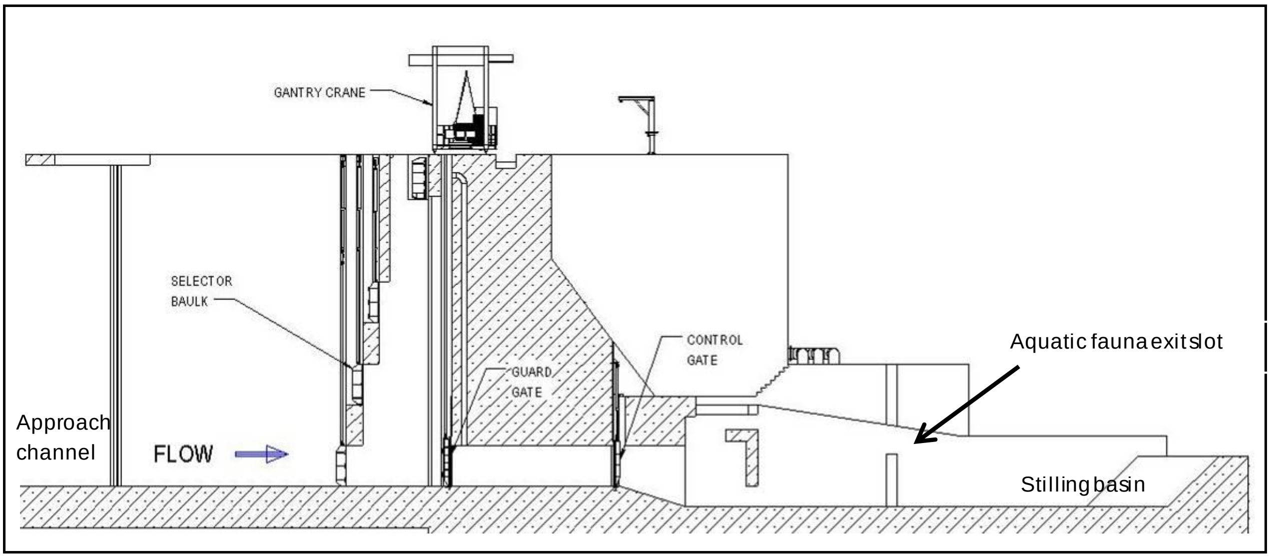


Table 6-2 Summary of Rookwood Weir design data

Criteria	Stage 1	Stage 2
Weir infrastructure		
Weir type	An uncontrolled gravity ogee weir constructed using roller compacted concrete and conventional concrete and earth embankment on the left abutment.	Addition of 14 flap gates (3.5 m high). An example of a flap gate is provided in Figure 6-1.
Purpose	Water supply	
Catchment area	135,000 km^2	
FSL	RL 45.5 m AHD	RL 49.0 m AHD
Storage at FSL	65,400 ML	117,290 ML
Yield at FSL	54,000 ML/a	86,000 ML/a
Dead storage level	RL 31.0 m	
Dead storage volume	2,640 ML	
Impoundment area at FSL	1,430 ha	1,930 ha
Impoundment extent at FSL	Mackenzie River: 322 km AMTD Dawson River: 10 km AMTD	Mackenzie River: 335 km AMTD Dawson River: 15 km AMTD
Impoundment length (main channel) at FSL (approximate)	61 km	84 km
Total weir length	460 m	
Fauna passage	Fish locks (right bank) Turtle ramp (right bank)	
Spillway section		
Type	Un-gated concrete ogee spillway (Figure 6-7)	3.5 m high crest gates with concrete ogee spillway (Figure 6-8)
Crest level	RL 45.5 m	RL 49.0 m
Crest length	209 m (Figure 6-9)	
Downstream slope	0.8 H: 1.0 V	
Energy dissipation method	Type 1 stilling basin	
Design headwater level (bank full level)	RL 56.7 m	
Control description	Not applicable	3.5 m high gates hydraulic controls
Height above riverbed	Approximately 14 m	Approximately 17.5 m
Other	A crane/pedestrian access bridge over the crest of the weir for maintenance purposes only	
Left abutment		
Crest level	RL 52.5 m	
Crest width (non-spillway)	6 m	
Section type	Roller compacted concrete	
Embankment downstream slope	0.8 H: 1.0 V	
Embankment slope protection	Wrap around embankment with roller compacted concrete face protection and rock filled mattresses	

Criteria	Stage 1	Stage 2
	downstream	
Right abutment		
Crest level	RL 52.5 m	
Crest width (non-spillway)	6 m	
Section type	Conventional concrete	
Embankment downstream slope	0.8 H : 1.0 V	
Embankment slope protection	Not required	
Outlet works (Figure 6-10 and Figure 6-11)		
Provision for selective withdrawal	Outlet control gates with selective withdrawal capability and trash screens	
Low level outlet conduit	1800 mm diameter inlet to a 1400 mm outlet	
Low level outlet valve	Vertical discharge regulating valve	
Low level outlet capacity	Discharge rate: 14.5 m^3/s (or a volume of 1250 ML/day)	
Siting	Adjacent to fish locks (right bank)	
Environmental flow outlet size	3 bays of culverts (1.5 m x 2 m)	
Environmental flow outlet length	Approximately 12 m	
Environmental flow outlet capacity	Discharge rate 58 m^3/s (or a maximum volume of 5,000 ML/d)	
Environmental flow outlet stilling basin type	USBR impact type basin	
Saddle dam	Earth embankment/reno mattress (6 m wide by 230 mm thick)	

Figure 6-7 Rookwood Weir Stage 1 ogee spillway section

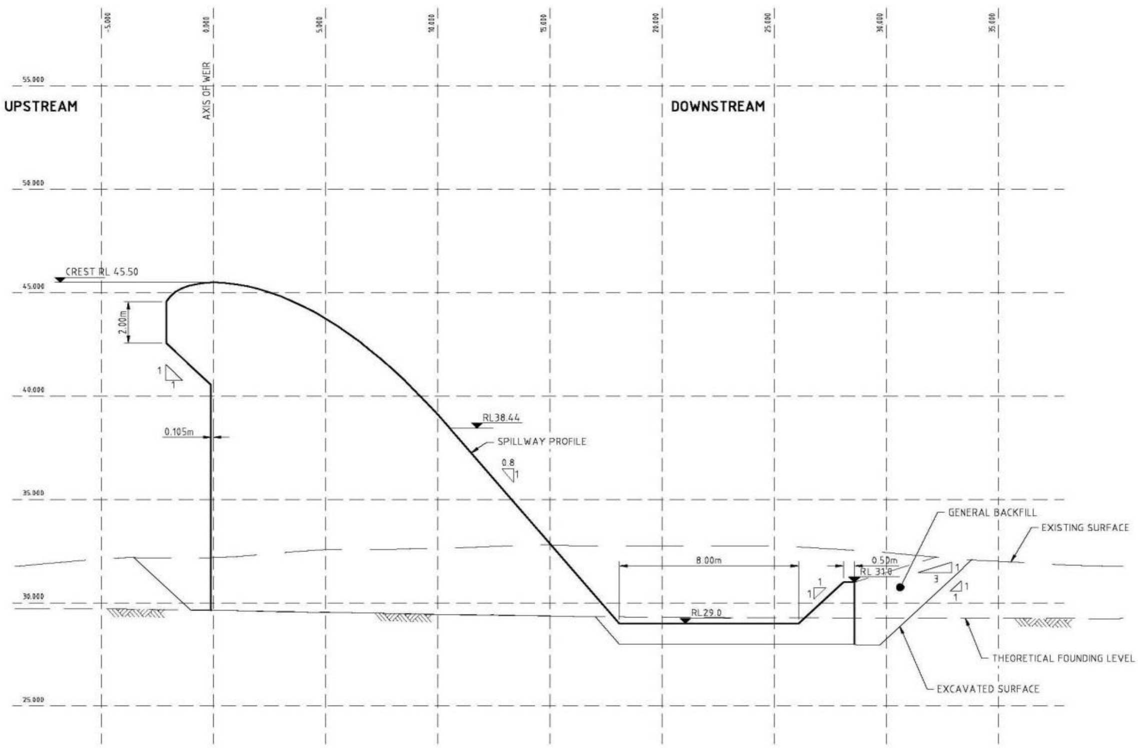
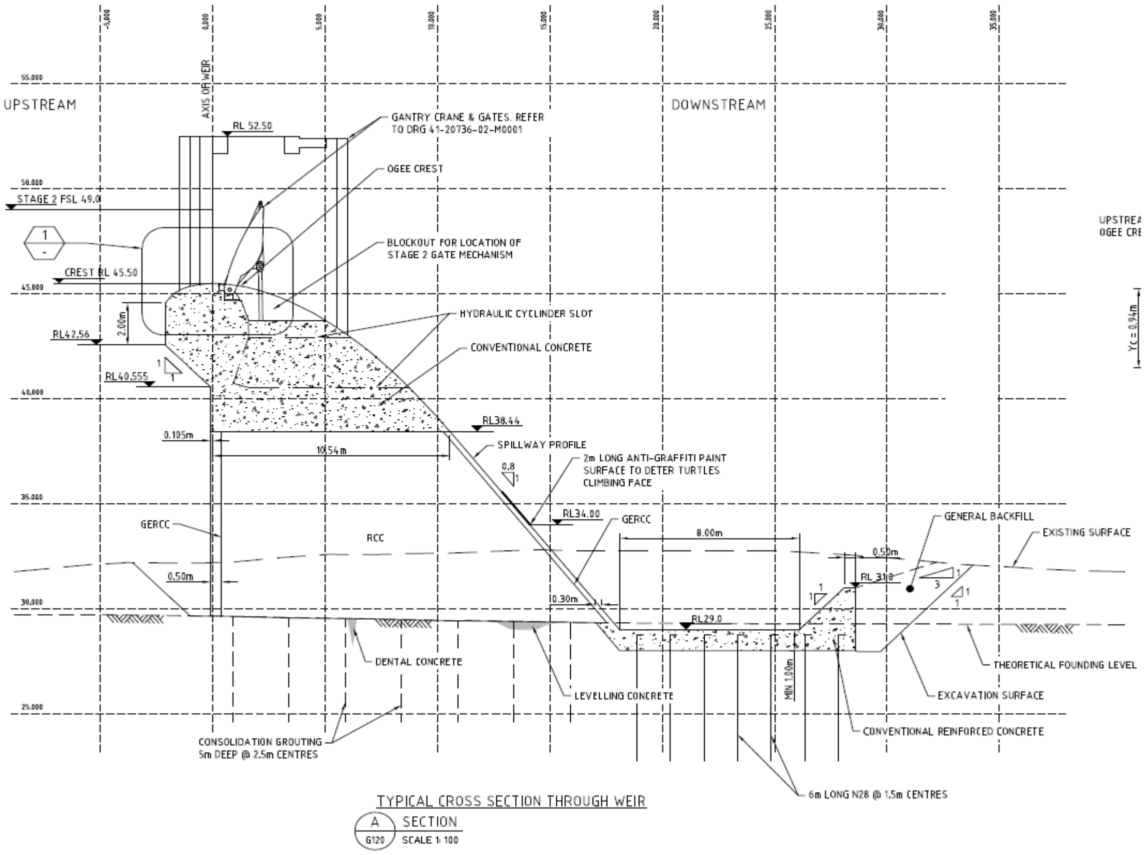
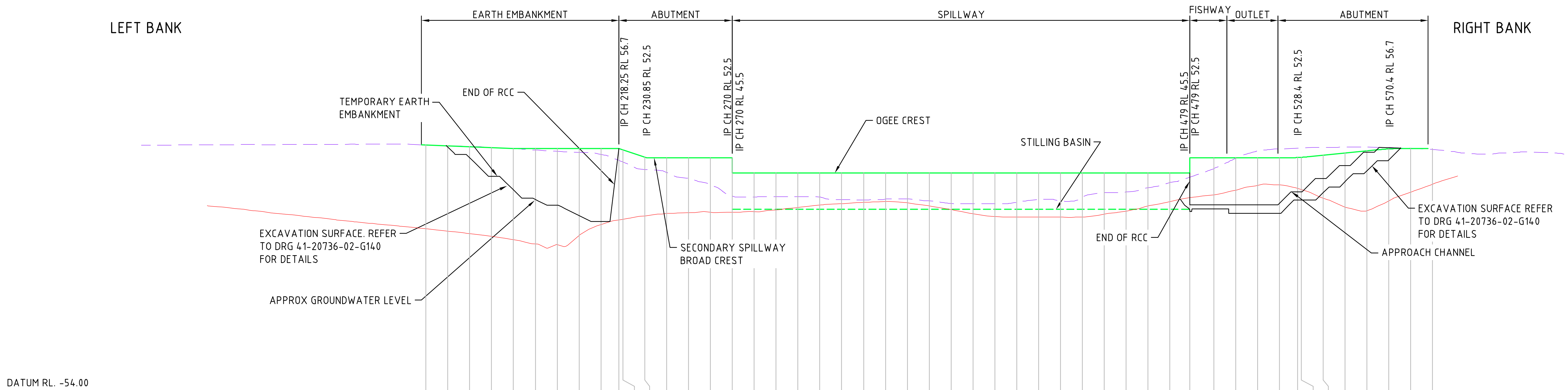


Figure 6-8 Rookwood Weir Stage 2 ogee spillway section





VERTICAL ALIGNMENT: L=42.0m; L=48.25m G=0%; L=12.6m G=-33.33%; L=39.15m G=0%; L=209m G=0%; L=44.4m G=0%; K=1 L=10m; L=32m G=10%; K=1 L=10m; L=12.6m G=0%

HORIZONTAL ALIGNMENT: L=650.00m 52°24'40"

CHAINAGE	EXISTING SURFACE LEVEL	DESIGN SURFACE LEVEL	LEVEL DIFFERENCE CUT - / FILL +	THEORETICAL FOUNDING LEVEL
0.00	58.27			
10.00	58.31			
20.00	58.37			
30.00	58.43			
40.00	58.48			29.72
50.00	58.55			28.51
60.00	58.51			27.27
70.00	58.54			26.29
80.00	58.58			25.20
90.00	58.63			24.05
100.00	58.68			23.01
110.00	58.75			22.07
120.00	58.73			21.09
130.00	58.39	58.390	0.00	20.06
140.00	58.03	58.030	0.00	19.00
150.00	57.69	57.690	0.00	17.82
160.00	57.22	57.220	0.00	16.59
170.00	56.73	56.730	0.00	15.01
180.00	56.05	56.700	0.65	13.15
190.00	55.42	56.700	1.28	12.89
200.00	54.99	56.700	1.71	17.03
210.00	54.09	56.700	2.61	21.96
218.25	51.27	56.700	5.43	24.11
220.00	50.57	56.117	5.55	24.40
230.00	47.12	52.783	5.66	25.96
240.00	45.84	52.500	6.66	27.18
250.00	43.07	52.500	9.43	27.39
260.00	40.30	52.500	12.20	27.57
270.00	35.00	52.500	17.50	27.65
280.00	34.50	45.500	11.00	27.86
290.00	34.75	45.500	10.75	28.63
300.00	34.75	45.500	10.75	29.84
310.00	34.54	45.500	10.96	30.91
320.00	33.34	45.500	12.16	31.53
330.00	33.27	45.500	12.23	32.17
340.00	33.58	45.500	11.92	32.59
350.00	33.75	45.500	11.75	31.96
360.00	32.88	45.500	12.62	30.54
370.00	31.64	45.500	13.86	28.82
380.00	31.50	45.500	14.00	26.93
390.00	31.50	45.500	14.00	25.66
400.00	32.18	45.500	13.32	25.35
410.00	33.50	45.500	12.00	25.47
420.00	32.72	45.500	12.78	25.39
430.00	34.61	45.500	10.89	25.44
440.00	36.57	45.500	8.93	26.73
450.00	36.88	45.500	8.62	28.03
460.00	38.80	45.500	6.70	30.48
470.00	41.17	45.500	4.33	32.50
479.00	43.62	45.500	1.88	34.24
490.00	47.53	52.500	4.97	35.61
500.00	52.23	52.500	0.27	37.65
510.00	55.64	52.500	-3.14	39.92
520.00	56.57	52.500	-4.07	40.22
528.40	56.93	52.625	-4.31	38.45
530.00	57.02	52.718	-4.30	37.95
540.00	57.25	53.660	-3.59	34.10
550.00	57.38	54.660	-2.72	29.90
560.00	57.41	55.660	-1.75	28.39
570.00	57.17	56.554	-0.62	32.83
580.00	56.84	56.700	-0.14	36.69
590.00	56.32	56.700	0.38	40.42
600.00	55.31			
610.00	54.29			
620.00	54.58			
630.00	55.13			
640.00	54.94			
650.00	54.27			

LONGITUDINAL SECTION - WEIR

HORZ 1:1000 VERT 1:1000

0 10 20 30 40 50m
SCALE 1:1000 AT ORIGINAL SIZE

NOTES

1. WEIR AXIS IS OFFSET 0.105m FROM UPSTREAM FACE OF WEIR.
2. GATES, PIERS & DECK HAVE BEEN OMITTED FOR CLARITY.

Figure 6-9 Rookwood Weir spillway longitudinal section inlcuding founding levels

Figure 6-10 Rookwood Weir right bank proposed outlets and fish lock design

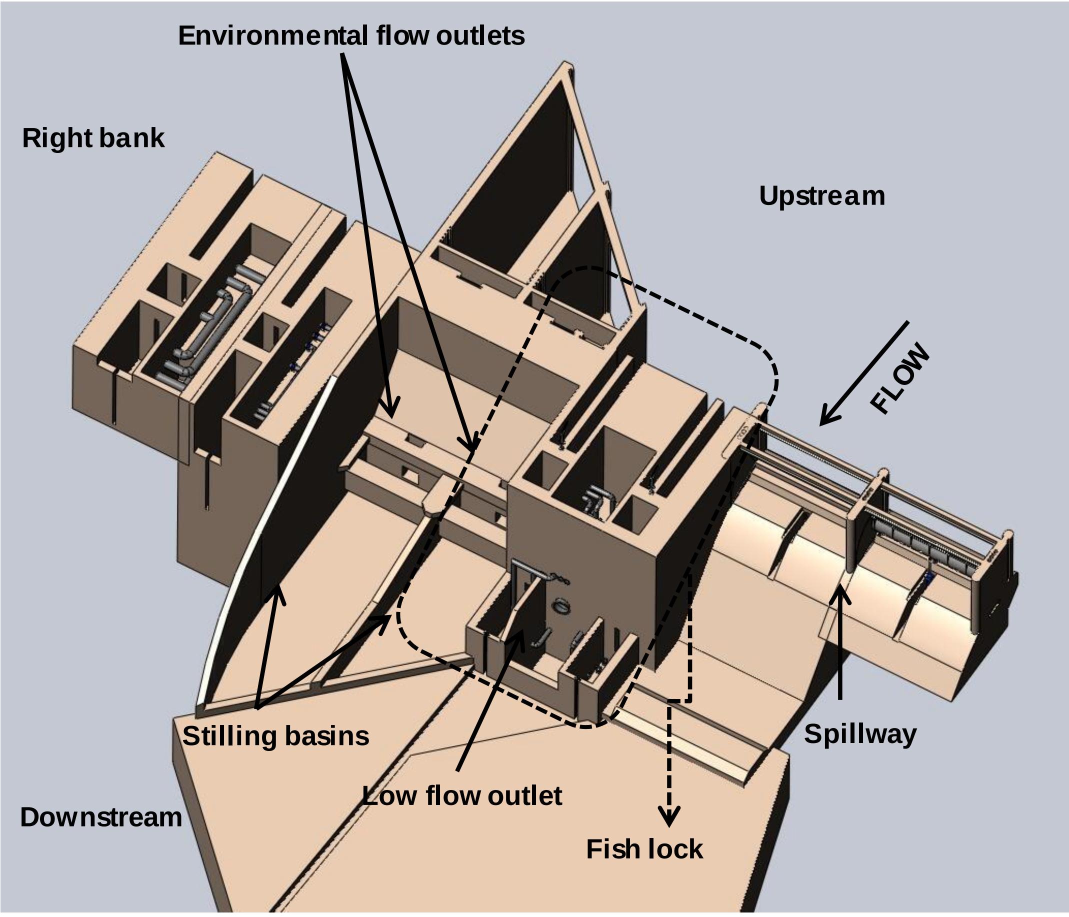
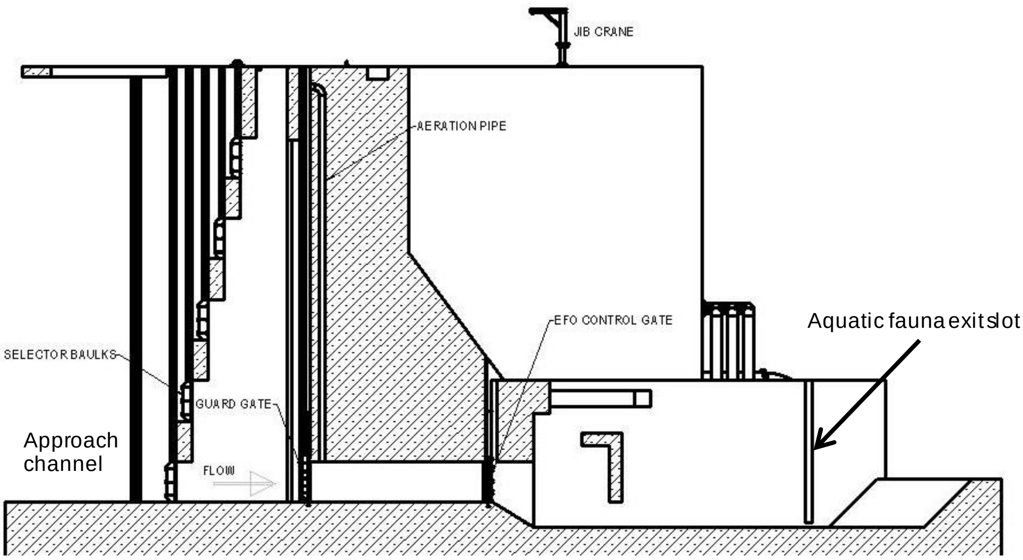


Figure 6-11 Section through Rookwood Weir environmental flow outlets



6.1.2 Environmental considerations

During operation, injury and mortality can occur when fish are swept over the spillway during periods of high flow, when they contact hard structures in the turbulence of downstream pools and when high velocity water is released during regulated flow discharges. Injury and mortality can also occur when species are trapped against trash screens or within fish transfer devices (Larinier 2000; Limpus et al. 2011a).

Fish species are particularly susceptible to shearing and abrasion injuries from contact with hard structures in the downstream pool and contact with the spillway during flooding events. Fish are also vulnerable to gill, eye and internal organ damage from the sudden changes in velocity and pressure that occur as the fish are swept over the spillway (Larinier 2000). Fish larvae are also known to suffer high levels of mortality (e.g. 95 per cent in golden perch) as a result of undershot gates (Baumgartner et al. 2006). The weir design for the Project has sought to minimise the risk of fish injury and mortality at Eden Bann Weir and Rookwood Weir. As shown in Figure 6-2, Figure 6-3, Figure 6-5, Figure 6-6, Figure 6-7, Figure 6-8, Figure 6-10 and Figure 6-11; the key design features responsible for high levels of fauna injury and mortality described above (stepped spillway, dissipater teeth, high turbulence, insufficient pool length and depth, high velocity trash screens) have been completely avoided in Project design thereby substantially reducing the risk of injury and mortality to fish and turtles.

Fishing practices can cause injury and mortality to aquatic fauna within impoundments from entrapment in traps, boat/propeller strikes and interaction with and ingestion of fishing hooks (Tucker 2000; Hamann et al. 2007; Limpus et al. 2011a). The Project will not promote or facilitate recreational activities and combined with the remote locations and limited access opportunities to each weir, impacts on aquatic fauna as a result are not expected.

The following measures would be implemented to avoid/minimise the risk of injury and mortality of aquatic fauna (in particular fish species) during operation:

- The structural components of the weirs and associated works are designed (concept/preliminary design level) to avoid/minimise risks of aquatic fauna injury and mortality. Specific design features of Eden Bann Weir and Rookwood Weir include:
  - A roller compacted concrete ogee spillway to provide a smooth formed surface finish at the crest of the weir in the spillway section
  - A smooth downstream face of the spillway section
  - Stilling basin (at Rookwood Weir) that extends the full length of the spillway to prevent fish being projected against hard concrete during spilling events. The current Eden Bann Weir spillway does not include a stilling basin as the foundation rock is non erodible and consists of very large boulders and irregular rock outcrop which assist in energy dissipation. Given the satisfactory performance of the existing structure over the last 15 years, no stilling basin is considered necessary for the raised structure.
  - Spillway gates have been designed such that, when they close, the shape mirrors that of the ogee crest. This limits fauna entrapment at the edge or under gates
  - Energy dissipater and stilling basin/plunge pool design minimises injury and mortality to fish and turtles

- The outlet works have been positioned adjacent to the fishway as they perform an important function in providing attraction flows at the downstream end of the fish locks
- Discharges from the outlets are sized to pass the flow in a manner suitable for fish attraction. A low level outlet has been incorporated in the design which discharges into a sump chamber located between the two low level fishlock entrance pits. A vertical discharge regulating valve was selected. This valve type discharges into a concrete chamber via a submerged vertical sleeve and multiple orifices. The submergence assists in energy dissipation. This type of valve can be used under a wide range of heads and can operate in a throttled condition.
- The inlet screens for the environmental flow outlets are designed to exclude fish from the outlets and to prevent fish being trapped by high water pressures on the upstream side of the outlet works. DEEDI (Queensland Fisheries) guidelines for this site require a maximum screen opening size of 20 mm and average water velocity through the screen of approximately 0.3 m/s. To allow for slightly higher water velocities, louver type screens are proposed. This type of screen relies on a sweeping velocity across the slats to discourage fish entering the screen. The screens proposed for the outlets are inclined at 45 degrees to the flow channel with the slats inclined at 60 degrees to the screen. This gives a total angle of 75 degrees to the flow. The angle of the screen has been arbitrary chosen at this stage and will be refined in the final design using CFD analysis or physical modelling. With the screen layout as at present, the following average flow velocities through the screen are expected:
  - Eden Bann Weir at FSL Stage 2 = 0.32 m/s
  - Eden Bann Weir at FSL Stage 3 = 0.28 m/s
  - Rookwood Weir at FSL Stage 1 = 0.20 m/s
  - Rookwood Weir at FSL Stage 2 = 0.17 m/s.
- Discussions with DAF (Queensland Fisheries) will be held during the detailed design phase to further refine the design features and identify any additional options for minimising the potential for injury and mortality.

The fishway exit screen comprises a trash screen. It is required to prevent large debris becoming lodged in the fishway channels. The screen openings are the same size as the downstream entrance to the holding chamber to allow any fish entering there to be able to exit the channel as well. The screens are installed and removed using a grapple and an auxiliary hoist on the gantry crane.

The screens and baulks fit into a stainless steel frame. The screens are also from stainless steel even though they can easily be removed. Using stainless steel screen will significantly reduce maintenance requirements with only periodic cleaning needed.

The fishway can be isolated from the reservoir by stacking baulks into the frame downstream of the screens allowing access for maintenance operations.

The exit channel gates are located in the fish lock chamber and used to release the fish into the exit chamber. These gates open downward as fish prefer not to swim under obstacles. The gates operate under balanced conditions and only far enough to induce an attraction flow and allow fish to swim over them out of the lock. In the closed position the gates are exposed to a maximum of FSL plus 0.5 m. During floods with higher levels than

FSL, all the low level locks have to be open to allow the tail water to balance the upstream level.

The exit channel gates components (sealing frame, gate and hydraulic cylinder) are manufactured from stainless steel as they will operate under submerged conditions. This will reduce maintenance requirements.

In some locations – particularly the high level fish locks – the gates are recessed into a shaft below the floor of the fish lock. This is required due to the gate height and short distance between the fish lock floor and fish lock exit. In most instances this shaft is below river bed level and cannot be drained by gravity. It is expected that the shaft will have a tendency to silt up under normal operating conditions and especially during floods. To minimise silting, the fish lock filling diffuser has been positioned at the bottom of the shaft to agitate the water and reduce the potential for silt settling out.

The shafts are generally 1.5 m across and the full width of the fish lock. This allows personnel to be lowered in with a cage and provides working space. Silt and smaller debris can also be removed using an airlift system.

No general maintenance of the exit channel gates is required. Should seals on the gates or actuators need replacement, the gate or actuator can be removed. The gate frame would not have to be removed.

The fish lock gates are located in the fish lock chamber and allow the fish to enter from the holding chamber. These gates open upward under balanced conditions. In the closed position the gates are exposed to a maximum of FSL plus 0.5 m. During floods with higher levels than FSL, all the low level fish lock gates have to be open to allow the tail water to balance the upstream level.

The fish lock gates are mounted in a sealing frame and components are manufactured from stainless steel as they will operate under submerged conditions thus reducing maintenance requirements.

No general maintenance of the fish lock gates is required. Should seals on the gates or actuators need replacement, the gate or actuator can be removed using a mobile crane and person cage or scaffolding. The gate frame would not have to be removed.

During construction the following management and mitigation is proposed:

- With reference to the environmental management plan (EMP) (Volume 1 Chapter 23) and species management programmes (as necessary and applicable); prior to any initial or new disturbance to aquatic habitat within the construction areas, all impact areas will be inspected by a fauna spotter/catcher for the presence of aquatic fauna. Pre-clearance surveys will be undertaken immediately prior to disturbance works. Aquatic fauna captured will be relocated and relevant measures implemented to exclude fauna access to active constructions areas (e.g. erection of exclusion fencing/netting, bund walls).
- A fauna spotter/catcher will be located on site during all works that have the potential to cause injury or mortality to aquatic fauna located in the area. The fauna spotter/catcher will identify, capture and relocate aquatic fauna and/or nests as required to avoid impact.
- If injury occurs, injured fauna will be immediately removed and taken to a qualified veterinary or wildlife carer for treatment or euthanized as appropriate. Suitable veterinarians and wildlife carers in nearby areas and Rockhampton will be identified

and commercial arrangements established to guarantee the financial costs of treatment and rehabilitation.

- All construction personnel will be informed of their environmental responsibility with respect to minimising the risk of fauna injury or mortality. Site inductions will include information on the identification of the Fitzroy River turtle, white-throated snapping turtle and estuarine crocodile, location of any confirmed nesting habitat areas within or adjacent to the construction areas and associated access tracks and relevant management actions.
- Resource extraction will not occur in Fitzroy River turtle important habitat areas (e.g. mapped essential habitat) or from historical, confirmed or high potential turtle nesting habitat.
- A Feral Animal Control Program will be developed and implemented. Management actions will be in accordance with the Project EMP (Volume 1 Chapter 23) may include culling, baiting and trapping of pigs, foxes, wild dogs and feral cats.

6.2 Construction methodology and work sequence

Raising Eden Bann Weir is scheduled to be constructed in four phases dictated by alternating wet (typically December to March) and dry (typically April to November) seasons over an approximate two-year period. Similarly, construction of a weir at Rookwood is scheduled to be constructed in four phases dictated by alternating wet and dry seasons over an approximate two-year period. Staging and development options may alter the sequencing but, in general, activities to be undertaken are summarised in Table 6-3 and

Table 6-4 for Eden Bann Weir and Rookwood Weir, respectively. Construction sequencing is illustrated in Figure 6-12 for Eden Bann Weir and Figure 6-13 for Rookwood Weir.

Normal daytime work hours for the Project's construction activities will generally be between 7.00 am and 6.00 pm. Construction activities will as far as practicable be restricted to daytime work hours. Limited evening and night-time works are proposed and night time haulage of materials and plant will be restricted.

Table 6-3 Eden Bann Weir construction methodology and work sequence

Phase	Description
Wet season 1	
Site establishment	• Development of site access and the site working areas (right bank followed by left bank) • Establish aggregate and concrete processing plants • Commence flap gate fabrication
Dry season 1	
Materials handling	• Aggregate extraction, processing and production (concrete batch plant operational) • Demobilise aggregate processing plant prior to the wet season
Right bank	• Complete right bank access road • Excavate right abutment and construct upstream cofferdam • Commence excavation and concrete works associated with the abutment raise, the fishway and the outlet works • Commence excavation of the intake and outlet channels and downstream coffer dam • Opportunistic placement of concrete to the downstream section of the outlet works

Phase	Description
	• In preparation for the wet season, the removal of the upstream and downstream cofferdams.
Spillway	• Establishment of an initial access road below the weir • Foundation preparation and preparation of the existing concrete spillway section. This work includes the installation of drill anchor holes and scabbling concrete for the spillway raise. Estimated foundation levels are presented in Figure 6-4 based on current geotechnical information • Commence construction of the spillway
Left bank	• Construction of the concrete works for the modified fishlock in outlet works block is complete along with the concrete works for the raising of the abutment • Installation of downstream coffer dam and upstream baffles (if required) to enable excavation, concrete cutting and demolition of sections in the existing concrete to form the opening for the modified fishway
Wet season 2	
	• Continue with right abutment concrete works to finished level • Continue with concrete placement on the left abutment • Commence installation and commissioning of mechanical and electrical equipment • Commence concrete construction for the intake structure
Dry season 2	
Right bank	• Complete concrete works to the downstream section of the outlet works • Complete concreting to the right abutment, fishway and outlet works • Installation of mechanical and electrical equipment • Commission fishway and outlet works
Spillway	• Reconstruction of the access road below the weir • Commence ogee crest concrete works • Construct piers for the installation of flap gates near the end of concrete placement
Left bank	• Complete excavation and construction of the earth embankment and backfill to the new spillway • Complete final concrete works to the left bank abutment • Mechanical and electrical equipment and commissioning of the modified fishway and outlet works • Complete the installation of trash racks and baulk system

Table 6-4 Rookwood construction methodology and work sequence

Phase	Description
Wet season 1	
Site establishment	• Development of site access and the site working areas (right bank followed by left bank) • Establish aggregate and concrete processing plants • Excavate the upper right abutment • Commence flap gate fabrication
Dry season 1	
Materials handling	• Aggregate extraction, processing and production (concrete batch plant operational) • Demobilise aggregate processing plant prior to the wet season

Phase	Description
Right bank	• Excavate for the right abutment • Construct the large cofferdam • Commence concrete works for the fishway and outlet works
Left bank	• Excavate for the left abutment • Construct the lower section of the left abutment monolith, backfilling, cut off wall left abutment, and the apron slab and training wall (no river diversion required)
Wet season 2	
	• Continue with concrete works on the right bank • Establish continuous concrete mixing plant
Dry season 2	
Right bank	• Continue with concrete works to fishway, outlet works and right abutment • Commence installation of mechanical and electrical equipment • Construct new transverse cofferdams upstream and downstream to allow access to riverbed in the existing channel • River diversion through the outlet works block-outs provides passage for low flows and fish and fauna passage
Spillway	• Prepare foundation (including stripping of loose rock and cleaning). Estimated foundation levels are presented in Figure 6-9 based on current geotechnical information • Concrete placement • Construct piers for the installation of flap gates near the end of concrete placement • River channel final closure (fishway commissioned)
Left bank	• Excavate, concrete and backfill the left abutment • Concrete placement • Backfill

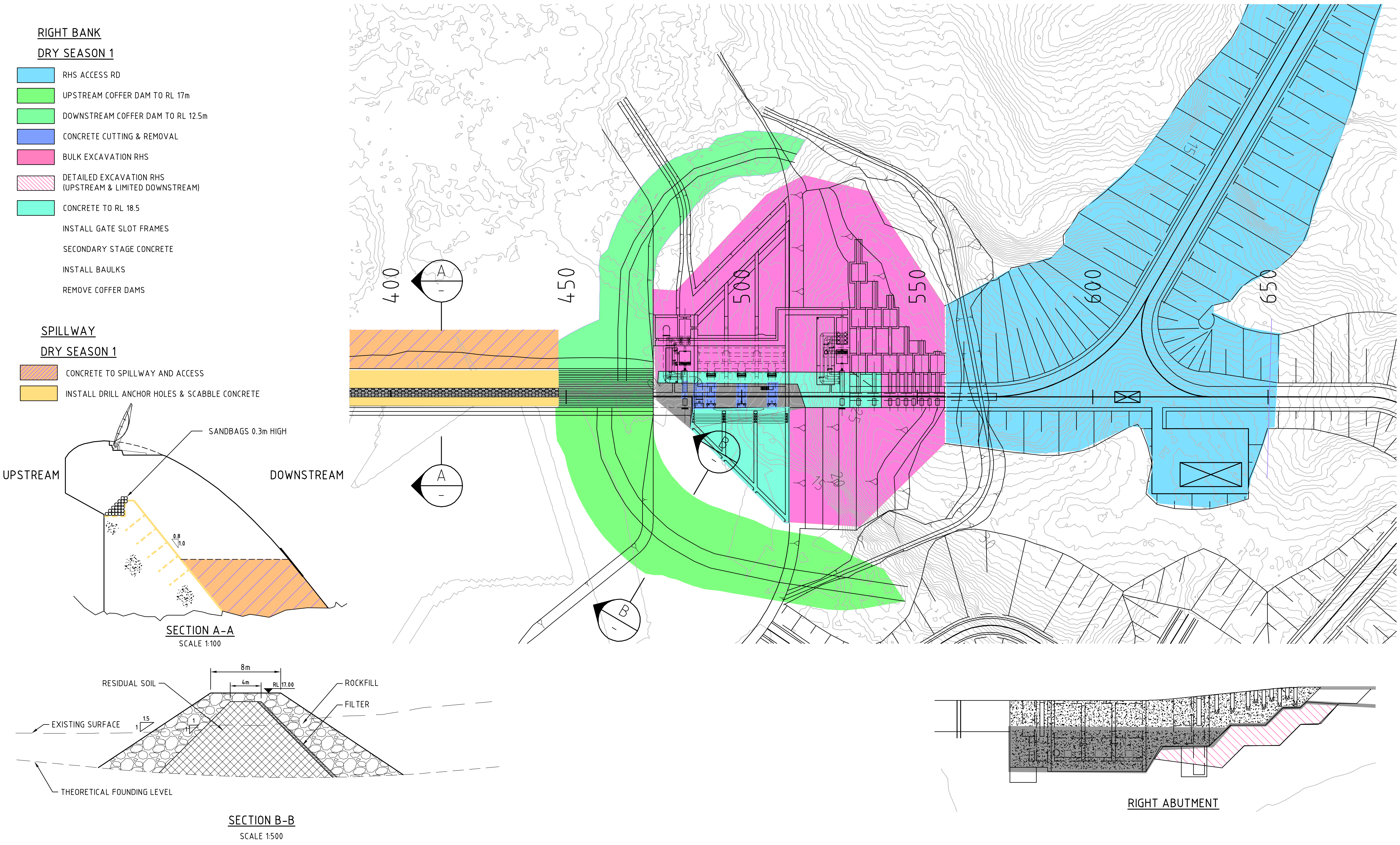
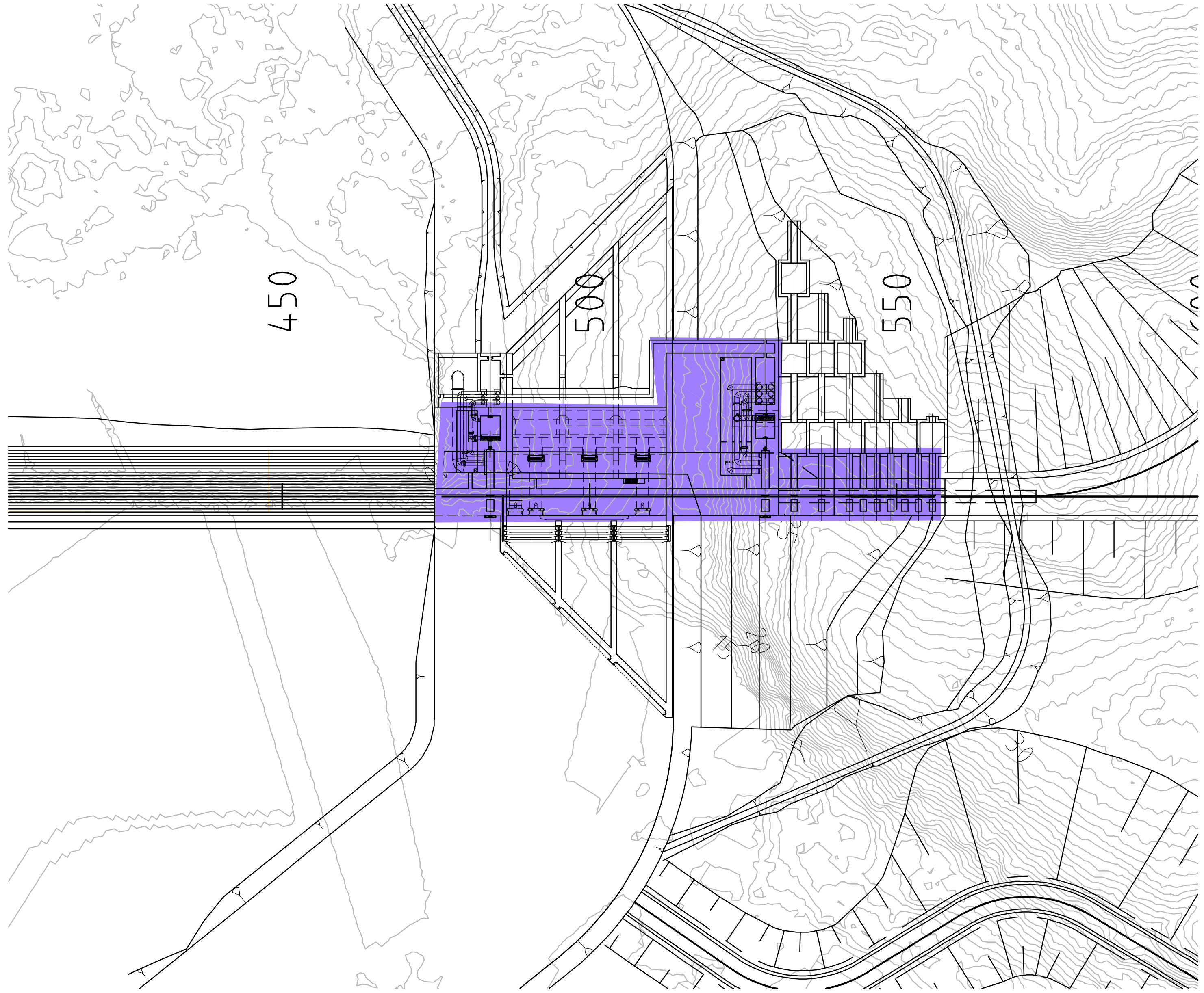


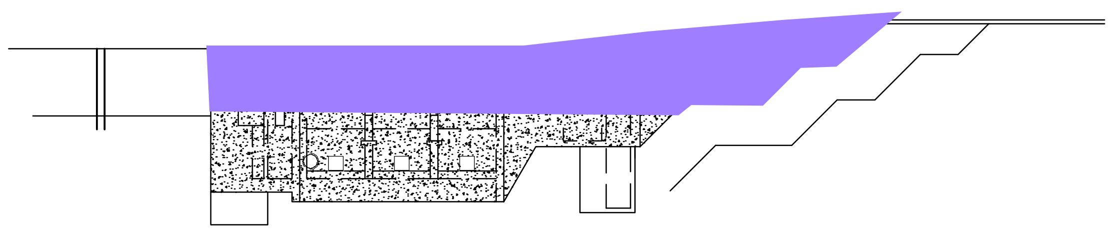
Figure 6-12 Eden Bann Weir construction sequencing (Sheet 1 of 4)

RIGHT BANK

WET SEASON 2

PROGRESS CONCRETE TO FINISHED LEVEL





RIGHT ABUTMENT

Figure 6-12 Eden Bann Weir construction sequencing (Sheet 2 of 4)

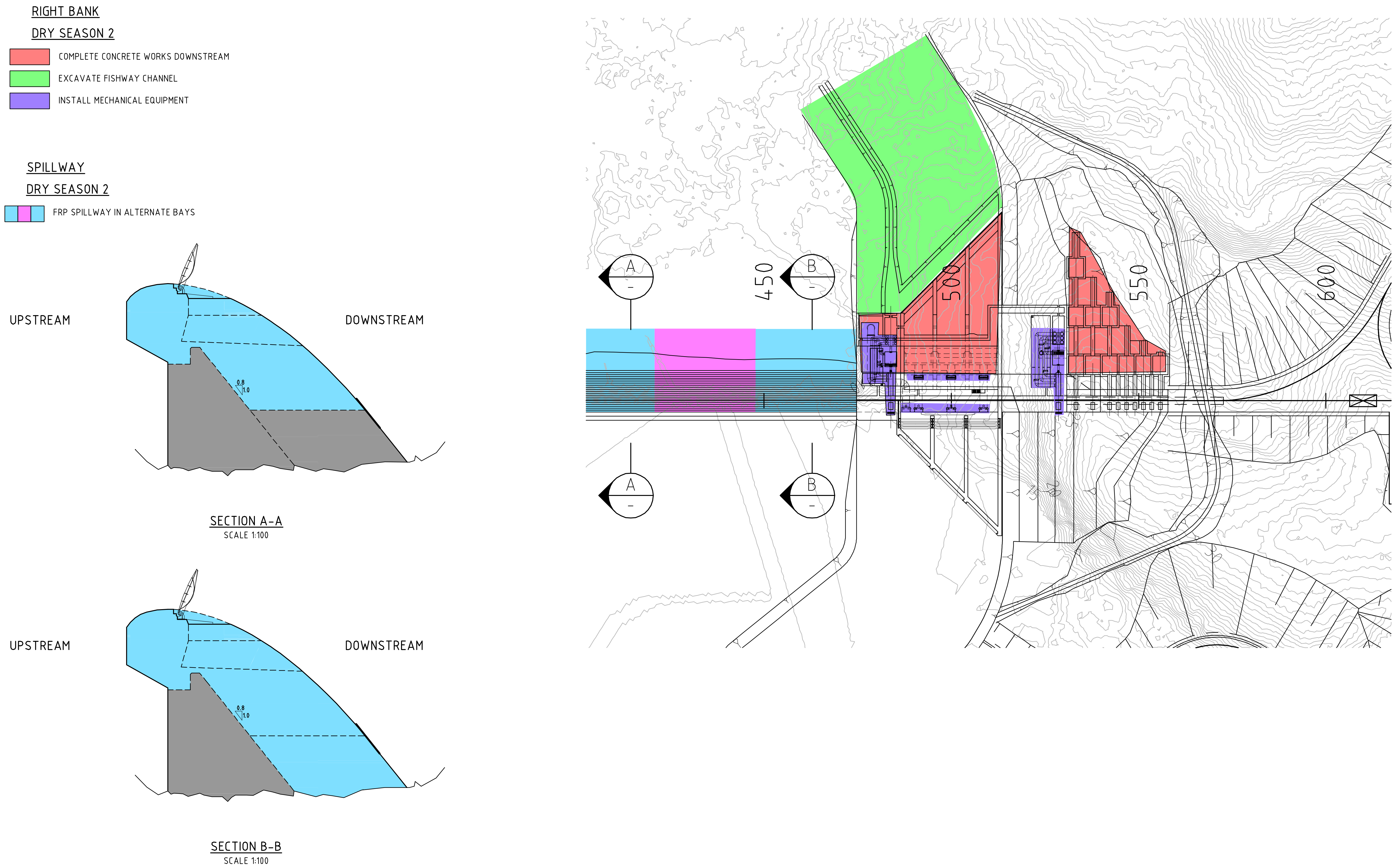


Figure 6-12 Eden Bann Weir construction sequencing (Sheet 3 of 4)

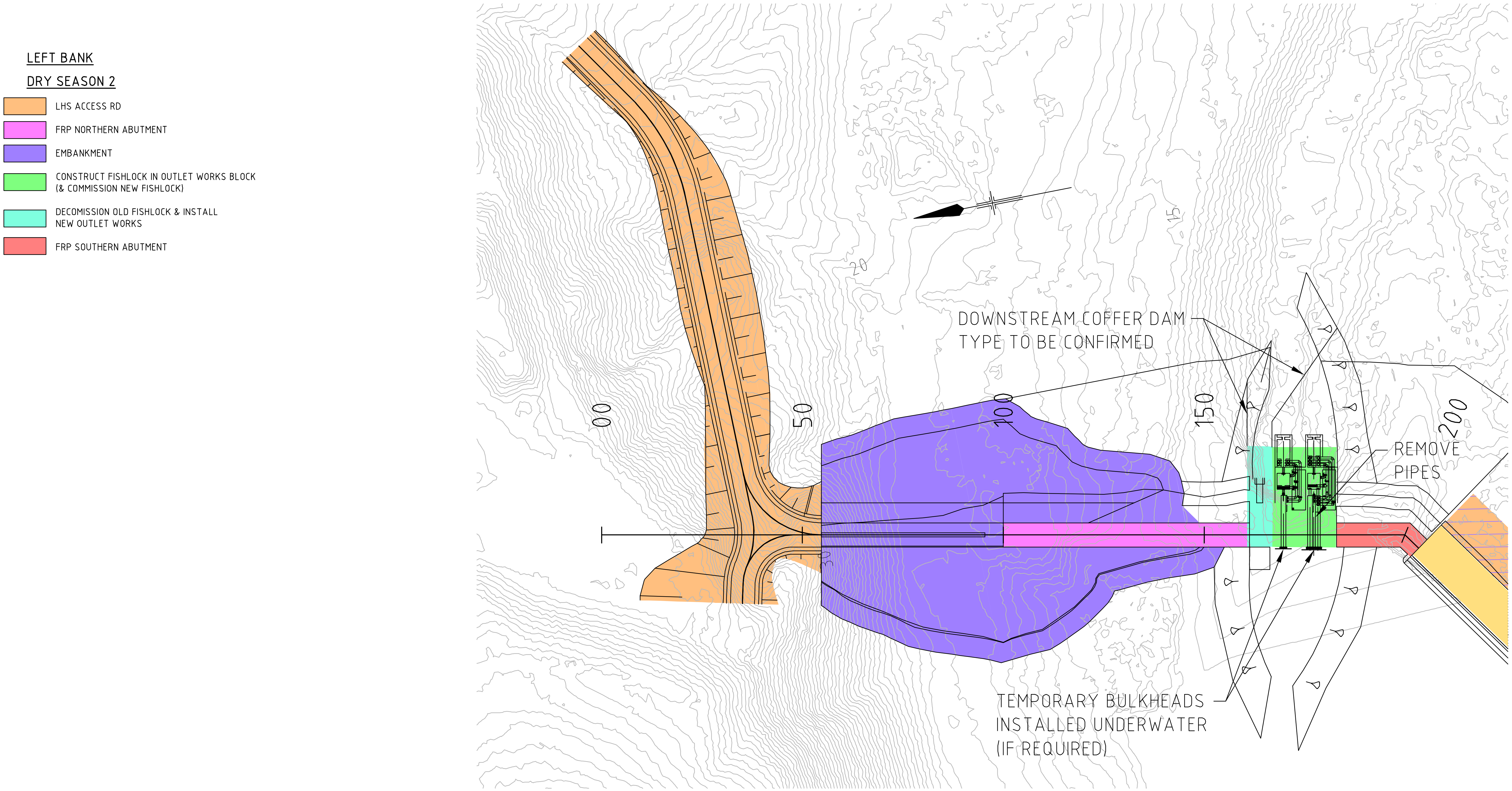


Figure 6-12 Eden Bann Weir construction sequencing (Sheet 4 of 4)

6.3 Diversion strategy

6.3.1 Eden Bann Weir

In accordance with Queensland Fisheries requirements to maintain fish movement upstream and downstream during construction, the following actions will be undertaken:

- The existing fish lock and outlet structure will remain operational until the second dry season
- During the second dry season, modification to the existing fishway structure will be provided with the fish passage through adjacent newly completed fishway or at least until the right bank fishway is operational
- When construction is complete or when the river channel is closed, the existing and new fish movement structures are fully operational.

Eden Bann Weir is an existing structure that has varying flood immunity for different work areas across its length. Work in the river channel downstream of the existing spillway will be limited to the depth of flow of water that can be channelled around areas so that work can continue. Work adjacent to the spillway needs to be protected by low height cofferdams. These will offer immunity to minor flooding events. Work to be carried out on both abutments can be carried out over longer periods as the abutments themselves offer a higher level of immunity to flooding. Through analysis of flood levels during the summer months, cofferdam levels have been estimated between 10 m and 17.5 m AHD in height to provide flood diversion capacities of between 300 m^3/s and 2,000 m^3/s.

River diversion sequencing is illustrated in Figure 6-12.

6.3.2 Rookwood Weir

In accordance with Queensland Fisheries requirements to maintain fish movement upstream and downstream during construction, the following actions will be undertaken:

- The river channel will remain open until the second dry season
- During the second dry season, a low level diversion though the completed base of the outlet works will be provided
- At weir closure the fish movement structure is operation

The diversion strategy adopted for Rookwood Weir is to limit river diversion to a single dry season with river diversion undertaken as follows:

- Low longitudinal cofferdams will be constructed to protect the works and secure the abutments with the river remaining in its natural course. High diversion capacities are achievable with relatively low cofferdams
- Longitudinal cofferdams between 1.5 m and 10 m high above the riverbed (to accommodate flood flows of between 90 m^3/s and 1,500 m^3/s, respectively) will be constructed across the river to allow for dewatering and excavation of the weir abutment foundations. Note that the river remains in its natural course at this time
- River flows will be diverted through the partly completed outlet structure (up to 90 m/s) which will be open to fish passage. Larger floods must pass over the partly completed roller compacted concrete embankment. Temporary works will either be removed prior to flooding or designed to withstand the predetermined flow event.

River diversion sequencing is illustrated in Figure 6-13.

7. Weir operation

For the purposes of the EIS, and to achieve Project objectives of capturing and storing all unallocated but available water, development of both the Eden Bann Weir raises and Rookwood Weir construction has been assumed. The Project will operate in concert with the existing Eden Bann Weir and Fitzroy Barrage.

On this basis, the overall storage and release strategy is proposed to operate as follows, subject to the Fitzroy WRP and subsequent Fitzroy ROP provisions:

- Nominal full supply levels will be maintained at Eden Bann Weir and the Fitzroy Barrage through releases from Rookwood Weir.
- Once the Rookwood Weir storage is emptied, nominal full supply would be maintained at the Fitzroy Barrage through releases from Eden Bann Weir.
- Once the storages at Rookwood Weir and Eden Bann Weir have been emptied, drawdown at the Fitzroy Barrage will occur.

These releases will allow the fishway at the Fitzroy Barrage to be maintained and, in addition, continue usage as a recreational area.

During operations, releases from Eden Bann Weir and Rookwood Weir can made as follows:

- Up to 15 m^3/s or a volume of up to 1,300 ML/day can be released through the low flow outlet at Eden Bann Weir. The outlet works also serve to provide attraction flows to fish at the downstream end of the fish locks
- Low flows through the outlet works at Rookwood Weir will have a capacity to discharge at a rate of 14.5 m^3/s. Releases for the required environmental flow base flow of 15 m^3/s will be supplemented through the fish locks (various release volumes and velocities). Preference will be given to releases through the fish lock over releases via the low flow outlet as far as is practicable. The outlet works also serve to provide attraction flows to fish at the downstream end of the fish locks.
- Up to 58 m^3/s or a volume of 5,000 ML/day can be released through the environmental flow outlets to satisfy environmental flow objectives when either weir is full. Environmental flow releases will be made in accordance with the Fitzroy WRP and ROP
- Over the spillway during flood events.

The environmental flow releases as defined in the Fitzroy WRP are based on maintaining a minimum water depth in the river. All environmental flow releases are tested using the Integrated Quantity and Quality Model to confirm compliance with the Fitzroy WRP and ROP.

8. Fishway design

8.1 Fish lock arrangements

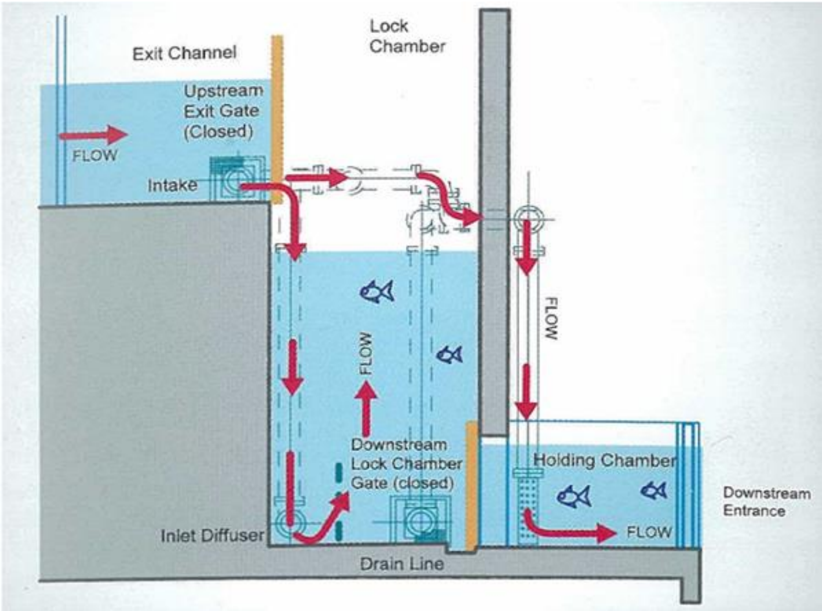
Fish passage infrastructure has been designed to preliminary level as follows:

- Eden Bann Weir fish passage infrastructure:
  - An upgraded fish lock on the left bank
  - A new fish lock located on the right bank for high and low reservoir levels to cater for flows from about 500 m^3/s to 2700 m^3/s. This provides for normal operating conditions as well as low spillway flow conditions at the weir.
- Rookwood Weir fish passage infrastructure:
  - A right bank fish lock to cover low and high reservoir levels to cater for flows from a minimum operating level up to 500 m^3/s.

The fish lock arrangement for a raised Eden Bann Weir and a new Rookwood Weir was based on existing fish lock arrangements at the existing Eden Bann Weir on the Fitzroy River and Claude Wharton Weir on the Burnett River. These arrangements have a record of successful operation for the range of flows they are designed to operate in. The Claude Wharton Weir fish lock was used as a base example as this is one of the most recent SunWater fish lock installations and incorporated a good combination of simplicity of operation of gates and other weir components with sufficient complexity to promote fish movement.

A typical fish lock arrangement is illustrated in Figure 8-1. It comprises an entry or holding chamber on the downstream side; a lock chamber and an upstream exit channel. At the downstream entrance, a gate lifts vertically upward to open the lock chamber and allows fish to enter. Upstream the gate drops vertically downwards to open and allow access to the exit channel. Associated valves and pipework between the entrance and exit allow water to flow into the holding chamber which acts as attraction flow, fills the lock chamber and drains from the lock to the downstream holding chamber.

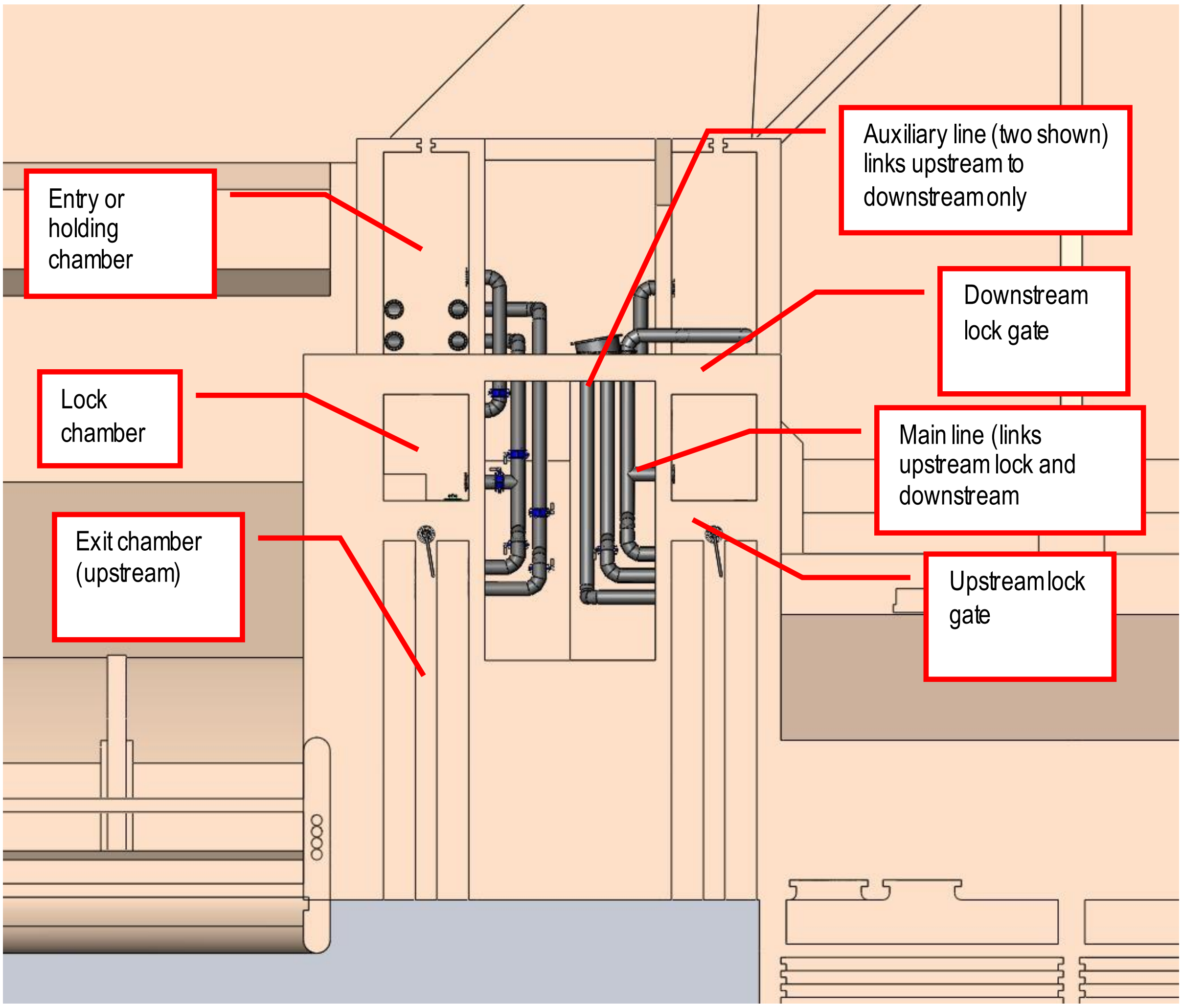
Figure 8-1 Typical fish lock arrangement



(Source: SunWater, Undated, Bowen River Weir Fishway brochure)

The fishway operation is a complex one, with valves and gates operating in stages as discussed. The velocities prescribed by fish biologists for ideal fish migration are around 0.3 m/s minimum velocity in the exit chamber and 1.8 m/s design velocity at the entry slot (at the downstream toe). The pipe arrangements must be able to provide velocities of this order, to allow throttling back of flow, with the valves provided to establish the necessary flow conditions. This will allow the peak velocities to be reduced to accommodate burst versus sustained fish swimming speeds. Note that the final arrangement will be model tested (CFD and/or physical model studies) during detailed design to confirm acceptable hydraulic performance. Figure 8-2 provides a schematic of normal operational lock pipe arrangements as proposed for Eden Bann Weir and Rookwood Weir.

Figure 8-2 Schematic of normal operation fish lock pipe arrangements



Fish lock arrangements and operations are described further in Section 8.2 and Section 8.3 for Eden Bann Weir and Rookwood Weir, respectively.

For both Eden Bann Weir and Rookwood Weir, all equipment on the weir will be controlled by hydraulics from the control room on the embankments. No electrical equipment will be used on the weir except where they are temporary and can be removed prior to flooding.

Four separate power packs will be used, two for the crest gates, one for the environmental flow outlets and low flow outlet and one for the fishways. Each power pack will have two identically sized pumps, one as duty and the other as standby.

A supervisory control and data acquisition (SCADA) system is proposed to be used. The system will facilitate the monitoring, controlling and alarming of the weirs from a central location, and is likely to be at Rockhampton from where SunWater currently operates the existing Eden Bann Weir.

Grid power will be used as the primary power source, with a standby generator as backup

The proposed infrastructure has been designed to reduce maintenance requirements and to allow adequate access for maintenance activities such as periodic cleaning and clearing of screens, hydraulic repairs, seal adjustment and/or replacement and corrosion repair of flap gates.

No general maintenance of the fish lock gates is expected to be required. Should seals on the gates or actuators need replacement, the gate or actuator would have to be removed using a mobile crane. Dismantling the gate or actuator would be undertaken from a person cage or scaffolding. The gate frame would not have to be removed.

8.2 Eden Bann Weir

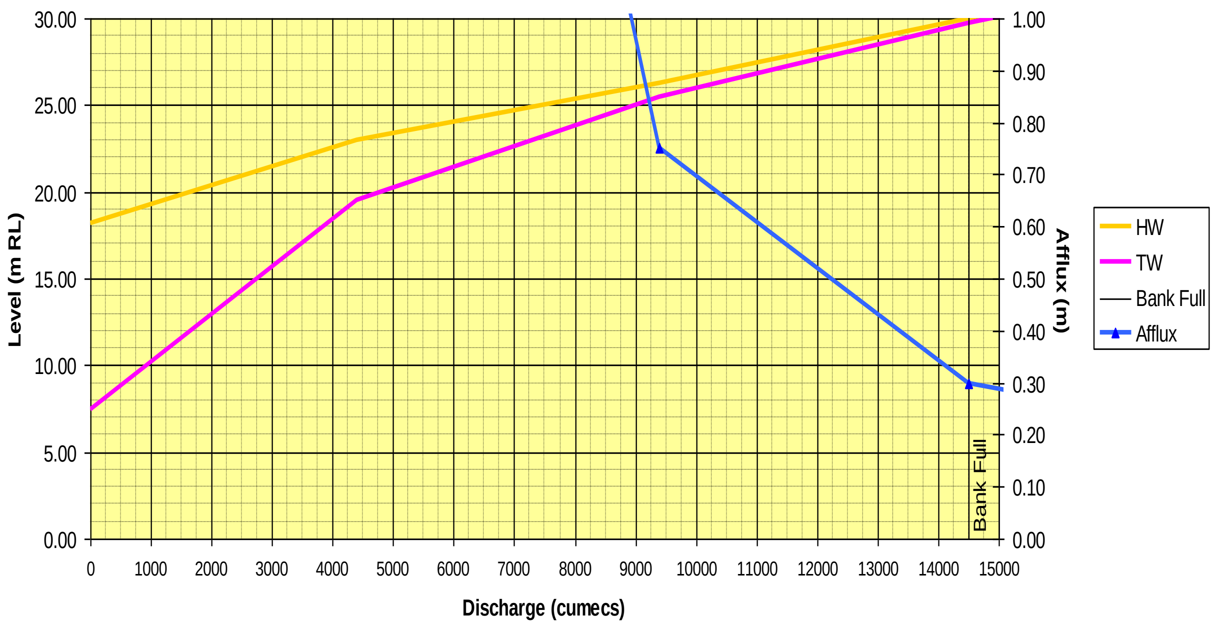
8.2.1 Hydrology and hydraulic considerations

Hydraulic modelling undertaken for the proposed Eden Bann Weir raise was used to define peak water levels at the weir pre- and post-development. In turn the estimated afflux generated for various annual exceedence probabilities (AEPs) was determined (Volume 3 Appendix P).

For Eden Bann Weir there is a negligible increase in peak water levels with the raised weir compared to the existing weir for the 1 in 50 and 1 in 100 AEP events as both weir arrangements are drowned by the flood flows for those design events. By a distance of 23 km upstream of the existing weir, the peak water level difference with the raised weir reduces to around 300 mm for the 1 in 10 AEP event. For the 1 in 2 and 1 in 5 AEP events, the peak water level difference reduces to around 300 mm at approximately 50 km upstream.

The headwater/tailwater curve developed for the proposed Eden Bann Weir raise and as adopted for the fishway design process is shown in Figure 8-3.

Figure 8-3 Eden Bann Weir rating curve adopted for fishway design



An analysis of the flow data (simulated from IQQM) was undertaken to establish the flow regime at Eden Bann Weir. That is, for each season, the flow data was analysed for mean flow, median flow and maximum flow as follows:

- Spring
  - Mean -12.13 m^3
  - Median - 2.06 m^3
  - Maximum – 1,262.12 m^3
- Summer
  - Mean – 327.44 m^3
  - Median – 18.65 m^3
  - Maximum – 20,600.19 m^3
- Autumn
  - Mean – 112.46 m^3
  - Median – 8.27 m^3
  - Maximum – 9,765.14 m^3
- Winter
  - Mean – 36.40 m^3
  - Median – 3.78 m^3
  - Maximum – 4,344.62 m^3

This analysis allowed a comparison between the general flow characteristics of the season and the flow range that the proposed mitigation covers. Table 8-1 details the per cent of the seasonal flow range that is covered by the proposed fish lock relative to the existing situation. . Table 8-1 shows that the proposed mitigation at Eden Bann Weir will improve the flow range covered by the existing Eden Bann Weir fish lock arrangement and improve fish passage.

Table 8-1 Seasonal flow range covered by the provision of fish locks

Season	Eden Bann Weir		Rookwood Weir	
	Seasonal flow range covered (%)			
	Pre-mitigation	Post-mitigation	Pre-mitigation	Post-mitigation
Spring	99.8	100	0	99.8
Summer	88.8	96.6	0	89.4
Autumn	95.8	99.0	0	95.8
Winter	98.3	99.9	0	98.4

8.2.2 Fish lock arrangement

Flood flow analysis has indicated that the river exceeds 500 m^3/s in flow between one and three times per year (a total of 117 times over a 95 year history). This occurrence is less than the life cycle of fish (average one to five years) and coupled with the known fish migration on flows greater than 500 m^3/s, it is considered important in the movement of fish for spawning. Sixteen fish species have been recorded migrating on flows between 500 m^3/s and 1,600 m^3/s. Four fish species, including the endemic leathery grunter, have been recorded moving on flows of 2,265 m^3/s. (Pers com, Queensland Fisheries, Fishway Design Team Workshops).

A new fish lock located on the right bank at Eden Bann Weir for low reservoir levels will cater for flows between 500 m^3/s and 2,700 m^3/s. This provides for normal operating conditions as well as low spillway flow conditions at the weir. A modified left bank lock will provide passage for flows up to 500 m^3/s.

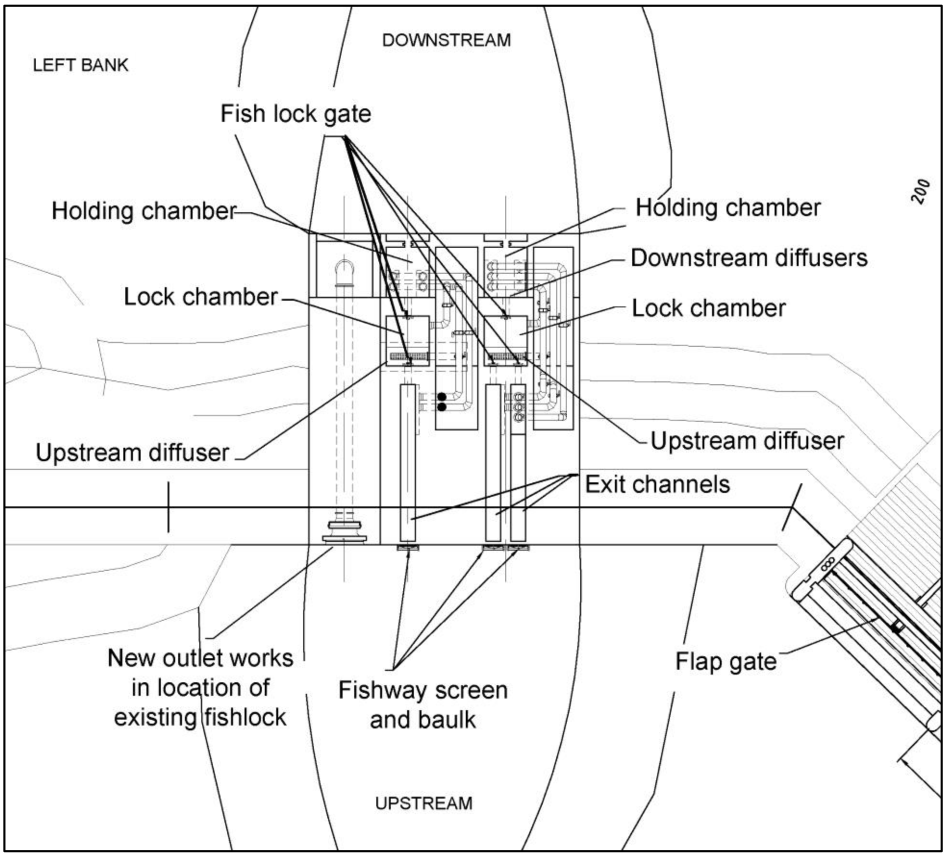
The fish lock arrangement for Eden Bann Weir comprises a modification to the existing fish lock on the left bank and the construction of a new fish lock on the right bank as shown in Figure 8-4.

The lock arrangement proposed is considered suitable for the purpose of fish passage at Eden Bann Weir as:

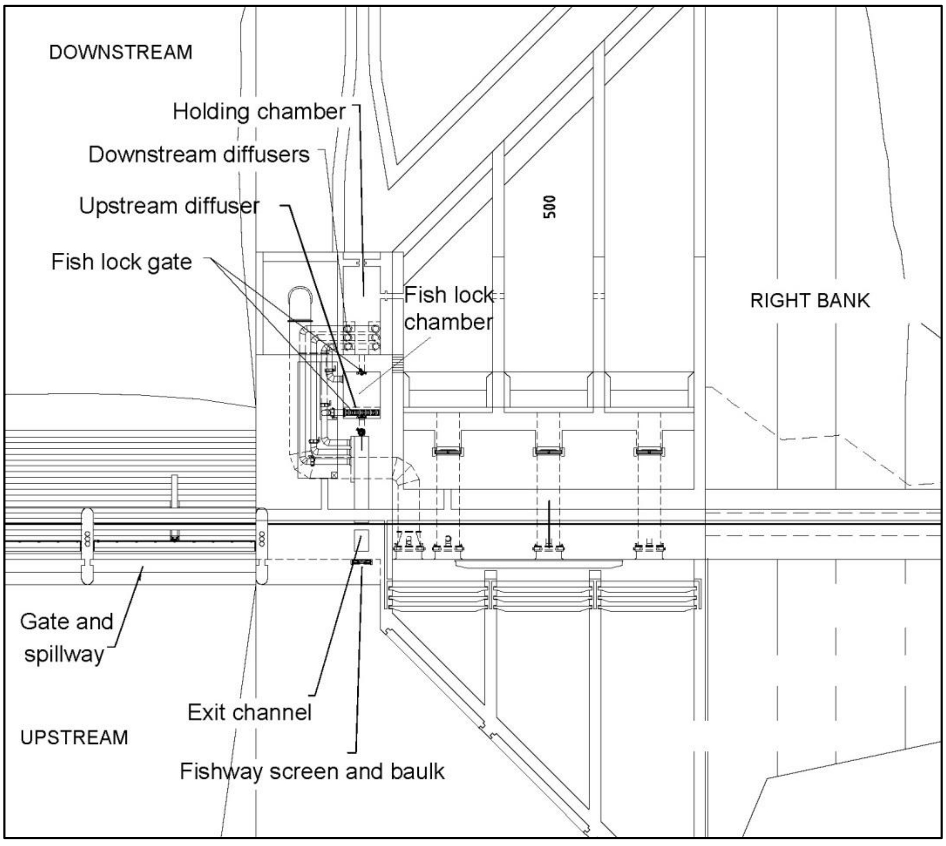
- The lock is in a configuration known to work (although physical model studies are required to assist with refinement of entry / exit conditions and sedimentation management).
- The addition of a right bank fish lock will improve on current passage efficiency above spilling flows (Table 8-1). Currently fish are attracted to the right bank spillway section of the weir, and as there is no passage become stranded as tailwater levels drop.
- The lock would provide passage for 87 out of 123 flood events as well as ongoing ‘normal flows’.
- It reduces average wait days per occurrence from 11 to seven. This is particularly important as it is possible that some species may wait up to seven days for passage
- The lock arrangement is capable of providing continuous attraction flows when the fishway is operating and allows for variable attraction flows between phases of the cycle. Attraction flow velocities can be varied between: 0.15 m/s and 1.8 m/s.
- It caters for small and large-bodied fish.
- It provides upstream and downstream passage.
- It can be shut down in large floods to maximize operation following flood.

Figure 8-4 Eden Bann Weir fishway and outlet works plans

Left bank



Right bank



8.3 Rookwood Weir

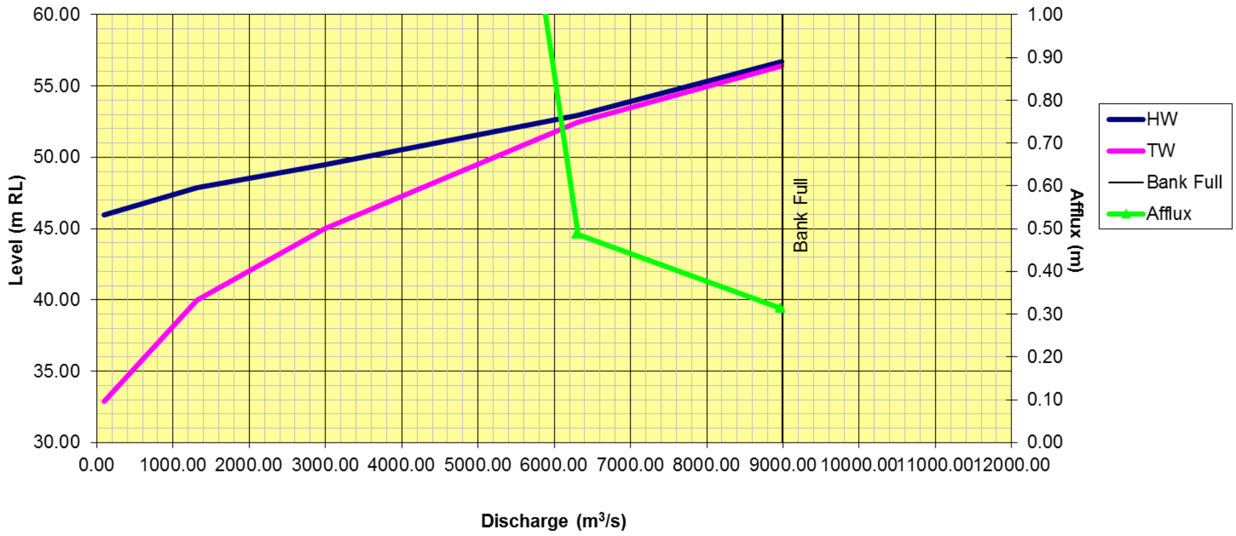
8.3.1 Hydrology and hydraulic considerations

Hydraulic modelling undertaken for the proposed Rookwood Weir was used to define peak water levels at the proposed Rookwood Weir pre- and post-development. In turn the estimated afflux generated for various annual exceedence probabilities (AEPs) was determined (Volume 3 Appendix P).

The results indicate that the peak tailwater level for a 1 in 2 AEP flood event almost inundates the fixed crest level, and the 1 in 5 AEP peak tailwater level exceeds the fixed crest by about 3 m. As the AEPs decrease, the afflux generated by the weir decreases. It appears that the weir is significantly drowned during a 1 in 20 AEP event, such that the estimated afflux at the weir is around 0.3 m and is less than 0.1 m at the upstream end of the Fitzroy River (at the junction of the Mackenzie and Dawson rivers). A review of the stage hydrographs suggests flow across the weir is expected for at least 20 days per annual exceedence probability.

The headwater/tailwater curve developed for the proposed Rookwood Weir and as adopted for the fishway design process is shown in Figure 8-5.

Figure 8-5 Rookwood Weir rating curve adopted for fishway design



An analysis of the flow data (simulated from IQQM) was undertaken to establish the flow regime at Rookwood Weir. That is, for each season, the flow data was analysed for mean flow, median flow and maximum flow as follows:

- Spring
  - Mean – 14.28 m^3
  - Median – 10.25 m^3
  - Maximum - 1250.18 m^3
- Summer
  - Mean – 14.28 m^3
  - Median – 10.25 m^3
  - Maximum – 1,250.18 m^3
- Autumn
  - Mean – 115.10 m^3

- Median – 11.12 m^3
- Maximum – 9,881.68 m^3

- Winter
  - Mean – 39.59 m^3
  - Median – 11.02 m^3
  - Maximum – 4,351.85 m^3

This analysis allowed a comparison between the general flow characteristics of the season and the flow range that the proposed mitigation covers. Table 8-1 details the per cent of the seasonal flow range that is covered by the proposed fish lock relative to no mitigation. Table 8-1 shows that the proposed mitigation at Rookwood Weir achieves a high per cent of the seasonal flow range; between 89.4 per cent and 99.8 per cent depending on the season.

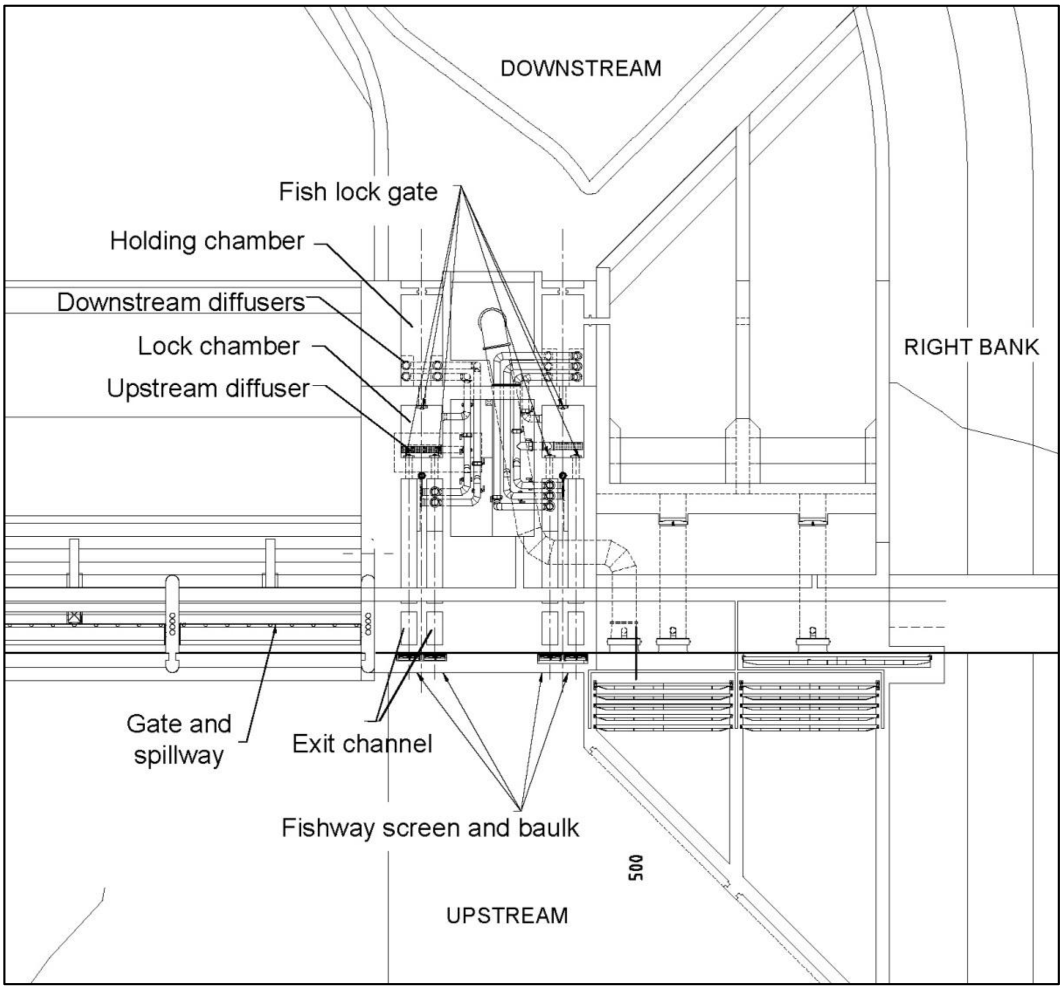
8.3.2 Fish lock arrangement

The fish lock arrangement for Rookwood Weir proposes to cater for flows from a minimum operating level up to 500 m^3/s and comprises two right bank fish locks to cover low and high reservoir levels as shown in Figure 8-6.

The lock arrangement proposed is considered suitable for the purpose of fish passage at Rookwood Weir as:

- The fish lock is a normal standard provision of infrastructure for fish passage at the current time and is in a configuration known to work (although physical model studies are required to assist with refinement of entry / exit conditions).
- It provides for between 89.4 per cent and 99.8 per cent of flows across the seasons (Table 8-1).
- The average number of waiting days per event is estimated at 10.
- The lock arrangement is capable of providing continuous attraction flows when the fishway is operating and allows for variable attraction flows between phases of the cycle. Attraction flow velocities can be varied between: 0.15 m/s and 1.8 m/s.
- The arrangement caters for small and large-bodied fish.
- It provides upstream and downstream passage.
- The fish locks can be shut down in floods to maximize operation following flood.

Figure 8-6 Rookwood Weir fishway and outlet works plan



8.4 Monitoring

A Fish Monitoring Program will be designed and implemented to monitor the effectiveness of fish passage infrastructure during both the construction and operation phases, as applicable. This Fish Monitoring Program will include at least the following:

- Records on the diversity of the fish population above and below the construction footprint
- The relative abundance of the fish population above and below the construction footprint
- Health of the fish population (injury/mortality rates) above and below the construction footprint
- Diversity of the fish population above and below the weir post construction
- Relative abundance of the fish population above and below the weir post construction
- Health of the fish population above and below the weir (injury/mortality rates) post construction
- Attraction to fishway entrance (assessment of fish diversity and abundance within the tailwater pool)
- Effectiveness of fishway transfer (assessment of fish within the entrance channel, holding chamber and exit channel)
- Relative health and behaviour of fish surveyed

- Hydrological monitoring – monitoring of storage water level, tailwater level, fishway discharge, outlet works discharge and spill discharge will facilitate interpretation of monitoring data.

The monitoring program will be undertaken biannually for a period of five years pre and post wet season to capture seasonal variation and will include areas upstream of the inundation area, within the impoundment and downstream of the weirs.

The monitoring program will be developed in consultation with DAF (Queensland Fisheries) during the detailed design phase.

8.5 Decommissioning and rehabilitation

While the design life of the Project is 100 years it is anticipated that the weir infrastructure will be maintained and operational after this period. As such, effective prescriptive planning for decommissioning and rehabilitation cannot be undertaken at present as best practice standards and legislative requirements are likely to change over the life of the Project. Management obligations for the infrastructure will continue in accordance with the approval requirements until such time as the infrastructure is decommissioned and the area rehabilitated. These responsibilities remain with the owner of the infrastructure.

Decommissioning of the Project may be required if the weirs are no longer needed for water supply or if the infrastructure is severely degraded and can no longer be maintained to meet safety standards. When decommissioning of the Project is required, an assessment of current legislative requirements and best practice decommissioning and rehabilitation methodologies will be undertaken. This assessment will inform the preparation of a decommissioning and rehabilitation plan which will be developed in consultation with relevant authorities prior to commencing works.

It is probable that all areas to be rehabilitated will be restored, where possible, to their condition prior to construction. Rehabilitation will be done progressively and achieve a stable and functioning landform consistent with the surrounding landscape and environmental values.

9. Conclusion

The raising of an existing weir and the development of a new weir is a waterway barrier works, and is assessable development under the SP Act. Therefore, development approval is required to raise Eden Bann Weir and construct Rookwood Weir.

The fishway design process undertaken for the Project was based on the process previously used for both Paradise Dam and Wyaralong Dam as recommended by DAF (Queensland Fisheries), was collaborative and included fishway design and fish biology specialists as well as Queensland Fisheries representatives.

Fish passage infrastructure has been designed to preliminary level as follows:

- Eden Bann Weir fish passage infrastructure:
  - An upgraded fish lock on the left bank
  - A new fish lock located on the right bank for high and low reservoir levels to cater for flows from about 500 m^3/s to 2700 m^3/s. This provides for normal operating conditions as well as low spillway flow conditions at the weir.
- Rookwood Weir fish passage infrastructure:
  - A right bank fish lock to cover low and high reservoir levels to cater for flows from a minimum operating level up to 500 m3/s.

A detailed construction plan will be developed during detailed design for a determined build scenario. Fish passage will not be inhibited during construction as flow is maintained instream and the existing fish lock would remain operational. Further, downstream works will only occur during the dry season when flows have ceased.

Detailed design will include the provision for CFD and physical model studies.

A Fish Monitoring Program will be designed and implemented to monitor the effectiveness of fish passage infrastructure during both the construction and operation phases.

It is considered that assessment, analysis, mitigation, management and monitoring proposed in relation to fish passage infrastructure at a raised Eden Bann Weir and a new weir at Rookwood satisfies performance objectives as defined in the State Development Assessment Provisions Module 5 Fisheries resources (V1.5) 5.2: Constructing or raising waterway barrier works in fish habitats state code included at Appendix A.

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Appendices

Appendix A Module 5 Fisheries resources

Assessment against the State Development Assessment Provisions

Module 5 Fisheries resources (V1.5)

5.2: Constructing or raising waterway barrier works in fish habitats state code

Response column key:	
☑	Achieved
P/S	Performance solution
N/A	Not applicable

5.2 Constructing or raising waterway barrier works in fish habitat state code

Table 5.2.1: Operational work

Performance outcomes	Acceptable outcomes	Response	Comment	Reference
All assessable waterway barrier works				
PO1 The development will not increase the risk of mortality, disease or injury or compromise the health and productivity of fisheries resources.	**AO1.1** The development ensures that one or more of the following is achieved: (1) the waterway barrier works includes a fish way that adequately provides for the movement of fish across the barrier works, or (2) the movement of fish across the waterway barrier works is, adequately provided for in another way, or (3) the height of the waterway barrier works allows enough water to flow across the barrier works to adequately provide for the movement of fish across the barrier works, or (4) the waterway barrier works is intended to exist only for a temporary period, and the level of disruption to fish movement in the area is acceptable, or (5) it is not necessary or desirable, for the best management, use, development or protection of fisheries resources or fish habitats, for the waterway barrier works to provide for the movement of fish across the barrier works. AND	☑ AO1.3(1) achieved	The design of Eden Bann Weir and Rookwood Weir include fishways that adequately provide for the movement of fish upstream and downstream across the weirs. Fishway design has been undertaken in accordance with the then Department of Department of Employment, Economic Development and Innovation (DEEDI) (Queensland Fisheries) Design Process criteria. The weir design for the Project has sought to minimise risk of fish injury and mortality at Eden Bann Weir and Rookwood Weir.	Volume 3 Appendix X Section 8 Fishway design Volume 3 Appendix X Section 3.1 Approach Volume 3 Appendix X Appendix A Design process criteria Volume 3 Appendix X Section 6.1.1 Design parameters Figure 6-2, Figure 6-3, Figure 6-6 [Eden Bann Weir] Volume 3 Appendix X Section 6.1.1 Design parameters Figure 6-7, Figure 6-8, Figure 6-10 and Figure 6-11 [Rookwood Weir] Volume 3 Appendix X Section 6.1.2 Environmental considerations

	AO1.2 Suitable habitat conditions, such as water and sediment quality, will be maintained to sustain the health and condition of fisheries resources within all fish habitats. AND	☑	Suitable habitat conditions including water and sediment quality will be maintained within and downstream of the impoundments during construction and operation. Construction and operational impacts on water quality will be managed through the implementation of environmental management plan (EMPs), inclusive of erosion and sediment controls and spill prevention measures. A water quality monitoring program including pre, during and post construction will be implemented in accordance with the DEHP Monitoring and Sampling Manual 2009. Parameters to be tested will include but not be limited to: – Temperature, conductivity, dissolved oxygen, pH, turbidity – Nuisance algae and chlorophyll-a – Total phosphorus, total nitrogen.	Volume 1, Chapter 11 Water quality Volume 3 Appendix X, Section 5.2 Water quality Volume 1 Chapter 23 Environmental management plan Section 23.4.4 Water management programme [construction] Volume 1 Chapter 23 Environmental management plan Section 23.5.2 Water management programme [operations]
	AO1.3 Cumulative effects of waterway barrier works do not impede fish movements, and will not affect reproductive success, health or mortality by depleting fish energy reserves. AND	☑	Fish passage infrastructure is included at the Fitzroy Barrage and the existing Eden Bann Weir. The provision of fish passage infrastructure as proposed for the Project will adequately provide for the movement of fish upstream and downstream of Eden Bann Weir and Rookwood Weir and maintain continuity of passage throughout the Project area and the Fitzroy River. The Project will not impede fish movement or adversely impact on reproductive success, fish health or mortality. The structural components of the weirs and associated works are designed to avoid and/or minimise risks of aquatic fauna injury and mortality. A Fish Monitoring Program will be designed and implemented to monitor the effectiveness of fish passage infrastructure during both the construction and operation phases including monitoring the abundance, diversity and health of the fish population.	Volume 3 Appendix X Section 5.5 Volume 1 Chapter 21 Cumulative impacts Volume 3 Appendix X Section 8.2 Eden Bann Weir [fishway design] Volume 3 Appendix X Section 8.3 Rookwood Weir [fishway design] Volume 3 Appendix X Section 6.1.1 Design parameters Volume 3 Appendix X Section 6.1.2 Environmental considerations Volume 1 Chapter 23 Environmental management plan Section 23.5.1 Nature conservation management programme Volume 3 Appendix X Section 4 Monitoring

	AO1.4 Fish will not become trapped or stranded as a result of development. OR	☑	The fish lock and outlet works at the existing Eden Bann Weir are located on the left bank whilst the main river channel and the majority of spillway flows occur adjacent to the right bank. A 110 m long channel connects the fish lock and outlet works to the main river channel downstream of the weir. For the raising of Eden Bann Weir the Project proposes to construct a new fish lock on the right bank while maintaining the fish lock (with modifications) on the left bank. This will limit the potential for entrapment and stranding. At the proposed Rookwood Weir, the main river channel is adjacent to the right bank at which location a fish lock is proposed. This will limit the potential for entrapment and stranding. During construction water flows downstream of the weir will be maintained within the river channel to prevent the drying of aquatic habitat and to maintain water quality. A flow diversion strategy will be implemented at the proposed Rookwood Weir while the existing fish lock at Eden Bann Weir will remain in operation during construction of the right bank. A fauna spotter/catcher will be located on site during all construction works that have the potential to cause injury or mortality to aquatic fauna located in the area. The fauna spotter/catcher will identify, capture and relocate aquatic fauna and/or nests as required to avoid impact.	Volume 3 Appendix X Section 5.5.2 Eden Bann Weir Volume 3 Appendix X Section 8.2.2 Fish lock arrangement [Eden Bann Weir] Volume 3 Appendix X Section 8.3.2 Fish lock arrangement [Rookwood Weir] Volume 3 Appendix X Section 6.3 Diversion strategy Volume 1 Chapter 23 Environmental management plan Section 23.4.3 Nature conservation management plan
	AO1.5 Risks of fish stranding occurring have been identified and are demonstrably manageable.	n/a	As above for AO1.4	-

PO2 Development maintains or enhances the community access to fisheries resources and fish habitats, through, for example fishing access and linkages between commercial fisheries and infrastructure, services and facilities.	**AO2.1** The development does not impact on existing infrastructure or access required by commercial or recreational fishing.	☑	The Project will not impact on existing infrastructure or access required by commercial and recreational fishing. The Fitzroy River is used for recreational activities but is largely restricted to the downstream reaches near Rockhampton and the Fitzroy River estuary. Commercial fishing does not occur upstream of, or within, the Project footprints. Recreational use at the existing Eden Bann Weir is not facilitated. Access to the weir itself is restricted to authorised personnel and the impoundment is largely bordered by private landholdings, restricting access to the river. It is proposed that this status will be retained for the Project at both Eden Bann Weir and the proposed Rookwood Weir. Opportunities to access the Fitzroy River may exist at river crossings however there will be no formal facilities developed that would encourage recreation activities.	Volume 3 Appendix X Section 6.1.2 Environmental considerations Volume 3 Appendix X Section 7 Weir operation
PO3 Development that has the potential to impact on the operations and productivity of commercial or recreational fisheries mitigates any adverse impacts due to adjustment of fisheries. Editor's note: The Guideline on fisheries adjustment provides advice for proponents on relevant fisheries adjustment processes and is available by request from the Department of Agriculture, Fisheries and Forestry.	**AO3.1** Affected fisheries and the impacts on those fisheries are identified. AND	☑	Whilst commercial fishing does not occur upstream of, or within, the Project footprints, the life-history traits of the barramundi include the use of both freshwater and saltwater habitats. As such, barramundi occurring in the Project footprints areas are considered to be a potential component of the downstream commercial fishery. Other commercially important species known to occur include sea mullet (Eden Bann Weir Project footprint only) and the long-finned eel (both Project footprints). Recreational target species previously recorded in the study area include barramundi, southern saratoga, golden perch, blue catfish, freshwater catfish, sleepy cod, oxeye herring and snub-nosed garfish. No impact to commercial or recreational fisheries as a result of the Project is anticipated. Fish passage infrastructure proposed will maintain upstream and downstream movement of fish species for the purposes of dispersal and breeding. Mitigation and management measures as proposed in the EMPs will minimise impacts on the aquatic environment (water quality, sedimentation, etc).	Volume 1 Chapter 7 Aquatic Ecology Section 7.2.2.2 Fish [Aquatic species] Volume 3 Appendix X Section 5.4.1 Species composition Volume 1 Chapter 23 Environmental management plan Section 23.5.1 Nature conservation management programme

	AO3.2 Fair and reasonable compensation to commercial fishers is determined. AND	n/a	No impact to commercial fisheries as a result of the Project is anticipated.	-
	AO3.3 The impact of the development on commercial fisheries and recreational fishers is mitigated.	n/a	No impact to commercial fisheries as a result of the Project is anticipated.	-
PO4 When the purpose of a waterway barrier is no longer relevant, or the design life of the structure is complete and the structure is not intended to be re-lifed, the waterway barrier will be removed.	**AO4.1** At the end of the viable operation of the development, the waterway barrier (and where appropriate any fish way) will be removed from the waterway and fish habitats and fish passage will be reinstated to previous or better levels. OR	☑	While the design life of the Project is 100 years it is anticipated that the weir infrastructure will be maintained and operational after this period. Management obligations for the infrastructure will continue in accordance with the approval requirements until such time as the infrastructure is decommissioned and the area rehabilitated. These responsibilities remain with the owner of the infrastructure. Decommissioning of the Project may be required if the weirs are no longer needed for water supply or if the infrastructure is severely degraded and can no longer be maintained to meet safety standards. When decommissioning of the Project is required, an assessment of current legislative requirements and best practice decommissioning and rehabilitation methodologies will be undertaken. This assessment will inform the preparation of a decommissioning and rehabilitation plan which will be developed in consultation with relevant authorities prior to commencing works.	Volume 1 Chapter 2 Project description Section 2.6 Decommissioning and rehabilitation Volume 3 Appendix X Section 8.5 Decommissioning and rehabilitation
	AO4.2 If the barrier remains in place, fish passage provision in accordance with the approved design and operation is maintained as long as the barrier remains.			Volume 1 Chapter 2 Project description Section 2.6 Decommissioning and rehabilitation Volume 3 Appendix X Section 8.5 Decommissioning and rehabilitation

PO5 Development demonstrates appropriate rights and an overriding public need for the development, including consideration of any impacts beyond the footprint of the constructed development. Editor's note: For example, dams and weirs affect fish habitats up and downstream from the structure by pooling and restricting water flows.	**AO5.1** The development is supported by a statutory instrument (for example, regional plans made under the Act, Shoreline Erosion Management Plan (SEMP), coordinated project approval under the *State Development and Public Works Organisation Act 1971*), and the impact on fish habitats have been properly considered. AND	☑	The Central Queensland Regional Water Supply Study recognised that there was a need to reserve additional water sources for future infrastructure projects. The Lower Fitzroy river system was identified as the next main supply source for urban and industrial needs of local governments and for the needs of GAWB's supply area. Raising Eden Bann Weir and constructing Rookwood Weir were identified as appropriate infrastructure to satisfy short- to medium-term supply requirements for high priority water Initially, environmental and technical investigations were commissioned by (the then) Department of Infrastructure and Planning, in response to the establishment of a state-wide water program of works to facilitate the development of water infrastructure projects. While the program of works has ceased, the proponents are committed to progressing the studies required for the Project in line with the Queensland Government's initiatives to secure future supply sources to address the future water needs of the Central Queensland region. Future demand for water resources is predicted to be primarily due to the continued growth of industrial and urban expansion in the Lower Fitzroy and Gladstone areas. In addition to direct increases in demand there is also a potential requirement to improve the level of reliability of the existing water supplies locally and regionally. This improved reliability may also take into account the need for some contingency within the system to meet climate change variability. The Project is deemed to be a coordinated project under the *State Development and Public Works Organisation Act 1971* and an environmental impact statement has been prepared inclusive of consideration of fish habitats and local, regional and national benefits arising from the Project.	Volume 1 Chapter 1 Introduction Section 1.4.1 Volume 1 Chapter 1 Introduction Section 1.4.2 Volume 1 Chapter 7 Aquatic ecology Section 7.2.1 Aquatic habitat Volume 1 Chapter 7 Aquatic ecology Section 7.2.2 Aquatic species Volume 1 Chapter 19 Economics

	AO5.2 The following can be demonstrated: (1) tenure is held for the land directly abutting the waterway where the works will be carried out and has the applicant has full riparian access rights on both sides of the barrier (2) tenure has been granted over the area of work, or (3) resource allocation or resource entitlement has been granted for the resource being developed. AND	☑	SunWater own and operate Eden Bann Weir under a Perpetual Lease (Lot 11 SP114939). The Perpetual lease at Eden Bann Weir is appropriate for the Project. It is expected that the Perpetual Lease will persist over lots impacted directly by weir infrastructure and associated ancillary work areas retained for operations. For the proposed Rookwood Weir, the majority of the weir itself is within the Fitzroy River on unallocated state land. The right (eastern) embankment will extend into freehold land on Lot 1 SP136791. The left (western) embankment extends into freehold land on Lot 3 PN106. Three saddle dams will be located within Lot 3 PN106 upstream of the weir. Similar to Eden Bann Weir a long-term lease will be acquired over Rookwood Weir and the associated infrastructure. Land tenure will be further addressed in consultation with State Land Asset Management and landholders as necessary and applicable.	Volume 1 Chapter 5 land Section 5.5 Land use and tenure
	AO5.3 Development is for public infrastructure. OR	☑	The Project meets the definition of 'Other Community Infrastructure' under Part 2 of Schedule 2 of the Sustainable Planning Regulation 2009. Further is it possible that the Project will seek community infrastructure designation (CID). Given that the Project seeks to provide regional water security, it is expected that the Project would satisfy a public benefit test with regard to a CID.	Volume 1 Chapter 3 Legislation and project approvals Section 3.3.18 Sustainable Planning Act 2009
	AO5.4 Development is for public infrastructure for which there is no alternative viable route that does not require waterway barrier works. OR	☑	Refer AO5.3. An assessment of alternatives with regard to water supply has been undertaken.	Volume 1 Chapter 1 Introduction Section 1.6 Project alternatives
	AO5.5 Development is for a legitimate public health or safety issue and the applicant is an entity or acting on behalf of an entity.	n/a	Development is not for public health or safety.	-
PO6 Development minimises stream crossings.	**AO6.1** Where multiple waterway barrier works are demonstrated to be essential, these are located a minimum of 100 metres apart (including existing structures).	☑	Eden Bann Weir and the proposed Rookwood Weir are located at 141.2 km AMTD and 265.3 km AMTD, respectively. The existing Fitzroy Barrage is located downstream at 59 km AMTD.	Volume 1 Chapter 2 Project description Section 2.2 Project location

PO7 Development avoids non-essential hardening or unnatural modification of channels.	**AO7.1** The development does not involve the channelisation of meandering waterways. AND	☑	The Project comprises the raising and operation of Eden Bann Weir and the construction and operation of Rookwood Weir. The Project does not involve the channelisation of the river and therefore will not alter the natural meander of the Fitzroy, Mackenzie or Dawson rivers.	Volume 1 Chapter 2 Project description
	AO7.2 Where channels need to be significantly modified, the development simulates natural watercourses by including meanders, pools, riffles, shaded and open sections, deep and shallow sections, and different types of substrata. Natural features such as rock outcrops and boulders are retained or recreated.	☑	The Project comprises the raising and operation of Eden Bann Weir and the construction and operation of Rookwood Weir. The Project does not involve the modification of river channels and will not alter the natural meander of the Fitzroy, Mackenzie or Dawson rivers.	Volume 1 Chapter 2 Project description
PO8 Impacts on water quality in declared fish habitat areas are minimised.	**AO8.1** Development involves erosion and sediment control measures. Editor's note: Erosion and sediment control should be in accordance with the *Best practice erosion and sediment control guidelines*, International Erosion Control Association Australasia, 2008.	☑	Erosion and sediment control measures employed during construction will be consistent with the practices described in the International Erosion Control Association (IECA), Best Practice Erosion and Sediment Control Guideline (2008).	Volume 1 Chapter 23 Environmental management plan Section 23.4.1 Soil management program
PO9 Development resulting in drainage or disturbance of acid sulfate soil is managed to prevent impacts on fisheries resources and fish habitats.	**AO9.1** Run-off and leachate from disturbed or oxidised acid sulfate soils is contained, treated and not released to a waterway or other fish habitat in accordance with the *Queensland acid sulfate soils technical manual: Soil management guidelines*, Department of Natural Resources and Mines, 2002.	☑	It is unlikely that acid sulfate soils (ASSs) would be encountered during construction activities as excavation below 5 m AHD is not anticipated. If ASS or potential ASS is encountered during pre-construction investigations, an ASS management plan will be developed based on the requirements of the Queensland Acid Sulfate Soils Investigation Team Acid Sulfate Soil Technical Manual (Dear et al. 2004; Ahern et al. 2004; Dear et al. 2002; Ahern et al. 1998) inclusive of monitoring and validation requirements.	Volume 1, Chapter 23 Environmental management plan Section 23.4.1 Soil management program
All development – environmental offsets				
PO10 Impact to fish passage is avoided, or mitigated and an environmental offset is provided for any significant residual impact.	**AO10.1** Impact is avoided or where this cannot be reasonably achieved, impacts are minimised. AND	☑	Fish lock arrangements will facilitate upstream and downstream movement at low and high reservoir levels, provide passage for most flows (in the order of 95 per cent of flows) and cater for small and large bodied fish.	Volume 3 Appendix X Section 8 Fishway design

	AO10.2 Residual impact to fish passage and any associated declared fish habitat areas and fisheries resources, is comprehensively and accurately documented. The level of significance of the residual impact is determined. AND	n/a	No *Nature Conservation Act 1992* (Qld) listed-threatened fish species have been previously recorded or are predicted to occur in the study area. No declared fish habitat areas occur within or near the study area. Fish lock arrangements will facilitate upstream and downstream movement at low and high reservoir levels, provide passage for most flows (in the order of 95 per cent of flows) and cater for small and large bodied fish. It is considered that mitigation and management will negate any potential significant residual impact.	Volume 3 Appendix X Section 2.2.2 Nature Conservation Act 1992 Volume 3 Appendix X Section 8 Fishway design
	AO10.3 An environmental offset is provided for any significant residual impact on fish passage, and associated fisheries resources, fish habitats and declared fish habitat areas. Editor's note: Applications for development should identify whether there is likely to be a significant residual impact and a need for an environmental offset having regard to the relevant Queensland Environmental Offsets Policy.	n/a	It is considered that mitigation and management will negate any potential significant residual impact and offsets are not proposed in this regard. Separately, aquatic habitat offsets in relation to the Fitzroy River turtle (*Rheodytes leukops*) are proposed in accordance with the *Environmental Offsets Act 2014* (Qld) and Queensland Environmental Offset Policy. A financial offset is proposed and has been calculated using the Queensland Government's financial settlement offset calculator. It is considered that offsets proposed in this manner will benefit a range of aquatic species.	Volume 3 Appendix X Section 2.2.2 Nature Conservation Act 1992 Volume 3 Appendix X Section 8 Fishway design Volume 1 Chapter 22 Offsets
Incorporation of fish ways				
PO11 Where the waterway barrier works will be a barrier to fish movement, provisions are made for adequate fish movement by incorporating a fish way or fish ways for the works.	No acceptable outcome is prescribed.	☑	The design of Eden Bann Weir and Rookwood Weir include fishways that adequately provide for the movement of fish upstream and downstream in accordance with the Queensland Fisheries Fishway Design Process criteria.	Volume 3 Appendix X Fish passage infrastructure technical report Appendix A

<table>
<tr><td rowspan="3">PO12 Any fish way proposed as part of the development is demonstrated to be a feasible and reliable solution that will provide adequate fish passage.
Editor’s note: Further information about the importance of fish passage and design considerations can be found in the book From sea to source: International guidance for the restoration of fish migration highways.</td><td>AO12.1 A person or entity that is suitably qualified and experienced in fish passage biology and fish way design and delivery demonstrates and verifies that any fish way design will provide adequate fish passage.
AND</td><td>☑</td><td>As part of the fishway design process, a fishway design team was established such that the range of engineering and scientific disciplines necessary for fish passage design were present and that representation from the range of key stakeholders were involved in the design process.
The fishway design team comprised proponent representatives, representatives from DEEDI (policy and fish biologists), an independent fish biologist specialist, an independent fishway design engineering specialist and GHD design engineers and environmental scientists.</td><td>Volume 3 Appendix X Section 3.2 Roles and responsibilities</td></tr>
<tr><td>AO12.2 Development uses a fish way design that has been successfully implemented under similar conditions (such as flows and fish communities) and has been demonstrated to provide adequate fish passage through actual scientific monitoring.
AND</td><td>☑</td><td>The fish lock arrangement for the Project is based on the existing arrangements at Eden Bann Weir and Claude Wharton Weir (on the Burnett River, Gayndah, Queensland).
However, improvements to the operation of the fish lock arrangement are incorporated into the design. This includes: increased operational range; variable attraction velocities (with the availability of operating at high velocities for strong swimming fish); increased entry slot width to allow larger fish access; increased efficiency of diffusers; deceased turbulence within chambers; and the use of overshot gates where possible</td><td>Volume 3 Appendix X Section 8.2.2 Fish lock arrangement [Eden Bann Weir]
Volume 3 Appendix X Section 8.3.2 Fish lock arrangement [Rookwood Weir]</td></tr>
<tr><td>AO12.3 Development provides for the installation of monitoring equipment, such as traps and lifting equipment, access for monitoring, and a monitoring program of sufficient rigour to:
(1) demonstrate the success of the fish way and fish passage at the site
(2) provide the basis for optimising operation of the works and fish way.
AND</td><td>☑</td><td>Subject to dam safety regulations the Project design provides for adequate monitoring to be undertaken.
A Fish Monitoring Program is proposed to be designed and implemented to monitor the effectiveness of the fish passage infrastructure.
The Fish Monitoring Program will be developed in consultation with the Department of Agriculture and Fisheries (DAF) (Queensland Fisheries) during the detailed design phase.</td><td>Volume 1 Chapter 23 Environmental management programme Section 23.5.1 Nature conservation management programme
Volume 3 Appendix X Section 8.4 Monitoring</td></tr>
</table>

	AO12.4 The fish way design maximises flexibility for future adjustments that may be needed once in place. AND	☑	Fish way design allows for adjustments to be made in commissioning and post commissioning including entrance/exit slot, diffuser orientation and velocities. Computational fluid dynamic and/or physical model studies are proposed to inform adjustments potentially required to the current design.	Volume 3 Appendix X Section 8 Fishway design
	AO12.5 The owner or operator demonstrates the means and commitment to promptly rectify any faults found in the fish way during commissioning, monitoring and operation, if these lead to inadequacies in the fish movement that are provided. AND	☑	GAWB and SunWater are committed to managing and operating their infrastructure in a safe and sustainable manner as is evident in their environmental policies. The economic assessment undertaken includes predicted costs associated with the development, construction, operation and monitoring of fish ways. An operations and maintenance plan will be developed for the project during detailed design, including a maintenance schedule and guidance on operations to maximise fish passage. A Fish Monitoring Program will be developed in consultation with the Department of Agriculture and Fisheries (DAF) (Queensland Fisheries) during the detailed design phase, inclusive of adaptive management measures as applicable.	Volume 1 Chapter 23 Environmental management plan Section 23.2 Environmental management framework Volume 1 Chapter 19 Economics
	AO12.6 Any tailwater control structures such as a gauging weir, rock bar or stream crossings are fitted with a fish way or designed to allow fish passage. AND	☑	An existing control weir and gauging station at Wattlebank, approximately 2 km downstream of Eden Bann Weir, maintains the tailwater level of the existing Eden Bann Weir. Wattlebank gauging weir has a small fish ladder installed. The Project will not alter the existing monitoring weir at Wattlebank, other than the need for recalibration of the stream gauge. Minor works are required approximately 700 m downstream of Rookwood Weir for the construction of a new monitoring weir. The weir is proposed to be located on a natural rock bar and is designed so as not to impede fish passage. A new gauge downstream of Rookwood Weir is proposed at the same location as the monitoring weir.	Volume 3 Appendix X Section 5.5.2 Eden Bann Weir

	AO12.7 Any existing in-stream structure downstream of the proposed waterway barrier works, which increases the barrier effect to fish passage through changes in flow characteristics, is fitted with adequate fish passage facilities.	☑	Hanrahan Road, comprising an existing track across the bed of the river, with an existing concrete causeway and pipe culvert at the low flow channel, may be impacted as a result of operational releases from Rookwood Weir. It is proposed that the crossing upgrade will comprise the installation of a new bank of culverts. Such culverts are large and will facilitate fish passage. Preliminary design for the bridges was undertaken in accordance with the Australian Standard for Bridge Design (AS 5100). During the early works phase waterway crossings will be detailed designed to meet the requirements of the *Fisheries Act 1994* and in consultation with DAF.	Volume 3 Appendix X Section 2.2.1 Fisheries Act 1994
PO13 Lateral (upstream and downstream) and longitudinal fish movement is provided for.	**AO13.1** More than one fish way is provided, for example, to provide up and downstream fish passage or to provide fish passage under a range of flow regimes.	☑	Eden Bann Weir fish passage infrastructure comprises an upgrade to the existing fish lock on the left bank and a new fish lock located on the right bank at Eden Bann Weir to cater for high and low reservoir levels. This provides for normal operating conditions as well as low spillway flow conditions at the weir. Rookwood Weir fish passage infrastructure comprises a right bank fish lock to cover low and high reservoir levels.	Volume 3 Appendix X Section 8 Fishway design
PO14 Any fish way is be capable of operating whenever there is flow in the waterway (inflow or release), the dam is above dead storage level, and the fish way will be operational for as long as the waterway barrier is in position.	**AO14.1** The operational range of a fish way is sufficient having regard to the hydrology of the site and the fish movement characteristics (in particular timing of movements in relation to seasons and hydrographs). AND	☑	The fishway design process had regard for the hydrology of the site and the fish movement characteristics to inform fishway design. Fish biology studies, hydrology and hydraulic analysis and assessment were undertaken. CFD and/or physical model studies are prosed during detailed design. As part of the Project fish locks at Eden Bann Weir will cover a flow range between 97 per cent and 100 per cent depending on the season. Rookwood Weir fish lock will cover a flow range of between modified left bank fish lock and new fish lock on the right bank at Eden Bann Weir covers between. between 89 per cent and 100 per cent depending on the season.	Volume 3 Appendix X Section 3.3.4 Design specifications and success criteria Volume 3 Appendix X Section 4 Ecological understanding for the provision of fish passage Volume 3 Appendix X Section 8 Fishway design

	AO14.2 The lower operational range of the fish way is down to at least 0.5 metres below minimum headwater drawdown level (dead storage or minimum off-take level, whichever is lower) and to at least 0.5 metres below minimum tail water level at the site. AND	☑	The design of Eden Bann Weir and Rookwood Weir include fishways that adequately provide for the movement of fish upstream and downstream in accordance with the then Department of Employment, Economic Development and Innovation (DEEDI) (Queensland Fisheries) Design Process criteria. The preliminary design allows for the fishway to operate with a minimum depth of 0.5 m below the minimum operating level on both the upstream and downstream sides of the fishway. The project commits to carrying this through into detailed design.	Volume 3 Appendix X Fish passage infrastructure technical report Section 3.3.4 Design specifications and success criteria Volume 3 Appendix X Fish passage infrastructure technical report Appendix A
	AO14.3 Upstream and downstream fish ways will be operated whenever there are inflows into the impoundment or release out of the impoundment, and during overtopping events. AND	☑	The design of Eden Bann Weir and Rookwood Weir include fishways that adequately provide for the movement of fish upstream and downstream in accordance with the DEEDI (Queensland Fisheries) Design Process criteria. The preliminary design allows for the fishway to operate on flows up to 2,700 m^3/s for Eden Bann Weir and flows up to 500 m^3/s for Rookwood Weir. This allows for operation of the fish lock for between 98 per cent and 95 per cent of flows prior to drownout at Eden Bann Weir and Rookwood Weir, respectively. During detailed design an operational plan will be developed and ROP rules defined in consultation with DAF.	Volume 3 Appendix X Fish passage infrastructure technical report Section 3.3.4 Design specifications and success criteria Volume 3 Appendix X Fish passage infrastructure technical report Appendix A
	AO14.4 All releases are directed firstly through the fish way as a priority over the outlet works, with the fish way being operated whenever a release is made through it, regardless of whether the release volume is less than the optimal minimum release for fish way operation. AND	☑	The design of Eden Bann Weir and Rookwood Weir include fishways that adequately provide for the movement of fish upstream and downstream in accordance with the then Department of Employment, Economic Development and Innovation (DEEDI) (Queensland Fisheries) Design Process criteria. Preliminary design and operation of the fishways allows for all releases to be directed firstly through the fish way as a priority over the outlet works, with the fish way being operated whenever a release is made through it, regardless of whether the release volume is less than the optimal minimum release for fish way operation.	Volume 3 Appendix X Fish passage infrastructure technical report Section 3.3.4 Design specifications and success criteria Volume 3 Appendix X Fish passage infrastructure technical report Appendix A

	AO14.5 The fish way is designed such that non-operation duration (for example, less than two weeks) and incidents due to maintenance issues (for example, siltation, debris, breakdowns, sourcing of parts) are minimised. AND	☑	Maximum likely downtime due to unplanned maintenance requirements will be minimised. Time that the fishway is not operational due to siltation and debris will be minimised by location and upstream design treatments to minimise silt and debris entering the fish locks.	Volume 3 Appendix X Section 6.1.2 Environmental considerations Volume 3 Appendix X Section 8 Fishway design
	AO14.6 Fish ways are monitored and maintained to ensure that the fish way is operational at all times.	☑	The fishways will be monitored and maintained. A concept design SCADA system is incorporated into the preliminary design and allows for monitoring of the operation of the fishway. An operations and maintenance plan will be developed for the project during detailed design, including a maintenance schedule and guidance on operations to maximise fish passage operation. A fishway monitoring programme will be designed to monitor the effectiveness of fish passage infrastructure during both the construction and operation phases. Refer to AO12.5.	Volume 1 Chapter 23 Environmental management plan Section 23.5.1 Nature conservation management programme Volume 3 Appendix X Section 8.4 Monitoring
PO15 Any fish way, and all associated componentry are designed to be durable, reliable and adequately protected from damage from high flow and flood events, to prevent or minimise non-operation.	**AO15.1** Development ensures that mechanisms are in place to ensure that operational issues in fish ways are promptly rectified for the life of the fish way. AND	☑	Durability, reliability and protection of fishways during operations are components of the fishway design process. Concept/preliminary fishway design has been undertaken using SOLIDWORKS (a 3D design package). This has enabled early identification of clashes between services, and ensuring there is adequate space and access for maintenance activities. The fishway can be isolated from the reservoir by stacking baulks into the frame downstream of the screens for maintenance purposes. Fishway management and monitoring programs will be further developed during detailed design on realisation of a Project trigger relative to a specific infrastructure build. A concept design SCADA system is incorporated into the preliminary design and allows for monitoring of the operation of the fishway. An operations and maintenance plan will be developed for the project during detailed design, including a maintenance schedule.	Volume 3 Appendix X Section 3.3.4 Design specifications and success criteria Volume 3 Appendix X Section 3.3.5 Preliminary fishway design Volume 3 Appendix X Section 7 Weir operation

	AO15.2 The quality of materials and components for construction of the fish way are appropriate for the intended service life of the fish way.	☑	The preliminary design criteria developed for the project include consideration of material properties for the purpose of design life in accordance with standard engineering design principles and are appropriate for the intended design life of the fish way. For example screens and baulks fit into a stainless steel frame. Using stainless steel will significantly reduce maintenance requirements with only periodic cleaning needed and fulfil design life requirements.	-
PO16 Any fish way is located in a position and manner that maximise the attraction and movement of fish, while also enabling access for monitoring, maintenance and operating purposes.	**AO16.1** Modelling demonstrates, by showing the likely flow patterns and adjacent to the fish way entrance that the location of the fish way entrance is optimal for fish attraction across the operational range of the fish way. AND	☑	The fishway design process has for concept/preliminary design considered the interaction of the fishway with the outlet works and attraction flow requirements. Preliminary design allows for the outlet works to be positioned adjacent to the fishway as they perform an important function in providing attraction flows at the downstream end of the fish locks. Further, discharges from the outlets are sized to pass the flow in a manner suitable for fish attraction. Based on preliminary design, the fishway entrance is considered optimal for fish attraction. CFD and/or physical model studies will however be undertaken during detailed design to further optimise these locations.	Volume 3 Appendix X Section 8.1 Fish lock arrangements Volume 3 Appendix X Section 3.3.5 Preliminary fishway design Volume 3 Appendix X Section 6.1.2 Environmental considerations Volume 3 Appendix X Section 8.2.2 Fish lock arrangement [Eden Bann Weir] Volume 3 Appendix X Section 8.3.2 Fish lock arrangement [Rookwood Weir]
	AO16.2 Outlet works are adjacent to the fish way, but are positioned and designed so as not to interfere with fish access and attraction to the fish way entrance during outlet releases. AND	☑	Outlet works are located adjacent to the fishway for attraction flows however hydraulic dissipation, flow patterns are such that attraction and entry to the fishway is not impeded. CFD and/or physical model studies to be undertaken during detailed design will seek to further optimise these locations.	Volume 3 Appendix X Section 8.1 Fish lock arrangements Volume 3 Appendix X Section 3.3.5 Preliminary fishway design Volume 3 Appendix X Section 6.1.2 Environmental considerations Volume 3 Appendix X Section 8.2.2 Fish lock arrangement [Eden Bann Weir] Volume 3 Appendix X Section 8.3.2 Fish lock arrangement [Rookwood Weir]

	AO16.3 Spillway overtopping flows initiate and terminate adjacent to the fish way or are directed parallel to the fish way entrance. AND	☑	For the gated weir structures, the gates are operated such that the gate closest to the fish way opens first and closes last to maintain spillway flows adjacent to the fishway. For non-gated infrastructure/stages during detailed design a slightly lower slot will be incorporated into the spillway structure (ogee crest) directly adjacent to the fishway to facilitate overtopping flows. CFD and/or physical model studies to be undertaken during detailed design will seek to further optimise this arrangement.	Volume 3 Appendix X Section 3.3.5 Preliminary fishway design Volume 1 Chapter 2 Project description
	AO16.4 Spillway flows are transferred to fish way releases as soon as possible during a flow recession. AND	☑	Preliminary fishway design allows for the fishway to continue to operate during spillway flows (up to 2,700 m^3/s and 500 m^3/s for Eden Bann Weir and Rookwood Weir, respectively). Once flow recession has occurred the fishway continues to operate.	Volume 3 Appendix X Section 3.3.5 Preliminary fishway design
	AO16.5 There is a continuous attraction flow at all times at the fish way entrance when the fish way is operating. AND	☑	The preliminary design necessitates that the outlet works operate during fishway operation and as such there is a continuous attraction flow at the fishway entrance. CFD and/or physical model studies will be undertaken during detailed design to refine flow patterns and velocities to optimise the fishway entrance arrangement.	Volume 3 Appendix X Section 3.3.5 Preliminary fishway design Volume 3 Appendix X Section 8.2.2 Fish lock arrangement [Eden Bann Weir] Volume 3 Appendix X Section 8.2.2 Fish lock arrangement [Rookwood Weir]
	AO16.6 Attraction flow velocities are sufficient and variable to attract the whole fish community. AND	☑	Data collected as part of the fishway design process included a review of fish assemblages at, up and downstream of the Project sites and any relevant behavioural data for species including: movement biology (for example, time of the year that upstream and downstream migration takes place, triggers for migration), breeding ecology, swimming ability (depth and velocity required for upstream and downstream migration; undertaken by GHD and reviewed by Ivor Stewart. Findings were used to inform fish way design. The lock arrangement is capable of providing continuous attraction flows when the fishway is operating and allows for variable attraction flows between phases of the cycle. Attraction flow velocities can be varied between: 0.15 m/s and 1.8 m/s	Volume 3 Appendix X Section 3.3.5 Preliminary fishway design Volume 3 Appendix X Section 5.4 Fish species Volume 3 Appendix X Section 8.2.2 Fish lock arrangement [Eden Bann Weir] Volume 3 Appendix X Section 8.2.2 Fish lock arrangement [Rookwood Weir]

	AO16.7 Appropriate light levels are maintained at fish way entrances. AND	☑	All fish lock chambers are designed to accommodate steel grates allowing light to penetrate.	Volume 3 Appendix X Section 3.3.5 Preliminary fishway design Volume 3 Appendix X Section 8.2.2 Fish lock arrangement [Eden Bann Weir] Volume 3 Appendix X Section 8.2.2 Fish lock arrangement [Rookwood Weir]
	AO16.8 Additional means of fish attraction are included in the fish way design if appropriate. AND	☑	Not applicable. Appropriate means of attraction are provided for through the outlet works.	-
	AO16.9 The fish way entrance is accessible under all flow conditions within its operating range. AND	☑	The fishway design process had regard for the hydrology of the site and the fish movement characteristics to inform fishway design. Fish biology studies, hydrology and hydraulic analysis and assessment were undertaken. The preliminary design allows for the fishway to be accessed under all flow conditions within its operating range (up to 2,700 m^3/s and 500 m^3/s for Eden Bann Weir and Rookwood Weir, respectively). CFD and/or physical model studies will be undertaken during detailed design to refine flow patterns and velocities and conditions to optimise the fishway entrance arrangement.	Volume 3 Appendix X Section 3.3.5 Preliminary fishway design Volume 3 Appendix X Section 8.2.2 Fish lock arrangement [Eden Bann Weir] Volume 3 Appendix X Section 8.2.2 Fish lock arrangement [Rookwood Weir]
	AO16.10 Fish attracted to the spillway are able to access the fish way without having to swim back downstream. AND	☑	The inclusion of a new fishlock on the right bank of Eden Bann Weir, together with the existing left bank fish lock, will facilitate that fish attracted to the spillway will be able to access the fish way without having to swim back downstream. The right bank fish lock at the proposed Rookwood Weir is located within the main channel and adjacent to the spillway. As such fish attracted to the spillway are able to access the fish way without having to swim back downstream.	Volume 3 Appendix X Section 3.3.5 Preliminary fishway design Volume 3 Appendix X Section 8.2.2 Fish lock arrangement [Eden Bann Weir] Volume 3 Appendix X Section 8.2.2 Fish lock arrangement [Rookwood Weir]
	AO16.11 Water supply for the fish ways and attraction flows are sourced from surface quality water or equivalent quality water. AND	☑	Preliminary design allows for the use of bulk head gates which enables selection of surface water levels for the purpose of attraction flows and fishway operation.	Volume 3 Appendix X Section 3.3.5 Preliminary fishway design

	AO16.12 There are adequate holding chamber dimensions for the fish biomass (for lock, lift, trap and transfer type fish ways). AND	☑	Based on a review of studies in other parts of the world, in conjunction with the findings of a study on the migratory biomass ascending the fishway at the Fitzroy Barrage (Stuart and Mallen-Cooper, 1999), Stuart et al. (2007) deduced that the fish lock at Eden Bann Weir has the potential to provide passage for the migratory biomass of freshwater fish in the Fitzroy River. Fish biology studies, analysis and assessment were undertaken for the project by GHD and reviewed by Ivor Stewart. Preliminary design has accounted for the biomass requirements of fish within the Fitzroy River and as such it is considered that the fishways proposed for the Project are adequate for the fish biomass expected to occur	Volume 3 Appendix X Section 4.2 Impacts of barriers to movement Volume 3 Appendix X Section 5.4 Fish species Volume 3 Appendix X Section 8 Fishway design
	AO16.13 The fish way has adequate hydraulic conditions for all fish within and throughout the fish ways.	☑	Data collected as part of the fishway design process included a review of fish assemblages at, up and downstream of the Project sites and any relevant behavioural data for species including: movement biology (for example, time of the year that upstream and downstream migration takes place, triggers for migration), breeding ecology, swimming ability (depth and velocity required for upstream and downstream migration); undertaken by GHD and reviewed by Ivor Stewart. Findings were used to inform fish way design, specifically hydraulic design criteria. This includes: variable attraction velocities with the availability of operating at high velocities for strong swimming fish, increased entry slot width to allow larger fish access, aeration and velocities offered by diffusers, deceased turbulence within chambers and the use of overshot gates where possible.	Volume 3 Appendix X Section 3.3.5 Preliminary fishway design Volume 3 Appendix X Section 5.4 Fish species Volume 3 Appendix X Section 5.4.4 Hydrological requirements Volume 3 Appendix X Section 8.2.2 Fish lock arrangement [Eden Bann Weir] Volume 3 Appendix X Section 8.2.2 Fish lock arrangement [Rookwood Weir]

PO17 The seasonal and flow-related biomass of the fish community at the location of the waterway barrier works has been surveyed, and has been catered for in the design of the fish way.	**AO17.1** The fish way design, operation and capacity will avoid or acceptably minimise failure to pass any members of the fish community, for example, due to size, class or swimming ability. AND	☑	Data collected as part of the fishway design process included a review of fish assemblages at, up and downstream of the Project sites and any relevant behavioural data for species including: movement biology (for example, time of the year that upstream and downstream migration takes place, triggers for migration), breeding ecology, swimming ability (depth and velocity required for upstream and downstream migration; undertaken by GHD and reviewed by Ivor Stewart. Findings were used to inform fish way design. It is considered that preliminary design will provide suitable passage for all members of the fish community. Preliminary design includes: variable attraction velocities with the availability of operating at high velocities for strong swimming fish, increased entry slot width to allow larger fish access, aeration and velocities offered by diffusers, deceased turbulence within chambers and the use of overshot gates where possible.	Volume 3 Appendix X Section 3.3.1 Data collection and review Volume 3 Appendix X Section 3.3.5 Preliminary fishway design
	AO17.2 Future increases in fish biomass are quantified and catered for in the design of the fish way (for example, in capacity or flexibility of operation).	☑	Yes. Variability and adaptability is incorporated into the design. The fish assemblages within the Fitzroy River are well understood. Data collected as part of the fishway design process included a review of fish assemblages at, up and downstream of the Project sites and any relevant behavioural data for species including: movement biology (for example, time of the year that upstream and downstream migration takes place, triggers for migration), breeding ecology, swimming ability (depth and velocity required for upstream and downstream migration); undertaken by GHD and reviewed by Ivor Stewart. The preliminary design features provide for flexibility of operations such as variable attraction velocities, aeration and velocities offered by diffusers, etc.	Volume 3 Appendix X Section 3.3.1 Data collection and review Volume 3 Appendix X Section 3.3.5 Preliminary fishway design

PO18 Fish ways and other means of fish passage at waterway barrier works cater for the whole fish community taking into account species, size classes, life stages and swimming abilities.	**AO18.1** The seasonal and flow-related composition of the fish community at the location of the waterway barrier works is well understood and catered for. AND	☑	Data collected as part of the fishway design process included a review of fish assemblages at, up and downstream of the Project sites and any relevant behavioural data for species including: movement biology (for example, time of the year that upstream and downstream migration takes place, triggers for migration), breeding ecology, swimming ability (depth and velocity required for upstream and downstream migration; undertaken by GHD and reviewed by Ivor Stewart. Findings were used to inform fish way design and include variable attraction velocities with the availability of operating at high velocities for strong swimming fish, increased entry slot width to allow larger fish access, aeration and velocities offered by diffusers, deceased turbulence within chambers and the use of overshot gates where possible. Operationally the fishways can accommodate high and low biomass conditions and cater for small and large-bodied fish. A concept design SCADA system is incorporated into the preliminary design and allows for monitoring of the operation of the fishway. A fishway monitoring programme will be designed to monitor the effectiveness of fish passage infrastructure during both the construction and operation phases and adaptive management measures implemented as applicable.	Volume 3 Appendix X Section 3.3.1 Data collection and review Volume 3 Appendix X Section 3.3.5 Preliminary fishway design

	AO18.2 The fish way design, operation and capacity will avoid or acceptably minimise any delays in fish movement.	☑	Stream flow and flood flow analysis was undertaken to allow assessment of the time periods that daily flows where in or out of range for use by fish passage infrastructure thereby providing quantification of whether the fish passage infrastructure was passing or not passing fish. Further this facilitated quantification and assessment of potential waiting periods experienced by fish species during periods that passage was not able to be provided. The preliminary design allows for the fishway to operate on flows up to 2,700 m^3/s for Eden Bann Weir and flows up to 500 m^3/s for Rookwood Weir. This allows for operation of the fish lock for between 98 per cent and 95 per cent of flows prior to drownout at Eden Bann Weir and Rookwood Weir, respectively. The fishlock arrangements proposed for Eden Bann Weir reduce the current average number of wait days per occurrence from 11 to seven. At Rookwood Weir the estimated average number of wait days per event is ten.	Volume 3 Appendix X Section 3.3.5 Preliminary fishway design Volume 3 Appendix X Section 8.2.2 Fish lock arrangement [Eden Bann Weir] Volume 3 Appendix X Section 8.2.2 Fish lock arrangement [Rookwood Weir]
PO19 Development does not increase the risk of mortality, disease or injury, or compromise the health and productivity in fish.	**AO19.1** All pathways providing fish passage at a proposed waterway barrier works are safe for fish to pass. AND	☑	The design of Eden Bann Weir and Rookwood Weir include fishways that adequately provide for the movement of fish upstream and downstream across the weirs. Fishway design has been undertaken in accordance with the then Department of Department of Employment, Economic Development and Innovation (DEEDI) (Queensland Fisheries) Design Process criteria. The weir design for the Project has sought to minimise risk of fish injury and mortality at Eden Bann Weir and Rookwood Weir.	Volume 3 Appendix X Section 8 Fishway design Volume 3 Appendix X Section 3.1 Approach Volume 3 Appendix X Appendix A Design process criteria Volume 3 Appendix X Section 6.1.1 Design parameters Figure 6-2, Figure 6-3, Figure 6-6 [Eden Bann Weir] Volume 3 Appendix X Section 6.1.1 Design parameters Figure 6-7, Figure 6-8, Figure 6-10 and Figure 6-11 [Rookwood Weir] Volume 3 Appendix X Section 6.1.2 Environmental considerations

	AO19.2 Fish passage will not adversely impact on the wellbeing of fish. AND	☑	Fish passage infrastructure is included at the Fitzroy Barrage and the existing Eden Bann Weir. The provision of fish passage infrastructure as proposed for the Project will adequately provide for the movement of fish upstream and downstream of Eden Bann Weir and Rookwood Weir and maintain continuity of passage throughout the Project area and the Fitzroy River. The Project will not impede fish movement or adversely impact on reproductive success, fish health or mortality. The structural components of the weirs and associated works are designed to avoid and/or minimise risks of aquatic fauna injury and mortality. A Fish Monitoring Program will be designed and implemented to monitor the effectiveness of fish passage infrastructure during both the construction and operation phases including monitoring the abundance, diversity and health of the fish population.	Volume 3 Appendix X Section 5.5 Volume 1 Chapter 21 Cumulative impacts Volume 3 Appendix X Section 8.2 Eden Bann Weir [fishway design] Volume 3 Appendix X Section 8.3 Rookwood Weir [fishway design] Volume 3 Appendix X Section 6.1.1 Design parameters Volume 3 Appendix X Section 6.1.2 Environmental considerations Volume 1 Chapter 23 Environmental management plan Section 23.5.1 Nature conservation management programme Volume 3 Appendix X Section 4 Monitoring

	AO19.3 The designs of all components of waterway barriers, including but not limited to spillway, stilling basin, apron and dissipation structures, are developed and implemented with safe downstream fish passage as a key design consideration. Note: A stepped spillway (including sheet pile weirs) is not an acceptable solution as high mortalities and injuries to fish have been associated with such designs. AND	☑	The provision of fish passage infrastructure as proposed for the Project will adequately provide for the movement of fish upstream and downstream of Eden Bann Weir and Rookwood Weir and maintain continuity of passage throughout the Project area and the Fitzroy River. The Project will not impede fish movement or adversely impact on reproductive success, fish health or mortality. The structural components of the weirs and associated works are designed to avoid and/or minimise risks of aquatic fauna injury and mortality include: – A roller compacted concrete ogee spillway to provide a smooth formed surface finish at the crest of the weir in the spillway section – A smooth downstream face of the spillway section – Energy dissipater and stilling basin/plunge pool design minimises injury and mortality to fish – A stilling basin (at Rookwood Weir) that extends the full length of the spillway to prevent fish being projected against hard concrete during spilling events. The current Eden Bann Weir spillway does not include a stilling basin as the foundation rock is non erodible and consists of very large boulders and irregular rock outcrop which assist in energy dissipation. Given the satisfactory performance of the existing structure over the last 15 years, no stilling basin is considered necessary for the raised structure – Spillway gates have been designed such that, when they close, the shape mirrors that of the ogee crest. This limits fauna entrapment at the edge or under gates – The inlet screens for the environmental flow outlets are designed to exclude fish from the outlets and to prevent fish being trapped by high water pressures on the upstream side of the outlet works	Volume 3 Appendix X Section 5.5 Volume 1 Chapter 21 Cumulative impacts Volume 3 Appendix X Section 8.2 Eden Bann Weir [fishway design] Volume 3 Appendix X Section 8.3 Rookwood Weir [fishway design] Volume 3 Appendix X Section 6.1.1 Design parameters Volume 3 Appendix X Section 6.1.2 Environmental considerations Volume 1 Chapter 23 Environmental management plan Section 23.5.1 Nature conservation management programme Volume 3 Appendix X Section 4 Monitoring

	AO19.4 There is adequate minimum tailwater depth at the toe of the spillway (for example, stilling basin) at commencement to spill (for example, 30 per cent of the head difference). AND	☑	Fishway design has been undertaken in accordance with the then Department of Department of Employment, Economic Development and Innovation (DEEDI) (Queensland Fisheries) Design Process criteria. Skimming flows over the spillway are expected to build up the tailwater quickly and as such tailwater depth at the toe of the spillway is adequate. CFD and/or physical model studies will be undertaken during detailed design to refine flow patterns and velocities and conditions to optimise the fishway entrance arrangement.	Volume 3 Appendix X Section 8.2 Eden Bann Weir [fishway design] Volume 3 Appendix X Section 8.3 Rookwood Weir [fishway design] Volume 3 Appendix X Section 6.1.1 Design parameters Volume 3 Appendix X Section 6.1.2 Environmental considerations
	AO19.5 Intake and outlet works adjacent to the waterway barrier are screened or otherwise designed and placed to prevent fish passing through or becoming trapped in these works. AND	☑	Inlet screens for the environmental flow outlets are designed to exclude fish from the outlets and to prevent fish being trapped by high water pressures on the upstream side of the outlet works. Louver type screens are proposed. The screens proposed for the outlets are inclined at 45 degrees to the flow channel with the slats inclined at 60 degrees to the screen. This gives a total angle of 75 degrees to the flow. The overall arrangement of inlet screens is such that it channels fish towards the fishlock. With the screen layout as at present, the following average flow velocities through the screen are expected: – –Eden Bann Weir at FSL Stage 2 = 0.32 m/s – –Eden Bann Weir at FSL Stage 3 = 0.28 m/s – –Rookwood Weir at FSL Stage 1 = 0.20 m/s – –Rookwood Weir at FSL Stage 2 = 0.17 m/s. Discussions with DAF (Queensland Fisheries) will be held during the detailed design phase to further refine the design features and identify any additional options for minimising the potential for injury and mortality.	Volume 3 Appendix X Section 3.3.5 Preliminary fishway design Volume 3 Appendix X Section 6.1.2 Environmental considerations
	AO19.6 Intake screen dimensions are such that small fish are not drawn through the outlet works and velocities are low enough that fish are not impinged or entrained on the screens. AND	☑	Refer to AO19.5	

	AO19.7 The fish way exit is located so as to avoid entrainment in any outlet work screens and avoid fish being washed back over the spillway during overtopping. AND	☑	Louver type screens are proposed. The screens proposed for the outlets are inclined at 45 degrees to the flow channel with the slats inclined at 60 degrees to the screen. This gives a total angle of 75 degrees to the flow. The overall arrangement of inlet screens is such that it excludes fish from the outlets.	Volume 3 Appendix X Section 8.1 Fish lock arrangements
	AO19.8 Cover is provided for fish moving from the exit. AND	☑	Fish passage proposed for the Project comprises fish locks. Provision of cover is not considered applicable. Fish moving from the exit into the reservoir are able to dive and scatter. Further consideration will be given to this during detailed design as necessary and applicable and in consultation with DAF.	Volume 3 Appendix X Section 8.1 Fish lock arrangements
	AO19.9 Fish exit upstream and downstream fish ways at the water level over the full range of tailwater and headwater levels. AND	☑	The design of Eden Bann Weir and Rookwood Weir include fishways that adequately provide for the movement of fish upstream and downstream across the weirs. The operating range of the fishlock is based on headwater/tailwater levels and the percentage of passage achieved.	Volume 3 Appendix X Section 3.3.4 Design specifications and success criteria Volume 3 Appendix X Section 8 Fishway design Figure 8-3 and Figure 8-5
	AO19.10 Trash and debris are excluded from the upstream fish way exit and downstream fish way entrance with designs that ensure that fish can access the exits and entrances, and that the fish way(s) are not blocked or damaged by trash or debris. AND	☑	Key design features included consideration of entry and exit conditions including for example flow velocities, turbulence and interference. The fishway exit screen comprises a trash screen. It is required to prevent large debris becoming lodged in the fishway channels. The downstream entry is protected by a grated cover over the holding chamber.	Volume 3 Appendix X Section 3.3.5 Preliminary fishway design
	AO19.11 Adequate minimum depth is maintained through the fish way. AND	☑	Key design features responsible for fauna injury and mortality such as a stepped spillway, dissipater teeth, high turbulence, insufficient pool length and depth and high velocity trash screens have been avoided in Project design.	Volume 3 Appendix X Section 3.3.5 Preliminary fishway design
	AO19.12 The risk of fish kills arising from the works are minimised (for example, through entrapment of fish upstream or between works). AND	☑	Key design features responsible for fauna injury and mortality such as a stepped spillway, dissipater teeth, high turbulence, insufficient pool length and depth and high velocity trash screens have been avoided in Project design. Refer to AO19.3.	Volume 3 Appendix X Section 3.3.5 Preliminary fishway design

	AO19.13 Contingency plans in case of mechanical or electrical failure of fish ways are in place. AND	☑	The fishway can be operated to facilitate trap and truck measures if necessary, with minor modifications to the existing fish lock arrangement. In relation to potential electrical failure; the fault tree analysis undertaken identified risks and consequently the design allows for three electrical power sources to be available to facilitate operation of the fishway. An operations and maintenance manual/plan will be developed for the project during detailed design, including the development of contingency and emergency management plans.	Volume 1 Chapter 23 Environmental management plan Section 23.5.1 Nature conservation management programme Volume 3 Appendix X Section 8.4 Monitoring
	AO19.14 The fish way design, operation and capacity will avoid or acceptably minimise predation within and upon the fish community using the fish way.	☑	Upstream and downstream passage for small, medium and large fish is provided through the provision of fish locks. Preliminary design allows for lock chambers of adequate size (243.2 m^3) to pass the expected biomass. The fishlock arrangements proposed for Eden Bann Weir reduce the current average number of wait days per occurrence from 11 to seven. At Rookwood Weir the estimated average number of wait days per event is ten. Preliminary design allows for operation of the fish lock for between 98 per cent and 95 per cent of flows prior to drownout at Eden Bann Weir and Rookwood Weir, respectively. Fishway design has minimised opportunities for predation as a result of the Project.	Volume 3 Appendix X Section 3.3.5 Preliminary fishway design Volume 3 Appendix X Section 8.2.2 Fish lock arrangement [Eden Bann Weir] Volume 3 Appendix X Section 8.2.2 Fish lock arrangement [Rookwood Weir]

Inherent barrier design and provision of fish passage				
PO20 Fish passage is provided for: (1) in the inherent design of the waterway barrier works (2) over the in-situ life of the barrier in that position through adequate construction and maintenance of the barrier.	**AO20.1** Development avoids or minimises loss of, or modification to, fish habitat. AND	☑ P/S	Aquatic habitat within the Project areas includes impounded pools, natural pools, runs and riffles, off-stream water bodies and creeks, all strongly influenced by seasonal dynamics. In the order of 282 ha and 660 ha of natural aquatic habitat occurs within the project footprints. These habitats will be altered, primarily through conversion from a lotic (flowing) state to a more homogenous lentic-type habitat characterised by a deep, wide river channel. This will occur on commissioning and persist through operations as the weir fills and is drawn down annually. It is important to note that the extent and duration of aquatic habitat alteration will be related to the amount of water stored in the impoundment (driven by climatic conditions (rainfall/drought) and management of the storage). While aquatic habitats nearer the weirs are likely to be inundated more permanently, habitats in the upper reaches of the weir impoundment will revert back to pool-riffle-run sequences (characteristic of the unimpounded reaches of the lower Dawson, lower Mackenzie and Fitzroy rivers) as the weir is drawn down and the volume of water in the storage is reduced. Aquatic habitat areas are contiguous with those of the Fitzroy River turtle (Rheodytes leukops). The impact associated with alteration of aquatic habitat is proposed to be offset in accordance with the Queensland Government's Environmental Offsets Policy. A Financial Settlement Offset I proposed.	Volume 1 Chapter 7 Aquatic ecology Volume 1 Chapter 22 offsets Volume 2 Chapter 14 Offsets Volume 3 Appendix X Section 3.3.4 Design specifications and success criteria Volume 3 Appendix X Section 8 Fishway design Figure 8-3 and Figure 8-5

	AO20.2 The drownout characteristics of the waterway barrier allow for adequate fish passage at the site. AND	☑ P/S	The preliminary design allows for the fishway to operate on flows up to 2,700 m^3/s for Eden Bann Weir and flows up to 500 m^3/s for Rookwood Weir. This allows for operation of the fish lock for between 98 per cent and 95 per cent of flows prior to drownout at Eden Bann Weir and Rookwood Weir, respectively The maximum fixed crest levels is set such that the afflux is 300 mm at both Eden Bann Weir and the proposed Rookwood Weir sites at bank full flows (9,000 m/s and above)	Volume 3 Appendix X Section 3.3.5 Preliminary fishway design
	AO20.3 At drownout, the conditions at the barrier are such that: (1) the tailwater and headwater levels across the weir are essentially equal (2) velocities are sufficiently low for fish passage (e.g. 0.3 metres/second) at or close to the edge of the spillway crest (3) the weir is fully submerged to a sufficient depth to allow for fish passage, and for the species and size classes of fish moving through the site to cross the weir (4) to the degree that provides for adequate fish passage at the site. AND	☑	The fixed crest levels is set such that the afflux is 300 mm or less at both Eden Bann Weir and the proposed Rookwood Weir sites at bank full flows. At drown out the weir no longer has any influence on flows or velocities within the system and is fully submerged.	Volume 3 Appendix X Section 3.3.4 Design specifications and success criteria Volume 3 Appendix X Section 8 Fishway design Figure 8-3 and Figure 8-5
	AO20.4 The frequency, timing and duration of drownout conditions are adequate for the movement requirements of the fish community moving past the barrier. AND	☑P/S	At drown out the weir no longer has any influence on flows or velocities within the system and is fully submerged. Regardless the preliminary design allows for operation of the fish lock for between 98 per cent and 95 per cent of flows prior to drownout at Eden Bann Weir and Rookwood Weir, respectively.	Volume 3 Appendix X Section 3.3.4 Design specifications and success criteria Volume 3 Appendix X Section 8 Fishway design

	AO20.5 Delays to fish passage when there are flows in the system but no fish passage in the rising hydrograph are accurately defined for the design, and avoided or limited to a maximum of three days. AND	☑P/S	No. of wait days. Biological data. Type of biomass moving. Barramundi. The preliminary design allows for the fishway to operate on flows up to 2,700 m3/s for Eden Bann Weir and flows up to 500 m3/s for Rookwood Weir. This allows for operation of the fish lock for between 98 per cent and 95 per cent of flows prior to drownout at Eden Bann Weir and Rookwood Weir, respectively. The fishlock arrangements proposed for Eden Bann Weir reduce the current average number of wait days per occurrence from 11 to seven. At Rookwood Weir the estimated average number of wait days per event is ten. Data collected as part of the fishway design process included a review of fish assemblages at, up and downstream of the Project sites and any relevant behavioural data for species including: movement biology (for example, time of the year that upstream and downstream migration takes place, triggers for migration), breeding ecology, swimming ability (depth and velocity required for upstream and downstream migration; undertaken by GHD and reviewed by Ivor Stewart.	Volume 3 Appendix X Section 8 Fishway design
	AO20.6 In assessing whether the inherent barrier design provides adequate fish passage, impacts on lateral and longitudinal fish movement are considered.	☑	Concept/preliminary design has considered lateral and longitudinal impacts. A second fishlock is proposed for the right bank at Eden Bann Weir with the existing (and upgraded) left bank fish lock retained. This provides for passage across the width of the watercourse. At Rookwood Weir the fishlock is proposed within the main river channel.	Volume 3 Appendix X Section 3.3.4 Design specifications and success criteria Volume 3 Appendix X Section 8 Fishway design
PO21 The use of floodgates is avoided or minimised.	**AO21.1** There is an overriding need for new floodgates, and other alternatives are unviable. AND	n/a	Floodgates are not proposed for the Project. A floodgate is a (top or side) hinged gate designed to regulate the flow of water in order to prevent flooding from one direction.	Volume 1 Chapter 2 Project description Volume 3 Appendix X section 1.1 Project overview
	AO21.2 Hydraulic conditions through the floodgates are adequate for fish passage. AND	n/a	n/a	n/a

	AO21.3 Floodgates are designed and operated as (tidally activated) automatic floodgates. AND	n/a	n/a	n/a
	AO21.4 The invert of the floodgate is at bed level. AND	n/a	n/a	n/a
	AO21.5 Floodgates allow for fish passage over an adequate duration of the tidal cycle. AND	n/a	n/a	n/a
	AO21.6 The operation of the floodgate will not result in impacts on water quality that may impact on fish or fish habitat.	n/a	n/a	n/a
PO22 Waterway barriers that are bridges are designed, constructed and maintained to provide adequate fish passage for the site and: (1) fish passage is provided for the life of the crossing (2) hydraulic conditions (depth, velocities and turbulence) from the downstream to the upstream limit of the structure allow for fish passage of all fish attempting to move through the crossing at all flows up to the drownout of the structure. Editor's note: For guidance on when a bridge is and is not considered to be waterway barrier work see the Department of Agriculture, Fisheries and Forestry 2014 fact sheets Maintaining Fish Passage in Queensland:	**AO22.1** A bridge that is designed to allow adequate fish passage is preferentially installed to a culvert. AND	☑	River crossings associated with the Project currently comprise low level causeways: – Glenroy Crossing comprises a 190 m long causeway with culverts and pipes – Riverslea Crossing comprises a low level, 120 m long causeway and bridge – Foleyvale Crossing comprises a low causeway with 18 semi-circular arches It is proposed that these crossings be upgraded to bridges as part of the Project (as applicable to impact resulting from the development stage). Existing infrastructure is proposed to be decommissioned and removed.	Volume 1 Chapter 2 Project description Volume 1 Chapter 16 Transport
	AO22.2 In-stream bridge structures such as piles are minimised. AND	☑	Preliminary design for the bridges was undertaken in accordance with the Australian Standard for Bridge Design (AS 5100). Waterway crossings will be designed to meet the requirements of the *Fisheries Act 1994* and in consultation with DAF. In the concept/preliminary design, bridge span length has been maximised as far as is practicably possible. This will result in the minimum number of piers being required.	Volume 1 Chapter 2 Project description Volume 1 Chapter 16 Transport
	AO22.3 Bridge support piles are not constructed within the low-flow channel or so that they constrict the edges of the low-flow channel. AND	☑	Bridge support piles are not constructed within the low-flow channel as far as is practicable.	Volume 1 Chapter 2 Project description Volume 1 Chapter 16 Transport

What is a Waterway Barrier Work? What is not a Waterway Barrier Work?	**AO22.4** Bridge abutments do not extend into the waterway beyond the toes of the banks. AND	☑	Bridge abutments do not extend into the waterway beyond the toes of the banks.	Volume 1 Chapter 2 Project description Volume 1 Chapter 16 Transport
	AO22.5 Bank revetment works do not extend into the waterway beyond the toes of the banks. AND	☑	Bank revetment works do not extend into the waterway beyond the toes of the banks as far as is practicable and will be further considered during detailed design.	Volume 1 Chapter 2 Project description Volume 1 Chapter 16 Transport
	AO22.6 Permanent access or erosion control structures within the main channel adjacent to the bridge are set at or below bed level, roughened to approximately simulate natural bed conditions, and maintained so that there are no drops in elevation at their edges or joins with the stream bed.	☑	No permanent access is proposed within the main channel. During detailed design, erosion control structures within the main channel adjacent to the bridge will be set at or below bed level, roughened to approximately simulate natural bed conditions, and maintained so that there are no drops in elevation at their edges or joins with the stream bed.	Volume 1 Chapter 2 Project description Volume 1 Chapter 16 Transport
PO23 Waterway barriers that are culverts provide adequate fish passage for the site, and: (1) fish passage is provided for the life of the crossing (2) hydraulic conditions (depth, velocities and turbulence) from the downstream to the upstream limit of the structure allow for fish passage of all fish attempting to move through the crossing at all flows up to the drownout of the structure. Editor's note: For guidance see the Department of Agriculture, Fisheries and Forestry 2014 Fact Sheet Maintaining Fish Passage in Queensland: What is a Waterway Barrier Work?	**AO23.1** Culverts are only installed where the site conditions do not allow for a bridge. AND	☑	Operational releases from Rookwood Weir will impact on Hanrahan Crossing. The existing crossing comprises a 600 m track along the riverbed with a 30 m to 40 m long concrete causeway (with pipe culverts) over the low flow section. As part of the Project (as applicable to impact resulting from the development stage) a bank of culverts and a causeway will be installed at Hanrahan Crossing to facilitate access during water releases from Rookwood Weir.	Volume 1 Chapter 2 Project description Volume 1 Chapter 16 Transport
	AO23.2 The combined width of the culvert cell apertures are equal to 100 per cent of the main channel width. AND	☑	The combined width of the culvert cell apertures are equal to 100 per cent of the main channel width. The design adopted is a 'fish friendly' 50 m long culvert crossing which will allow for greater flood immunity then the present system. The culverts size selected will provide satisfactory conditions for fishway passage. Final design will consider road safety, hydrology and environmental concerns based on more detailed survey.	Volume 1 Chapter 2 Project description Volume 1 Chapter 16 Transport
	AO23.3 The culvert crossing and associated erosion protection structures are installed at no steeper gradient than the waterway bed gradient. AND	☑	During detailed design, as far as is practicable culvert crossing and associated erosion protection structures will be designed to be are installed at no steeper gradient than the waterway bed gradient.	Volume 1 Chapter 2 Project description Volume 1 Chapter 16 Transport

	AO23.4 For the life of the culvert crossing, relative levels of the culvert invert, apron and scour protection and the stream bed are kept so that there are no drops in elevation at their respective joins. AND	☑	During detailed design, as far as is practicable the relative levels of the culvert invert, apron and scour protection and the stream bed will be designed so that there are no drops in elevation at their respective joins.	Volume 1 Chapter 2 Project description Volume 1 Chapter 16 Transport
	AO23.5 The base of the culvert is: (1) buried a minimum of 300 millimetres to allow bed material to deposit and reform the natural bed on top of the culvert base, or (2) the base of the culvert is the stream bed, or (3) the base of the culvert cell is roughened throughout the culvert floor to approximately simulate natural bed conditions. AND	☑	These measures will be incorporated during detailed design.	Volume 1 Chapter 2 Project description Volume 1 Chapter 16 Transport
	AO23.6 The outermost culvert cells incorporate roughening elements such as baffles on their bankside sidewalls. AND	☑	These measures will be incorporated during detailed design.	Volume 1 Chapter 2 Project description Volume 1 Chapter 16 Transport
	AO23.7 Roughening elements are installed on the upstream wingwalls on both banks to the height of the upstream obvert or the full height of the wingwall. AND	☑	These measures will be incorporated during detailed design.	Volume 1 Chapter 2 Project description Volume 1 Chapter 16 Transport
	AO23.8 Roughening elements provide a contiguous lower velocity zone (no greater than 0.3 metres/second) for at least 100 millimetres width from the wall through the length of the culvert and wingwalls. AND	☑P/S	These measures will be incorporated during detailed design.	Volume 1 Chapter 2 Project description Volume 1 Chapter 16 Transport
	AO23.9 In-stream scour protection structures are roughened throughout to approximately simulate natural bed conditions. AND	☑	These measures will be incorporated during detailed design.	Volume 1 Chapter 2 Project description Volume 1 Chapter 16 Transport
	AO23.10 Culvert alignment to the stream flow minimises water turbulence. AND	☑	Culvert alignment is in line with the stream flow and will minimise water turbulence	Volume 1 Chapter 2 Project description Volume 1 Chapter 16 Transport

	AO23.11 There is sufficient light at the entrance to and through the culvert so that fish are not discouraged by a sudden descent into darkness. AND	☑P/S	This measure will be incorporated during detailed design.	Volume 1 Chapter 2 Project description Volume 1 Chapter 16 Transport
	AO23.12 The depth of cover above the culvert is as low as structurally possible, except where culverts have an average recurrence interval (ARI) greater than 50 years. AND	☑	A nominal depth of cover is proposed, comprising of the road surface treatment only.	Volume 1 Chapter 2 Project description Volume 1 Chapter 16 Transport
	AO23.13 For culvert crossings designed with a flood immunity >ARI 50, fish passage is provided up to culvert capacity. AND	n/a	The culvert crossing has a flood immunity of less than ARI 1.	Volume 1 Chapter 2 Project description Volume 1 Chapter 16 Transport
	AO23.14 Adequate design (for example, culvert aperture) and maintenance measures are in place for the life of the crossing to keep crossings clear of blockages through a regular inspection program in order to retain fish passage through the crossing. AND	☑P/S	Hanrahan Crossing is currently owned and maintained by the Rockhampton Regional Council (RRC). Concept/preliminary design was undertaken in accordance with Council standards and where no council standard exists the roads were designed to Austroads or ARRB “Unsealed Road Manual: Guidelines for good practice” 3rd Ed. Standards. The same applies to the detailed design. Operations and maintenance requirements will be developed and discussed with RRC during detailed design.	Volume 1 Chapter 2 Project description Volume 1 Chapter 16 Transport
	AO23.15 Crossings within the bed and banks do not incorporate culverts.	n/a	-	-
PO24 Waterway crossings other than bridges or culverts provide adequate fish passage for the site and: (1) fish passage is provided for the life of the crossing (2) hydraulic conditions (depth, velocities	**AO24.1** The crossing is built at or below bed level so that the surface of the crossing is no higher than the stream bed at the site. AND	n/a	Waterway crossings proposed for the Project comprise bridges and/or culverts as addressed in PO22 and PO23.	Volume 1 Chapter 2 Project description Volume 1 Chapter 16 Transport
	AO24.2 For the life of the crossing, relative levels of the crossing, any bed erosion or scour protection and the stream bed are kept so that there are no drops in elevation at their respective joins. AND	n/a	n/a	n/a

and turbulence) from the downstream to the upstream limit of the structure allow for fish passage of all fish attempting to move through the crossing at all flows up to the drownout of the structure. Editor's note: For guidance on when a waterway crossing is not considered to be waterway barrier work see the Department of Agriculture, Fisheries and Forestry 2014 fact sheet Maintaining Fish Passage in Queensland: What is not a Waterway Barrier Work?	**AO24.3** The crossing and associated erosion protection structures are installed at no steeper gradient than the waterway bed gradient. AND	n/a	n/a	n/a
	AO24.4 The crossing and associated erosion protection structures are roughened throughout to approximately simulate natural bed conditions. AND	n/a	n/a	n/a
	AO24.5 The lowest point of the crossing is installed at the level of the lowest point of the natural stream bed (pre-construction), within the footprint of the proposed crossing. AND	n/a	n/a	n/a
	AO24.6 There is a height difference from the lowest point of the crossing to the edges of the low flow section of the crossing to channel water into the low flow section. AND	n/a	n/a	n/a
	AO24.7 The level of the remainder of the crossing is no higher than the lowest point of the natural stream bed outside of the low flow channel.	n/a	n/a	n/a
PO25 All waterway barriers are designed, constructed and maintained to provide adequate fish passage for the site and fish passage is provided for the life of the barrier.	**AO25.1** Hydraulic conditions (depth, velocities and turbulence) from the downstream to the upstream limit of the structure allow for fish passage of all fish attempting to move through the barrier at all flows up to the drownout of the structure. AND	☑	The fishway design process had regard for the hydrology of the site and the fish movement characteristics to inform fishway design. Fish biology studies, hydrology and hydraulic analysis and assessment was undertaken. CFD and/or physical model studies are prosed during detailed design. Refer to PO14, PO16 and PO19.	Refer to PO14, PO16 and PO19.
	AO25.2 Aperture size of openings (for example, at screens or trash racks) ensures adequate fish passage. AND	☑	The fishway exit screen comprises a trash screen. It is required to prevent large debris becoming lodged in the fishway channels. The screen openings are the same size as the downstream entrance to the holding chamber to allow any fish entering there to be able to exit the channel as well. Refer to PO19.	Refer to PO19.

	AO25.3 Hydraulic conditions are such that adequate fish passage is provided. AND	☑	The fishway design process had regard for the hydrology of the site and the fish movement characteristics to inform fishway design. Fish biology studies, hydrology and hydraulic analysis and assessment was undertaken. CFD and/or physical model studies are prosed during detailed design. Refer to PO14, PO16 and PO19.	Refer to PO14, PO16 and PO19.
	AO25.4 Flows across, or releases out of, the structure are such that adequate fish passage is provided in terms of timing, frequency and duration, as well as water volume and depth. AND	☑	The design of Eden Bann Weir and Rookwood Weir include fishways that adequately provide for the movement of fish upstream and downstream across the weirs. Fishway design has been undertaken in accordance with the then Department of Department of Employment, Economic Development and Innovation (DEEDI) (Queensland Fisheries) Design Process criteria. The fishway design process had regard for the hydrology of the site and the fish movement characteristics to inform fishway design. Fish biology studies, hydrology and hydraulic analysis and assessment was undertaken. CFD and/or physical model studies are prosed during detailed design.	Volume 3 Appendix X Section 3.3.5 Preliminary fishway design Volume 3 Appendix X Section 8 Fishway design
	AO25.5 Water quality across the barrier allows for fish passage.	☑	Suitable habitat conditions including water and sediment quality will be maintained within and downstream of the impoundments during construction and operation. Construction and operational impacts on water quality will be managed through the implementation of EMPs, inclusive of erosion and sediment controls and spill prevention measures. A water quality monitoring program including pre, during and post construction will be implemented in accordance with the DEHP Monitoring and Sampling Manual 2009. Parameters to be tested will include but not be limited to: – Temperature, conductivity, dissolved oxygen, pH, turbidity – Nuisance algae and chlorophyll-a – Total phosphorus, total nitrogen.	Volume 1, Chapter 11 Water quality Volume 3 Appendix X, Section 5.2 Water quality Volume 1 Chapter 23 Environmental management plan Section 23.4.4 Water management programme [construction] Volume 1 Chapter 23 Environmental management plan Section 23.5.2 Water management programme [operations]

Temporary waterway barrier works				
PO26 The temporary waterway barrier works will exist only for a temporary period and cause a minimal and acceptable disruption to fish movement in the area, during the period of installation. Editor's note: *Code for self assessable development Temporary waterway barrier works* (*WWBW02),* Department of Employment, Economic Development and Innovation, 2010 and the GIS data layer 'Queensland Waterways for Waterway Barrier Works' provide guidance on the length of time that a temporary barrier may be acceptable in particular streams.	**AO26.1** Temporary waterway barrier works can be in place at a given site for no more than 12 months. AND	☑	Temporary waterway barrier works (cofferdams) will not be in place for longer than 12 months at any given site. At Eden Bann Weir, the existing fish lock and outlet structure will remain operational throughout construction. When construction is complete or when the river channel is closed, the existing and new fish movement structures will be fully operational. The diversion strategy adopted for Rookwood Weir is to limit river diversion to a single dry season.	Volume 1 Chapter 2 Project description Section 2.4 Construction phase Volume 3 Appendix X Section 6.2 Construction methodology and work sequence
	AO26.2 In tidal waters, to ensure significant impacts on upstream and downstream habitats are avoided, the temporary waterway barrier works will not completely block the waterway for more than three weeks, unless steps taken to ensure water exchange occurs (such as breaching of the bund or pumping water), to prevent upstream marine plants and benthos being submerged in freshwater, or the barrier is sufficiently permeable. AND	n/a	No works associated with the Project will be undertaken in tidal areas.	n/a
	AO26.3 Delays to fish movement are avoided at times when fish are known to be undertaking upstream spawning migrations, even on very small or zero flow events or river rises. Waterway barrier works are scheduled out of this period, or other provision for fish movement is made (for example, the use of a partial barrier, periodic barrier, stream diversion or fish way). AND	☑	Weir construction will be primarily undertaken during two consecutive dry seasons when flows are reduced and the river is likely to exist as a series of isolated pools. Movement of fish during this period is likely to be low. At Eden Bann Weir, the existing fish lock and outlet structure will remain operational throughout construction phase. When construction is complete or when the river channel is closed, the existing and new fish movement structures will be fully operational. An in-stream diversion strategy will be put in place at the proposed Rookwood Weir, limited to the dry season that will allow species to move up and downstream.	Volume 1 Chapter 2 Project description Section 2.4 Construction phase Volume 1, Chapter 7 Aquatic ecology 7.3 Potential impacts and mitigation measures Volume 3 Appendix X Section 6.2 Construction methodology and work sequence

	AO26.4 Where there are species at the site that require downstream movement during works, provisions are made to allow those species to move downstream. AND	☑	Weir construction will be primarily undertaken during two consecutive dry seasons when flows are reduced and the river is likely to exist as a series of isolated pools. Movement of fish during this period is likely to be low. At Eden Bann Weir, the existing fish lock and outlet structure will remain operational throughout construction phase. When construction is complete or when the river channel is closed, the existing and new fish movement structures will be fully operational. An in-stream diversion strategy will be put in place at the proposed Rookwood Weir, limited to the dry season that will allow species to move up and downstream.	Volume 1 Chapter 2 Project description Section 2.4 Construction phase Volume 1, Chapter 7 Aquatic ecology 7.3 Potential impacts and mitigation measures Volume 3 Appendix X Section 6.2 Construction methodology and work sequence
	AO26.5 Water diversion around the site or through the barrier is implemented if the barrier is in position for more than four weeks, and there is any flow in the system for the purpose of ensuring that vegetation die-off, decomposition and associated reduction in water quality does not become an issue upstream of the barrier, in areas where there is more than 30 per cent coverage of terrestrial grasses within the ponded area. AND	☑	Weir construction will be primarily undertaken during two consecutive dry seasons when flows are reduced and the river is likely to exist as a series of isolated pools. Movement of fish during this period is likely to be low. At Eden Bann Weir, the existing fish lock and outlet structure will remain operational throughout construction phase. When construction is complete or when the river channel is closed, the existing and new fish movement structures will be fully operational. An in-stream diversion strategy will be put in place at the proposed Rookwood Weir, limited to the dry season that will allow species to move up and downstream.	Volume 1 Chapter 2 Project description Section 2.4 Construction phase Volume 1, Chapter 7 Aquatic ecology 7.3 Potential impacts and mitigation measures Volume 3 Appendix X Section 6.2 Construction methodology and work sequence
	AO26.6 Where there are aquatic macrophytes immediately downstream of the barrier and those macrophytes would ordinarily be submerged or partially submerged, water will need to be passed across the barrier at all times to avoid their desiccation. AND	☑	Weir construction will be primarily undertaken over two consecutive dry seasons when flows within the river are low and natural/existing conditions will be maintained for as long as possible. An in-stream diversion strategy will be put in place at the proposed Rookwood Weir to maintain flows. The existing fish lock will be used to maintain flows within the Eden Bann Weir construction area.	Volume 1 Chapter 2 Project description Section 2.4 Construction phase Volume 1, Chapter 7 Aquatic ecology 7.3 Potential impacts and mitigation measures Volume 3 Appendix X Section 6.2 Construction methodology and work sequence

	AO26.7 On removal of a temporary barrier, full movement for fish is reinstated. AND	☑	On removal of the temporary waterway barrier works (cofferdams) or when the river channel is closed, the new fishway structures will be fully operational.	Volume 1 Chapter 2 Project description Section 2.4 Construction phase Volume 3 Appendix X Section 6.2 Construction methodology and work sequence
	AO26.8 On removal of a temporary barrier, the waterway bed and banks are returned to their original profile and stability, so that long-term fish movement at the site is not compromised.	☑	Banks slopes will be stabilised and disturbed areas will be reinstated as soon as possible after work in an area is complete.	Volume 1 Chapter 2 Project description Section 2.4 Construction phase Volume 1 Chapter 23 Environmental management plan Section 23.4 Construction management plans Volume 3 Appendix X Section 6.2 Construction methodology and work sequence
PO27 Fish movement is required past temporary waterway barrier works where the duration of the barrier is greater than that allowed for under the *code for self assessable development Temporary waterway barrier works* (*WWBW02*), Department of Agriculture, Fisheries and Forestry, April 2013. Editor's note: *Code for self assessable development Temporary waterway barrier works* (*WWBW02),* Department of Agriculture, Fisheries and Forestry, April 2013 and the GIS data layer 'Queensland waterways for waterway barrier works' provide guidance on the acceptable length of time that a temporary barrier may remain in place in particular streams.	**AO27.1** Development provides for adequate fish movement through the incorporation of a fish way or fish ways for the works. AND	n/a	It is not intended that temporary waterway barrier works (cofferdams) will be required for more than 12 months at any given site.	Volume 1 Chapter 2 Project description Section 2.4 Construction phase Volume 3 Appendix X Section 6.2 Construction methodology and work sequence
	AO27.2 The barrier: (1) is a partial barrier (2) does not constrict the area or flows of a low flow channel (3) all work will be completed (and the barrier removed) during low flows when the flow will be contained wholly within a low flow channel. This would require a predictable flow regime where the likelihood of flow events during the works is very small (for example a 1 in 20 year probability). AND	n/a	n/a	n/a
	AO27.3 The barrier is opened periodically every five days for at least 48 hours to allow fish movement and water exchange. AND	n/a	n/a	n/a
	AO27.4 Fish movement is provided for via a stream diversion.	n/a	n/a	n/a

PO28 Erosion control elements of the temporary waterway barrier works do not impact on fish passage.	**AO28.1** The use of gabions is avoided to prevent fish entrapment on receding flows.	☑P/S	The use of gabions will be avoided as far as is practicably possible. A fauna spotter/catcher will be located on site during all works that have the potential to cause injury or mortality to aquatic fauna located in the area. The fauna spotter/catcher will identify, capture and relocate aquatic fauna as required to avoid impact.	Volume 1 Chapter 2 Project description Section 2.4 Construction phase Volume 1 Chapter 23 Environmental management plan Section 23.4.3 Nature Conservation Management Programme
PO29 Fish passage is not necessary or desirable, for the best management, use, development or protection of fisheries resources or fish habitats, for the temporary waterway barrier works to provide for the movement of fish across the barrier works. Editor's note: 'Other barriers' referred to in the *Fisheries Act 1994* may be applied to existing natural barriers that preclude upstream fish movement. Provision of upstream fish movement at barrier works on the site of a waterfall that does not drownout is not necessary, providing that the works do not impact on climbing fish species (for example, with the installation of smooth surfaces or overhangs).	**AO29.1** It is demonstrated through an appropriate level of scientifically designed and executed fish survey by a suitably qualified and experienced entity that there are no fish in the area during any flow regimes. AND	n/a	Fish passage at Eden Bann Weir is maintained during construction. In stream diversions proposed for the construction phase of Rookwood Weir such that fish passage is not inhibited.	Volume 1 Chapter 2 Project description Section 2.4 Construction phase Volume 3 Appendix X Section 6.2 Construction methodology and work sequence
	AO29.2 The conditions at the site causing fish to be absent are not able to be remediated while the proposed barrier is in place. OR	n/a	n/a	n/a
	AO29.3 There are other barriers in the area where the waterway barrier works is, or is to be, located which prevent movement of fish located in the area. AND	n/a	n/a	n/a
	AO29.4 Other barriers in the area of the waterway barrier works could not reasonably be expected to be modified or removed in the future to restore fish passage. AND	n/a	n/a	n/a
	AO29.5 Fish passage is not provided where this would introduce fish (including non-endemic fish or noxious fish) into an area where these species were not previously found, and this would be more detrimental to the existing fish community than the effect of the barrier.	n/a	n/a	n/a
Construction				
PO30 The construction of waterway barrier works does not limit the movement or wellbeing of fish.	**AO30.1** Work does not commence during times of elevated flows. AND	☑	In general, construction is scheduled over a two-year period, allowing for the majority of construction activities to be undertaken over two dry seasons. In-stream work will not be undertaken during times of elevated flows.	Volume 1 Chapter 2 Project description Section 2.4 Construction phase Volume 3 Appendix X Section 6.2 Construction methodology and work sequence

	AO30.2 Excavation work in unbunded tidal areas is to be scheduled to occur within two hours either side of low tide. AND	n/a	No works will be undertaken in tidal areas.	n/a
	AO30.3 In-stream work is scheduled for the driest time of the year. AND	☑	In general, construction is scheduled over a two-year period, allowing for the majority of construction activities to be undertaken over two dry season.	Volume 1 Chapter 2 Project description Section 2.4 Construction phase Volume 3 Appendix X Section 6.2 Construction methodology and work sequence
	AO30.4 In-stream construction is completed as quickly as possible to lessen the impact on fish and habitats, and timed to minimise conflict with fish migrations. AND	☑	Weir construction will be primarily undertaken during two consecutive dry seasons when flows are reduced and the river is likely to exist as a series of isolated pools. Movement of fish during this period is likely to be low.	Volume 1 Chapter 2 Project description Section 2.4 Construction phase Volume 3 Appendix X Section 6.2 Construction methodology and work sequence
	AO30.5 Routes for the developments are planned to minimise the impact on fish passage and fish habitat (for example, roads and railways minimise crossings and avoid crossings in environmentally sensitive areas).	☑	As far as is practicable use will be made of existing access routes. Access to Eden Bann Weir is via an existing road on the left bank. A new access is required to the right bank. It is not expected that watercourse crossings will be required to facilitate this access route. Access to the proposed Rookwood Weir site is via an existing access road. Upgrades to existing bed level crossings will be undertaken in accordance with DAF's Code for self-assessable development Minor waterway barrier works Part 4: bed level crossings (Code number: WWBW01 April 2013) as applicable.	Volume 3 Appendix X Section 2.2.1 Fisheries Act 1994
PO31 The development does not cause, or minimises direct or indirect disturbance to the bed and banks adjacent to the approved footprint of works.	**AO31.1** Removal of stream-bank vegetation and disturbance to the natural banks and bed of the waterway is avoided or minimised. AND	☑	Disturbance and/or destruction of native vegetation in watercourses will be restricted to smallest practical area required for site works. As far as is practicable use will be made of previously disturbed areas. It is not proposed to clear vegetation or disturb natural banks outside of construction areas. If native vegetation will be destroyed, it is to be cut off at ground level, except as required for excavation.	Volume 3 Appendix X Section 1.1 Project overview

	AO31.2 Disturbance to the outer bank of waterway beds during work and while gaining access is minimised. AND	☑	Disturbance to the outer bank to facilitate construction activities at the weir sites and at river crossings have been minimised as far as is practicable by locating infrastructure and work areas within existing cleared or non-remnant vegetation and making use of existing roads and tracks.	Volume 3 Appendix X Section 1.1 Project overview
	AO31.3 Heavy machinery is excluded from fragile areas and areas which host fisheries resources. AND	☑	Construction activities are proposed within designated and defined areas and will be marked up on maps and figures prior to construction. Potentially sensitive areas will be demarcated as such and management measures implemented to avoid or minimise impacts.	Volume 1 Chapter 23 Environmental management plan Section 23.4 Construction management plans Volume 3 Appendix X Section 1.1 Project overview
	AO31.4 After completion of the in-stream works, all areas of the bed and banks of the waterway that are outside of the approved permanent footprint of the works, and which have been disturbed as a result of the construction or raising of the waterway barrier works, are returned to their original profile and stabilised to promote regeneration of natural fish habitats. AND	☑	Where practicable, revegetation activities would be commenced in and adjacent to construction areas as soon as possible after the completion of local construction works.	Volume 1 Chapter 23 Environmental management plan Section 23.4 Construction management plans
	AO31.5 By the completion of works, the profiles of the bed and banks are reinstated to natural stream profiles and stability. AND	☑	Banks slopes will be stabilised and disturbed areas will be reinstated as soon as possible after work in an area is complete as necessary and applicable.	Volume 1 Chapter 23 Environmental management plan Section 23.4 Construction management plans
	AO31.6 The waterway bed will be retained with natural substrate, or reconstructed with substrate comparable to the natural substrate size and consistency. AND	☑	The waterway bed is not proposed to be disturbed outside of the weir construction footprints, areas which will not be retained as a result of constructing the weir infrastructure in situ (for example, spillway, stilling basin, outlet works, abutments, etc.)	Volume 3 Appendix X Section 1.1 Project overview
	AO31.7 Vegetation and cover will be rapidly re-established so that the native plant community at the site can recover or be enhanced (for example, by using native species). AND	☑	Where practicable, revegetation activities would be commenced in and adjacent to construction areas as soon as possible after the completion of local construction works.	Volume 1 Chapter 23 Environmental management plan Section 23.4 Construction management plans

	AO31.8 Fish habitats, including fisheries resource values, will be able to naturally regenerate to pre-works conditions. Editor's note: Monitoring of the success of fish habitat regeneration, within and adjacent to the work site, will be a development permit condition.	☑	Fish passage infrastructure is included at the Fitzroy Barrage and the existing Eden Bann Weir. The provision of fish passage infrastructure as proposed for the Project will adequately provide for the movement of fish upstream and downstream of Eden Bann Weir and Rookwood Weir and maintain continuity of passage throughout the Project area and the Fitzroy River. The Project will not impede fish movement or adversely impact on reproductive success, fish health or mortality. A Fish Monitoring Program will be designed and implemented to monitor the effectiveness of fish passage infrastructure during both the construction and operation phases including monitoring the abundance, diversity and health of the fish population Suitable habitat conditions including water and sediment quality will be maintained within and downstream of the impoundments during construction and operation. Construction and operational EMPs will be implemented to mitigate and manage impacts.	Volume 1 Chapter 23 Environmental management plan Volume 3 Appendix X Section 1.1 Project overview
Additional requirements for development within a strategic environmental area				
PO32 Sediment and other polluting material must be captured during construction and operation of a waterway barrier.	**AO32.1** During construction: (1) environmental safety measures such as silt curtains are used to capture sediments, (2) materials that are pollutants (such as debris, chemicals, or construction material) are not stored in the stream bed, unless they are to be used immediately.	n/a	The Project does not occur in or near a strategic environmental area.	Volume 1 Chapter 3 Legislation and project approvals

	AO32.2 After construction the stream bed and banks are protected to prevent erosion or slumping, by ensuring: (1) the waterway bed is lined with the original top soil retained during the construction (2) materials that are pollutants (such as debris, chemicals, or construction material) are removed from the location and appropriately treated and disposed of as waste outside the strategic environmental area – for example to a managed landfill (3) temporary barriers are removed after use and the natural materials either returned to their original location in the strategic environmental area, or if not taken from the strategic environmental area, appropriately treated and disposed of as waste outside the strategic environmental area – for example to a managed landfill.	n/a	n/a	n/a
PO33 The works do not impede fish passage particularly during critical periods, that are important for breeding, feeding, nursery and recruitment of indigenous fish species.	**AO33.1** Works (except temporary works required for less than 20 business days) that are not drowned out regularly must contain a fish way, the design of which is approved by the Department of Agriculture, Fisheries and Forestry. AND	n/a	The Project does not occur in or near a strategic environmental area.	Volume 1 Chapter 3 Legislation and project approvals
	AO33.2 Any fish way must be operational at all times except where natural flows would have prevented fish passage. AND	n/a	n/a	n/a
	AO33.3 In the case of drought, any fish trapped in the impoundment must be rescued according to the *Fish Salvage Guidelines*, Department of Primary Industries and Fisheries, 2004 AND	n/a	n/a	n/a
	AO33.4 Vegetation and cover is retained or replaced to pre-work levels and conditions. AND	n/a	n/a	n/a
	AO33.5 All works are constructed during periods when fish passage is least affected.	n/a	n/a	n/a

PO34 Development avoids or minimises any adverse impacts on environmental values and water quality objectives for receiving waters (surface and groundwater) on site or leaving a site from pollutants.	AO34.1 Development demonstrates best practice environmental management to meet relevant environmental values and water quality objectives of the *Environmental Protection (Water) Policy*. OR	n/a	The Project does not occur in or near a strategic environmental area.	Volume 1 Chapter 3 Legislation and project approvals
	AO34.2 All stormwater, wastewater, discharges and overflows leaving the site are: (1) treated to the quality of the receiving waters prior to discharge, or (2) reclaimed or re-used such that there is no export of pollutants to receiving waters.	n/a	n/a	n/a

Appendix B Fishway design process criteria

Fishway design process and criteria for dams and major weirs

DESIGN PROCESS

Background
Under the *Fisheries Act 1994* all dam and weir proposals will require approval to undertake waterway barrier works as part of the development permit, and approval will only be given if fish passage is satisfactorily addressed. In most cases for dams and weirs the incorporation of fishways is the likely method for providing for fish passage.

The process set out below details the steps QPIF consider necessary for a successful design process. This summarises the process used for the design of major fishways in Queensland. It is QPIF'S experience that the best fishways come out of a highly consultative process. Maximum use should be made of existing expertise among external (overseas and Australian) fishway designers and biologists as this only adds to the quality of the outcome. The requirements of other aquatic fauna such as turtles and platypus should also be considered during the process, to ensure that there are no adverse effects on these animals and that any facilities are complimentary and not detrimental to non-target fauna.

It is also important that the operations of the dam or weir in terms of water releases, spillway gates, environmental flow provisions, offtake works and fishways are integrated so that no single component compromises the operation of the others.

The timing of the design process will to a degree depend on the availability of critical data however the first meeting must be initiated as soon as possible once the data is available or the project is confirmed.

Design steps

1. Collate as much as possible of the following data:
- fish assemblages at the site, up and downstream of the site and any relevant behavioural data for those species
- fish habitat at the site, up and downstream of the site
- (as above for turtles, platypus etc.)
- existing hydrological data (e.g. flow duration curves, annual exceedance probabilities, flow event curves)
- projected headwater/tailwater levels at a range of flows
- rate of tailwater rise over a range of flows
- modelled storage levels at full entitlements scenario over the simulation period
- periods of no flows
- relevant water management impacting on the site (e.g. environmental flow release requirements, ROP requirements)

- likely dam/weir operation (including gate operation, flow releases, water offtake, inflow outflow mimicry etc.). Also proposed on-site personnel or remote operation
- proposed dam/weir design including spillway design; all outlet and offtake works; dissipater designs; location and design of associated upstream and downstream gauging structures.

As far as possible this data should be provided for review prior to the first design meeting.

2. First meeting (once data is collated)
- Discuss existing data; identify data gaps.
- Initiate steps to fill data gaps where practicable.
- Identify a date by which additional data will be collected, and disseminated (before first site inspection).
- Discuss possible design types.
- Agree on how the preferred design type will be arrived at.
- Agree on date for site inspection.

3. Site inspection
- Inspect site of waterway barrier and any associated works (e.g. gauging structures).
- Inspect catchment below site to identify further impediments to fish passage that may be affected by changes in flow regimes.
- Inspect catchment above site where additional instream works may be required e.g. raising road crossings above full supply level (FSL).
- Determine how access to fishways will be provided for monitoring and maintenance purposes.
- Relate hydrological data to site.
- Agree on date for workshop.

4. Development of design specifications
The development of the design specifications could be done during a discussion meeting and through collating submissions from QPIF and any other players (e.g. DERM).

5. Design workshop
The design workshop allows fishway design issues to be identified and discussed with input from all the relevant players and experts. It is critical that the proceedings and outcomes of the workshop are captured and adequately recorded by someone with sufficient technical understanding. These minutes will constitute an important part of the whole design documentation.

Fish passage issues to be discussed are:
- fishways providing upstream passage across the dam/weir
- fishways providing downstream passage across the dam/weir
- fishways providing passage across temporary structures associated with the construction of the dam/weir (e.g. haul roads, bunds etc.)
- provision of fish passage during stream diversion
- fishway passage provision at other sites within, up or downstream of the dam/weir where passage opportunities are further limited by the presence/operation of the dam/weir.
- interactions between fishways and other dam/weir components (e.g. intake works, environmental release works etc.)

- operation of the dam/weir and fishway design implications
- fish passage over the spillway and spillway and dissipater design that maximises fish survival.

Concept designs agreed upon and disseminated prior to next meeting.

6. Post workshop meetings (regular)

- Discuss concept designs.
- Agree consultative process and contacts for input into the development of the design.
- Discuss post-construction monitoring requirements, including design elements related to monitoring.
- Establish processes for developing post-construction monitoring, budgets for monitoring, monitoring outcomes, contingencies for post-construction adjustments etc.
- Establish processes for developing fishway management plan including operation and maintenance manual, maintenance program, contingency plans for fishway failure, continuous improvement program etc.

7. Modelling (once QPIF agrees to concept designs)

A scale model will need to be constructed and run under various flow scenarios to evaluate entrance and exit conditions and flow patterns at the dam/weir wall. QPIF must be present at this modelling exercise. Outcomes of the modelling exercise are then incorporated into the concept designs and these are disseminated for approval by QPIF.

8. Ongoing input

When any change is made to the fishway designs (including during construction) that could affect their capacity to pass fish, its operation or monitoring, QPIF must be consulted.

Once a close-to-final design is available, this should be disseminated and a meeting date agreed upon.

9. Final design meeting(s)

- Discuss final designs and agree on any further modifications.
- Final plans must be provided to QPIF for inspection prior to commencement of fishway(s) construction.
- Agree on the process for consultation and close communication between the construction contractor and QPIF and regular (fortnightly) site visits by QPIF during the construction of the fishways to avoid unilateral decisions on the fishways by the construction contractors that could affect their capacity to pass fish, their operation or monitoring).
- Agree on the fishways inspection program during and close to completion of construction.
- Outline contents of the fishway management plan.
- Set up ongoing management committee/process for the fishways to deal with issues arising such as:
  - monitoring outcomes
  - associated modifications to the operation or structure of the fishways
  - implementation of continuous improvement obligations
  - operating contingencies
  - long-term outcomes.

- Agree on commissioning process and key players.
- Look at community education programs relating to the completed fishways and biopasses to increase public acceptance of the technologies and to improve public ownership of the structures.

Key players

1. **Biological**

- Input required from QPIF fishway biologists.
- Input required from DERM aquatic fauna biologists.
- Input required from DERM ROP managers.
- There is an expectation that the design engineers (successful tenderers) would have access to a fishway biologist with some experience in major fishway projects.
- Proponent may be required to fund additional fishway biological or fishway engineering expertise as required, as identified by QPIF, to assist in the assessment of and input into the design.
- Where deemed necessary by QPIF (e.g. for major structures, innovative technology etc.), an independent (possibly overseas) fishway biologist with experience in providing fish passage at similar structures and preferably with comparable biota will peer review the design.

2. **Engineering**

- Engineers should have fishway design experience.
- Construction managers who have already had experience in constructing and commissioning fishways are preferred.
- Where necessary, independent fishway engineer(s) with experience in providing fish passage at similar structures and preferably with comparable biota will peer review the design.

3. **Operational**

- Input is sought from dam/weir operators with experience of similar dams/weirs (and possibly fishways) to uncover any operational issues that may have been missed by the design engineers or fishway biologists.
- The future operator must be involved at every step of the design process from the beginning.

4. **Proponent**

The presence of the proponent at all elements of the design process ensures that decisions can be made on the fishway design made more readily (e.g. in terms of expenditure implications) without constantly having to refer back to the developer for agreement, outside the process.

DESIGN PRINCIPLES FOR FISHWAYS (NON-EXHAUSTIVE)

General

- QPIF advice on fishway design (including capacity and downstream passage) and operation will necessarily be conservative given the current knowledge available, the longevity of water infrastructure and potential changes to the fish communities and fish behaviour over time.

- The quality of the materials and componentry used in the construction of the fishway should be commensurate with its intended service life and operation (i.e. to the same standard as the outlet works).

- The fishways must cater for the whole fish community at each site in terms of size classes, swimming abilities and biomass. This includes all life stages of the fish species at each site.

- Fishways must provide both upstream and downstream passage all year round for the whole fish community.

- The fishways must be designed to be operational all year round when there is an inflow into the impoundment or a release from the impoundment.

- The fishways will be required to operate when there are inflows to the dam/weir, above dead storage level. An inflow/outflow operational model will need to be developed for the fishways.

- The fishways must be constructed to operate down to 0.5 m below minimum tailwater (to allow for changes in tailwater levels and modelling errors) and 0.5 m below minimum headwater drawdown levels (dead storage level or minimum offtake level, whichever is lower and up to a one in 50 year flood or drownout (whichever is lower). (*QPIF experience is that tailwaters at sites after weir or dam construction are generally lower than the modelled tailwater and the 0.5 m below tailwater rule addresses this anomaly.*)

- Other seasonal fish migration requirements must be identified and included in the operating requirements for the fishways, irrespective of flows.

- All releases from the impoundments must be directed first through the fishway as a priority over the outlet works (design to take account of this operational requirement if necessary), with the fishway being operated whenever a release is made through it, regardless of whether the release volume is less than the optimal minimum release for fishway operation.

- Spillway flows should be transferred to fishway releases as soon as possible during a flow recession.

- Allocated water volume to the fishway must be at design levels for the fishways as opposed to minimum possible water usage.

- Adjacent outlet works should be screened or otherwise designed and placed to prevent fish passing through or becoming trapped in these works.

- Spillway design, aprons, stilling basins and dissipater design must be demonstrated to minimise fish injury, mortality and entrapment.

- Fishway entrances must be sited where fish can access them over the full operational range of the fishway.

- Outlet works must be positioned so as not to interfere with fish access to the fishway entrance.

- Spillway overtopping flows must initiate and terminate adjacent to the fishway or be directed parallel to the fishway entrance.

- There must be a continuous attraction flow at all times at the fishway entrance when the fishway is operating.

- Appropriate light levels must be maintained at fishway entrances.

UPSTREAM PASSAGE

Entrance

- The fishway entrance must be accessible under all flow conditions within its operating range.

- Fish attracted to the spillway must be able to access the fishway without having to swim back downstream.

- Attraction flow velocities must be sufficient and variable to attract fish but not too high for smaller fish to navigate.

- Water supply for the fishways and attraction flows must be sourced from surface quality water.

- There must be adequate holding chamber dimensions (for lock, lift, trap and transfer type fishways).

- There must be adequate hydraulic conditions for all fish within the fishways.

- Attraction flow diffuser must be vertical and fixed on the back wall of the holding chamber (for lock, lift, trap and transfer type fishways).

- Turbulence and velocities need to be balanced to ensure attraction without precluding smaller fish.

- The entrance slot must be adjustable.

Exit

- Fish exit so as to avoid entrainment in any outlet work screens and avoid being washed back over the spillway during overtopping.
- Cover is provided for fish moving from the exit.
- Fish exit at water level.
- Weeds are controlled at the fishway exits and entrances to ensure that fish swim into water free of weed mats.
- Trash is excluded from the upstream fishway exit and downstream fishway entrance to ensure that fish can access the exits and entrances and that the fishways are not blocked or damaged by trash.

Outlet works

- Outlet works should be adjacent to the fishway.
- The orientation of the outlet works water jet is angled so that it does not mask or isolate the entrance to the fishway or impinge on fish moving up the adjacent riverbank.
- High flow (slug release) should not cause confusing flows at the fishway entrance.

Screens

- Intake screens dimensions must be such that small fish are not drawn through the outlet works and velocities should be low enough that fish are not impinged on the screens.

Tailwater control and crossing structures

- Any tailwater control structures such as a gauging weir (proposed and existing), rock bar or stream crossings are fitted with fish passage facilities or designed to allow fish passage.
- Any existing instream structure downstream of the proposed dam/weir, whose barrier effect to fish passage is increased by changes in flow characteristics due to the proposed dam/weir, must be fitted with fish passage facilities.

DOWNSTREAM PASSAGE

- Downstream passage must be provided whenever the upstream fishway is operating.
- Fish must be delivered into the tailwaters at or below water level over the full range of tailwater levels including with no flow over the spillway.
- Appropriately screened to prevent blockage by debris but allow fish passage.
- Spillway design and associated dissipation structures must be shown to minimise the potential for fish injury and mortality during passage over the spillway in overtopping flows.

PROVISION OF FISH PASSAGE DURING CONSTRUCTION

- Temporary fish passage must be provided during all phases of construction and during the period prior to the filling of the impoundment and operation of the fishway.
- Stream crossings for construction traffic must be provided for by full channel bridges.
- Where culvert type crossings are necessary, the culverts must be of suitable dimensions to pass all flows up to drownout without constriction of the river channel.
- Flow velocities within any culvert crossings must be controlled so as to permit fish passage over the full range of flows.

For design principles relating to other aquatic fauna (e.g. turtles) refer to DERM for advice.

CONSTRUCTION PRINCIPLES

- In the experience of QPIF, construction managers and teams that have worked on fishways previously (e.g. the installation of vertical slots, fishlocks etc.) have been far more successful when building subsequent fishways than those who have never built a fishway. Continuity of experience in fishway construction is preferred.
- Fish passage must be maintained during the construction of the weir or dam. Provision will need to be made for fish passage through any coffer dams and access causeways and also through diversion conduits.
- Impacts to water quality must be minimised during the construction process. Poor water quality can impact both on downstream habitat and also on fish movement, as fish may be unwilling to move into poor quality (e.g. turbid, deoxygenated or different temperature) water.
- QPIF fishway biologists will be required on site during construction at the following times:
  - where a rock ramp fishway is being built, at the commencement of construction of the rock ramp and also close to completion of the rock ramp
  - for other fishways, in the latter half of the fishway construction so that the general form of the fishway can be checked for visible errors
  - at the dry and wet commissioning of any fishway.
- Monitoring access and equipment, such as traps, lifting equipment etc. will need to be installed and tested as part of the construction phase.

It is important to note that structural adjustments are likely to be required to fishways in almost every case. Generally, these adjustments are not all identified until after the fishway and weir has been completed, and commissioned and operated for a sufficient period to allow a full performance monitoring program of the fishway to be undertaken. This may go beyond the handover period between developer and owner and allowance will need to be made to pay for and undertake the required adjustments.

FISHWAY OPERATION PRINCIPLES

The optimal operating regime for the fishways will be an outcome of the results of monitoring as well as a degree of trial and error. It is not expected that the fishway will be optimally operated from day one. However, there are some minimum operating requirements that the designers need to be mindful of:

- The fishways must be operated as per the design levels until monitoring results suggest otherwise and QPIF stipulate changes.
- The fishways should be designed to operate to 0.5 m below minimum tailwater and 0.5 m below minimum headwater drawdown levels (dead storage level or minimum offtake level, whichever is lower) and up to a one in 50 year flood or drownout (whichever is lower).
- The fishways will be required to operate when there are inflows to the dam above dead storage level. An inflow/outflow operational model will need to be developed for the fishways and fishways may need to be operated in the absence of other (allocated) releases from the dam/weir.
- Other seasonal fish migration requirements must be identified and included in the operating requirements for the fishways, irrespective of flows.
- The fishways should be operated when there is any release from the impoundment

PROJECT INFORMATION

Information availability at the commencement of the design process will vary from site to site and depend on how comprehensive and/or close to completion the impact assessment process is. Information about a dam or weir project relevant to the fishway design process includes:

- identity of the operator
- proposed operation of the dam/weir
- regulatory processes relating to the dam/weir operation, releases etc. (e.g. resource operating licences, resource operations planning etc.)
- final dam/weir design
- spillway and dissipation designs
- gate operation
- weed control/exclusion
- downstream release regime and offtake volumes and timing
- diversion works
- outlet works capacities
- downstream barriers and impact of the dam/weir on fish passage at these.

As the design process proceeds, further information requirements may be identified.

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Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
0	C Mills K Hryczyszyn	G Squires L Delaere	[signature]	L Delaere	[signature]	09/06/2015

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