CHAPTER 7

Aquatic Ecology

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7 Aquatic Ecology

This chapter assesses the impact of the Six Mile Creek Dam upgrade project on aquatic ecology in and around the Project area.

7.1 Background

Six Mile Creek Dam (also known as Lake Macdonald) is located in the upper reaches of Six Mile Creek at ATMD 55 km. Therefore, this chapter identifies:

- Existing aquatic ecological values in Six Mile Creek and Lake Macdonald
- The potential impacts on aquatic ecological values associated with the Project
- Mitigation measures to be implemented to minimise the potential impacts on aquatic ecological values.

To determine the impact of the Project on aquatic ecological values, the aquatic ecological assessment considered an area comprising Six Mile Creek downstream of Lake Macdonald to the confluence with the Mary River, Lake Macdonald, and Six Mile Creek upstream of Lake Macdonald (Figure 7-1).

The chapter is structured as follows:

- Section 7.2 describes the methods used to assess the aquatic ecological values in Six Mile Creek and Lake Macdonald
- Section 7.3 identifies the aquatic ecological values in Six Mile Creek and Lake Macdonald and describes the existing aquatic ecology
- Section 7.4 provides an assessment of potential impacts to aquatic ecological values from the Project
- Section 7.5 discusses management and mitigation measures that can be implemented to minimise impacts on aquatic ecological values.

The legislative framework relevant to aquatic ecology is discussed in Chapter 2 – Planning and Approvals. Potential impacts to water quality are assessed in detail in Chapter 6 – Water Resources, but are briefly discussed in this chapter in relation to potential impacts on aquatic ecology.

7.2 Methodology

7.2.1 Overview

The aquatic ecological values of Six Mile Creek and Lake Macdonald were assessed by frc environmental through:

- Literature and database review that included, but was not limited to
  - Mary Basin Draft Water Resource Plan: Environmental Conditions Report including Mary River, Burrum River and Beelbi Creek Catchments (DNRM, 2004)
  - The MNES Protected Matters Search Tool and the Species Profile and Threats (SPRAT) database
  - The MSES search tool (for relevant MSES including declared fish habitat areas, waterways providing for fish passage and marine plants, wetland protection areas, High Ecological Value (HEV) waters, regulated vegetation in riparian areas)
  - Department of Environment and Science's (DES's) Wildlife Online database
  - Atlas of Living Australia
- Synthesis of existing data for aquatic habitat, water quality, aquatic plants, fish and turtles collected:
  - Within the scope of the Northern Pipeline Interconnector Stage 2 (NPI2) Aquatic Habitat Monitoring Program (AHMP)
  - Within the scope of baseline studies, including field surveys, completed for the Six Mile Creek Dam Safety Upgrade Project (frc environmental 2016, Appendix G)
  - By Seqwater during routine water quality monitoring programs
- Field survey for macroinvertebrates, as there was no recent existing macroinvertebrate data from other surveys for the Project
- Consultation with key experts, including academics, agency staff and other relevant stakeholders (frc environmental 2016, Appendix G).

Aquatic ecology field surveys were conducted in August and October 2015 and February 2018 under ethics (CA 2015/08/893) and fisheries (181742) permits held by frc environmental. The survey methods were consistent with methods for the survey of large freshwater perches and lungfish presented in the *Survey Guidelines for Australia's Threatened Fish* (SEWPAC 2011a) and the *Survey Guidelines for Australia's Threatened Reptiles* (SEWPAC 2011b). All specimens of native fish and turtle were released unharmed at the location of capture. Pest fish species were euthanised in accordance with methods approved under the ethics permit.

Consultation with key experts was completed in 2015/2016 and comprised a survey distributed by email. The experts consulted were selected due to their recognised experience in fish / turtle distribution and ecology in the Mary River and Six Mile Creek. Responses to the survey were received from:

- Andrew McDougall, Project Leader (Aquatic Ecology), Water Services (South), Queensland Department of Natural Resources, Mines and Energy
- Tom Espinoza, Project Officer (Aquatic Ecology), Water Services (South), Queensland Department of Natural Resources, Mines and Energy
- David T. Roberts, Team Leader Asset Efficiency and Optimisation, Seqwater
- Dr John Harris, Adjunct Associate Professor, Centre of Ecosystem Science, University of New South Wales
- Russel Manning, Manning Fish Hatchery (frc environmental 2016).

Further information on the assessment methods used to collect the existing data and the macroinvertebrate field survey is provided in the sections below.

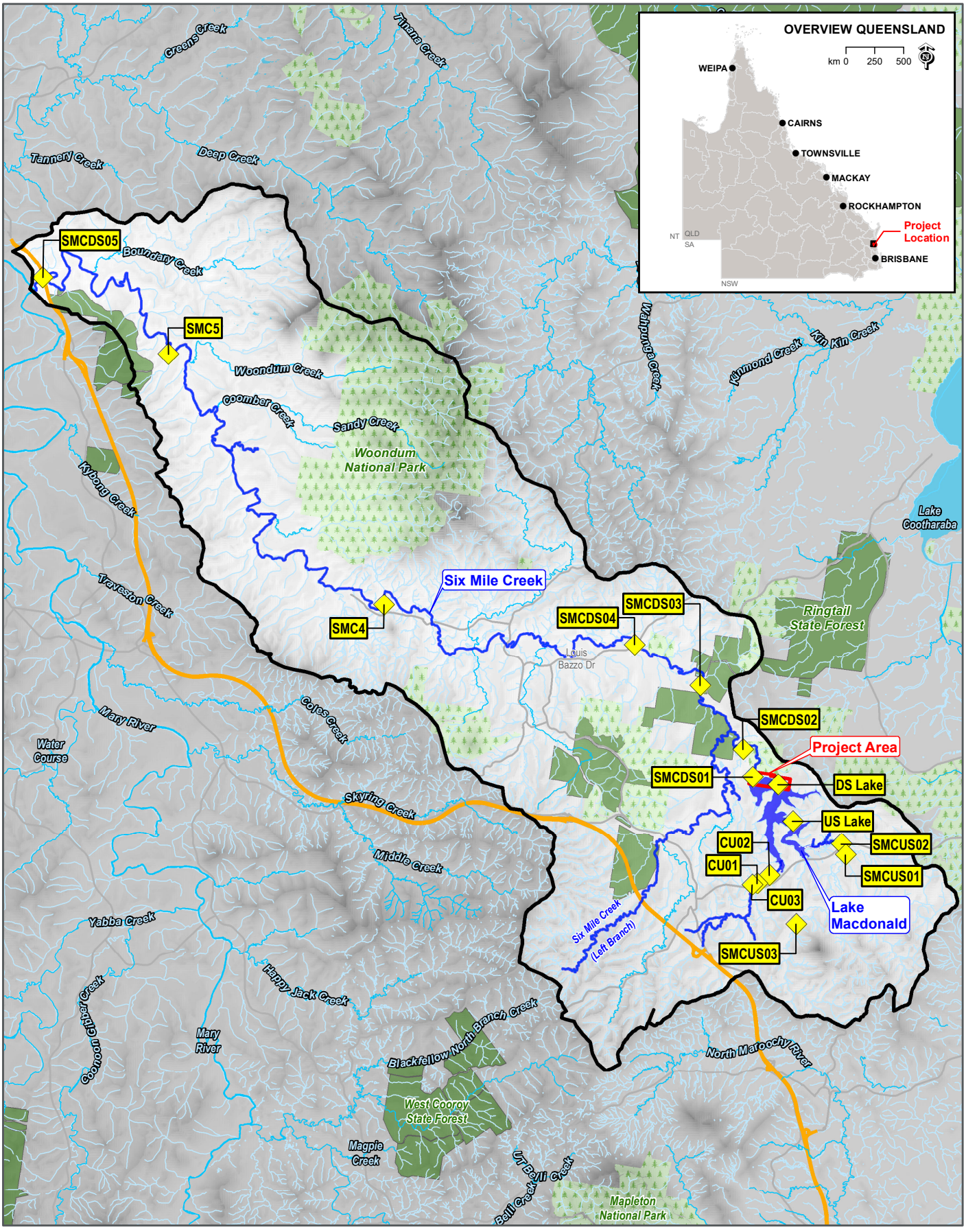
7.2.2 Survey Sites

Overall, across all field surveys completed for the Project, aquatic ecology was assessed at 13 sites on Six Mile Creek and two sites on Lake Macdonald (Table 7-1 and Figure 7-1).

Consultation with key experts was completed in 2015 / 2016 and was presented with the detailed baseline aquatic ecology study completed by frc environmental in 2016 (Appendix G).

FIGURE 7-1:
AQUATIC ECOLOGY SURVEY SITES AND ASSESSMENT AREA

Six Mile Creek Dam Safety Upgrade Project



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seqwater
WATER FOR LIFE

LEGEND

- Water Quality Sites
- Watercourse
- MSES Drainage Line
- Six Mile Creek
- Lake Macdonald
- Bruce Highway
- Secondary Road
- Project Area
- Aquatic Study Area

Protected Areas

- National Parks
- State Forest

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Table 7-1: Description of aquatic ecology survey sites

SITE	DESCRIPTION	EASTING [A]	NORTHING [A]	ASSESSED PARAMETERS [B]	SURVEY DATES
Six Mile Creek – Downstream (DS) of Lake Macdonald					
SMC4	Six Mile Creek; approximately 19 km DS of the Lake Macdonald spillway	480965	7087785	H, WQ	Oct-13, Nov-14, Nov-15, Oct-16, Nov-17
SMC5	Six Mile Creek; approximately 28.5 km DS of the Lake Macdonald spillway	473906	7095982	H, WQ	Oct-13, Nov-14, Nov-15, Oct-16, Nov-17
SMCDS05	Six Mile Creek; approximately 45 km DS of the Lake Macdonald spillway	469799	7098501	H, WQ, F, T	Aug-15
SMCDS04	Six Mile Creek; approximately 7 km DS of the Lake Macdonald spillway	489171	7086480	H, WQ, F, T	Aug-15, Oct-15, Feb-18
SMCDS03	Six Mile Creek; approximately 4.5 km DS of the Lake Macdonald spillway	491312	7085143	H, WQ, P, F, T, M	Aug-15, Oct-15, Feb-18
SMCDS02	Six Mile Creek; approximately 1.5 km DS of the Lake Macdonald spillway	492715	7083047	H, WQ, P, F, T, M	Aug-15, Oct-15, Feb-18
SMCDS01	Six Mile Creek; directly DS of the Lake Macdonald spillway within the spillway stilling basin	493026	7082149	H, WQ, P, F, T, M	Aug-15, Oct-15, Feb-18
Lake Macdonald					
DS Lake	Lake Macdonald; approximately 1 km US of the spillway	493864	7081893	H, WQ, F, T, M	Aug-15, Oct-15, Feb-18
US Lake	Lake Macdonald; approximately 2.5 km US of the spillway	494340	7080694	H, WQ, F, T	Aug-15, Oct-15
Six Mile Creek – Upstream (US) of Lake Macdonald					
CU02	Cooroy Creek; approximately 4 km US of the Lake Macdonald spillway	493582	7078933	H, WQ, F, T	Aug-15, Oct-15
CU01	Cooroy Creek; approximately 4.5 km US of the Lake Macdonald spillway	493179	7078657	H, WQ, F, T	Aug-15, Oct-15

SITE	DESCRIPTION	EASTING [A]	NORTHING [A]	ASSESSED PARAMETERS [B]	SURVEY DATES
CU03	Cooroy Creek; approximately 5 km US of the Lake Macdonald spillway	493019	7078615	H, WQ, F, T	Aug-15, Oct-15
SMCUS02	Six Mile Creek; approximately 5.5 km US of the Lake Macdonald spillway	495930	7079951	H, WQ, F, T	Aug-15, Oct-15
SMCUS01	Six Mile Creek; approximately 6 km US of the Lake Macdonald spillway	496073	7079594	H, WQ, F, T, M	Aug-15, Oct-15, Feb-18
SMCUS03	Six Mile Creek; approximately 11 km US of the Lake Macdonald spillway	494453	7077331	H, WQ, F, T	Aug-15, Oct-15

[A] WGS84 (Zone 56J)

[B] H = habitat; WQ = water quality; P = aquatic plants; M = macroinvertebrates; F = fish; T = turtles

7.2.3 Aquatic Habitat

Additional literature and databases reviewed for the assessment of aquatic habitat included:

- Aquatic Conservation Values, as assessed by the Queensland Environmental Protection Agency using the Aquatic Biodiversity Assessment and Mapping Method (AquaBAMM)
- The Department of Agriculture and Fisheries' (DAF's) Waterway barrier risk layer
- DES's WetlandMaps layer
- Queensland's floodplain assessment and groundwater-dependent ecosystem (GDE) layers.

Survey data were collected using the methods used for the NPI2 AHMP (for Seqwater), which were modified from State of the River methodology (Anderson 1993a, Anderson 1993b). The habitat assessment method was developed to specifically assess suitability of aquatic habitat for Mary River cod (*Maccullochella mariensis*), Australian lungfish (*Neoceratodus forsteri*), Mary River turtle (*Elusor macrurus*) and white-throated snapping turtle (*Elseya albagula*) at each site, which are the aquatic MNES with potential to occur in the Project area. The habitat assessment included:

- Habitat condition, and type and cover of key habitat features (e.g. pools, riffles, undercut banks, large woody debris)
- Depth and width of streams
- Substrate composition
- Habitat sensitivities to various impacts
- Identification of existing disturbances, including fish passage barriers.

7.2.4 Aquatic Plants

Additional information reviewed for the assessment of aquatic plants included the Mary River Aquatic Weeds Strategy 2010-2014 (Mary River Pest Management Group 2010).

The field survey was based on a timed meander (approximately 15 minutes per site), as described in Flora Survey Guidelines for Protected Plants (EHP 2016), with both in-stream and bank habitats surveyed.

7.2.5 Macroinvertebrates

A macroinvertebrate survey was undertaken in February 2018, following nearly two months of base-flow conditions and after several periods of brief elevated flows in October, November and December 2017, but before a high flow event in late February 2018 (i.e. during typical wet season conditions).

Sampling was completed in accordance with the AUSRIVAS protocol (DNRM 2001). Samples were collected over a 10 m length of stream using a standard triangular-framed dip net (250 µm mesh size) and the kick-sweep method to dislodge macroinvertebrates from the substrate. At each site, one sample was collected from bed habitat and another one from edge habitat. Samples were sorted in frc environmental's biological laboratory, identified to the lowest practical taxonomic level (in most instances, family), and counted.

Standard macroinvertebrate indices were calculated (i.e. taxonomic richness, PET richness and SIGNAL-2 Scores) and compared to the guidelines for biological indicators for South East Queensland for lowland freshwaters (EHP 2013), as there are no biological guidelines in the *Environmental Protection (Water) Policy 2009* (EPP (Water)) for the Mary River. These guidelines are:

- Taxonomic richness: ≥ 22
- PET richness: ≥ 4, and
- SIGNAL-2 score: ≥ 4.

7.2.6 Fish

In addition to the data and information sources previously described, fish stocking data and reports for Lake Macdonald were also reviewed and the Department of Natural Resources, Mines and Energy (DNRME) provided fish data for a survey (November 2015) of large bodied fish (boat electrofishing) at the Lake Macdonald tail water, which included records for Mary River cod and Australian lungfish.

The habitat preferences, reproductive ecology and migration strategies of fish species from Six Mile Creek were reviewed and are described in Appendix G.

Fish survey methods were consistent with methods for the survey of large freshwater perches and lungfish in the Survey Guidelines for Australia's Threatened Fish (SEWPAC 2011a). The survey methods included:

- Active fishing methods
  - Underwater camera with live viewing – Where turbidity and light conditions allowed, an underwater camera with live viewing was used to actively search for aquatic MNES species at each site. For watercourse sites, where possible, the full length of the site was walked on the bank so as not to disturb fish and turtles, with the camera mounted on a pole to provide live footage of underwater life in deep pools, under logs, in undercut banks and amongst other habitat features. For sites in Lake Macdonald, the camera was mounted on a pole and operated from the boat prior to electrofishing.
  - Electrofishing – Experienced and certified operators electrofished in accordance with the Australian Code of Electrofishing Practice. Boat electrofishing units were used at the two sites in Lake Macdonald; backpack electrofishing units were used in watercourse sites.
  - Angling – Two set lines using baited barbless hooks were set at each site for one hour at dusk.
- Passive fishing methods
  - Fyke nets – Two fyke nets were set overnight with appropriate floating devices to ensure that air breathing species had access to the surface at all times. For watercourse sites deep pools were targeted, with one fyke oriented in the upstream direction and the other in the downstream direction. In Lake Macdonald, fyke nets were set at sites where water depth allowed (i.e. if water was too deep (> 3 m) then fyke nets could not be set).
  - Baited box traps / bait fish traps – Five box traps were set overnight to sample small / juvenile fish. These traps were placed in appropriate habitat, such as shallow water amongst aquatic plants or other habitat features.

The sampling effort used at each site in each survey is presented in Appendix G.

All fish were identified to species in the field and the abundance recorded. The total length of all fish was also measured in the field.

7.2.7 Turtles

In addition to the data and information sources described above, the turtle assessment included review of 'Freshwater turtles in the Mary River: review of biological data for turtles in the Mary River, with emphasis on *Elusor macrurus* and *Elseya albagula*' (Limpus, 2008).

Turtle field survey methods were consistent with the Survey Guidelines for Australia's Threatened Reptiles (SEWPAC 2011b) and comprised:

- Baited cathedral traps – Three cathedral traps, baited with ox heart meat, were set overnight to capture turtles at sites that had suitable characteristics for setting cathedral traps.

Turtles were also assessed using the fish survey methods described above.

Turtles were identified to species in the field, where possible. Identification of some turtle species was confirmed in the office by review of photographs taken during the field surveys. The species and abundance were recorded along with the life history stage (juvenile, intermediate, adult).

7.2.8 Platypus

Platypus records from Six Mile Creek and Lake Macdonald were obtained from Atlas of Living Australia (viewed 9 October 2018) and from direct observations by Seqwater rangers.

7.2.9 Stygofauna

Stygofauna were assessed using only a desktop approach, including review of relevant literature (e.g. Tomlinson & Boulton 2008; Glanville et al. 2016) and the groundwater study for the Six Mile Creek Upgrade Project (SLR 2018).

7.2.10 Aquatic Ecology Values Assessment

The aquatic ecological value of Six Mile Creek and Lake Macdonald was assessed using the criteria provided in Table 7-2.

Table 7-2: Criteria used to assess the environmental value of each aquatic ecology survey site

AQUATIC ECOLOGICAL VALUE	CRITERIA / DESCRIPTION
Very High	Known occurrence and breeding of aquatic MNES and / or threatened species protected under Queensland *Nature Conservation Act 1992*
High	Known or likely occurrence of aquatic MNES and / or threatened species protected under Queensland *Nature Conservation Act 1992* and / or HEV Waters under the EPP (Water)
Moderate	Aquatic MNES, threatened species protected under Queensland *Nature Conservation Act 1992* and HEV waters unlikely to occur, but suitable habitat for non-listed aquatic species of turtles and fish is present. Regulated vegetation categories under the Queensland *Vegetation Management Act 1999* may be present in riparian areas, and watercourses may be important for fish passage under the Queensland *Fisheries Act 1994* (mapped as having higher than low risk of impact to fish passage by waterway barriers)
Low	Ephemeral watercourse without refugial pools; limited aquatic habitat features present; likely to provide low quality habitat for non-listed aquatic species during high flow events only
Negligible	Site is a drainage feature as per the definition in the Queensland *Water Act 2000*

7.3 Existing Environment

7.3.1 Overview

Six Mile Creek

Six Mile Creek is a large (stream order 5) tributary of the Mary River, that originates inland from Noosa Heads and flows for approximately 60 km north-west before it joins the Mary River approximately 4.5 km south of Gympie (Figure 7-2). Land uses in the catchment of Six Mile Creek include forestry, grazing, horticulture, rural residential and urban areas.

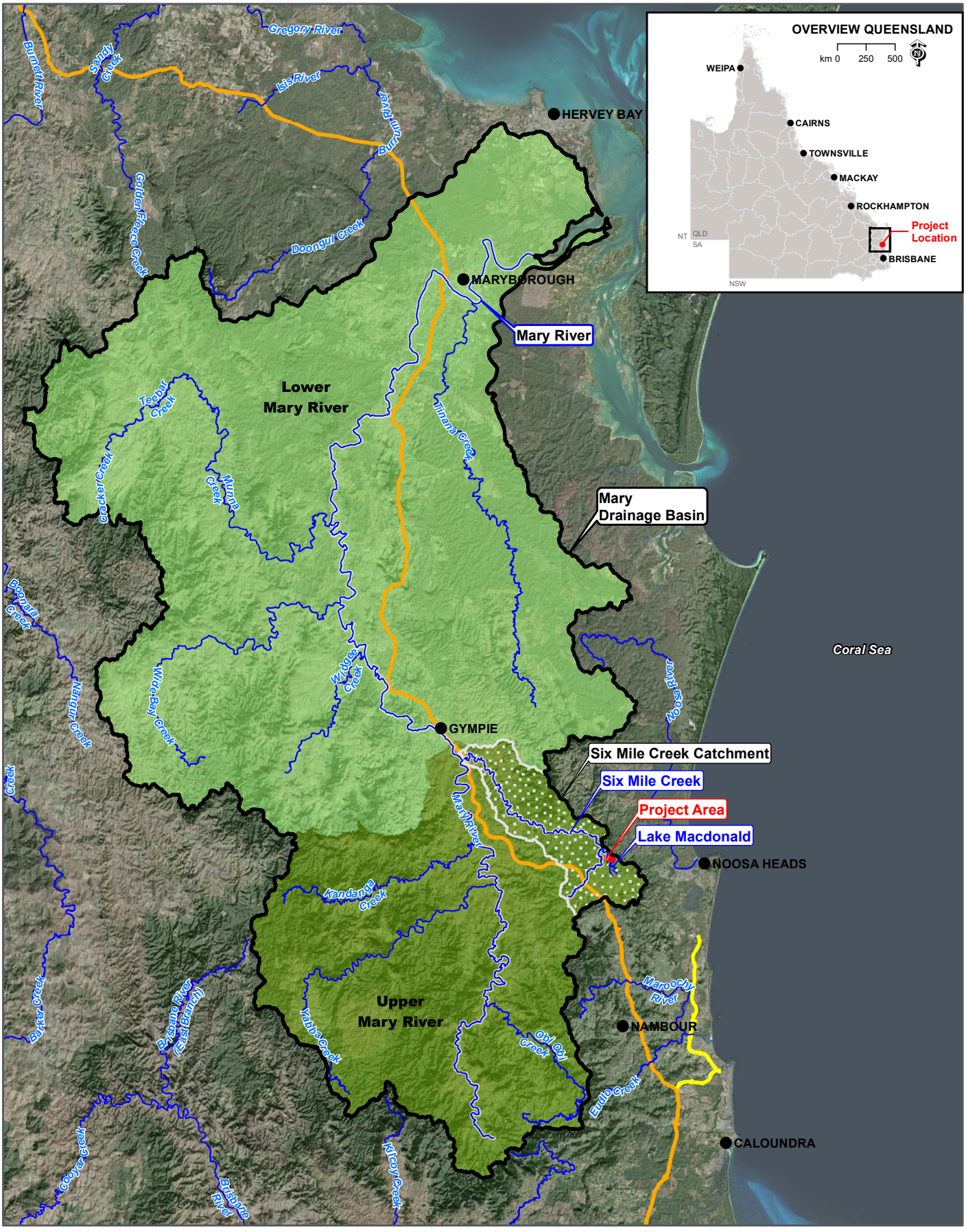
Six Mile Creek has reasonably perennial, albeit variable, flow. Flows greater than 10 ML/day occur approximately 80% of the time at the Cooran gauging station (AMTD 32.4 km), which is downstream of Six Mile Creek Dam. Monthly median flows are highest in March and lowest through the late winter and spring months (Hydrobiology 2008), although there is high variability in the magnitude of daily and inter-annual flows. Detailed discussion of the hydrology of Six Mile Creek and Lake Macdonald is provided in Chapter 6 – Water Resources.

Applicable Environmental Values (EVs) pursuant to the EPP (Water) for Six Mile Creek are shown in Table 8-3 along with the values for the Mary River. An overview of the Mary River is provided in Appendix G.

The *Water Plan (Mary Basin) 2006* presents ecological outcomes for the Six Mile Creek. These include minimising changes to the low flow regime of the creek, and minimising changes to the hydraulic habitat requirements of species such as the Mary River cod and Australian lungfish.

FIGURE 7-2: RIVER BASINS / CATCHMENTS

Six Mile Creek Dam Safety Upgrade Project



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seqwater WATER FOR LIFE

LEGEND

- Locality
- Bruce Highway
- Sunshine Motorway
- Major Watercourse Line
- Lake Macdonald
- Six Mile Creek Catchment Area (Aquatic Study Area)
- Mary Drainage Basin
- Lower Mary River Drainage Sub-Basin
- Upper Mary River Drainage Sub-Basin
- Project Area

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Table 7-3: Environmental Values pursuant to the EPP (Water) for the Mary River and Six Mile Creek

ENVIRONMENTAL VALUE	UPPER MARY RIVER	LOWER MARY RIVER	SIX MILE CREEK
Aquatic ecosystems	✓	✓	✓
Irrigation	✓	✓	✓
Farm supply	✓	✓	–
Stock water	✓	✓	✓
Aquaculture	✓	✓	✓
Human consumers of fisheries	✓	✓	✓
Primary recreation	✓	✓	✓
Secondary recreation	✓	✓	✓
Visual recreation	✓	✓	✓
Drinking water	✓	✓	✓
Industrial use	✓	✓	–
Cultural and spiritual values	✓	✓	✓

✓ EV applies
– EV does not apply

Lake Macdonald

Six Mile Creek Dam, which forms Lake Macdonald, is located on the upper reaches of Six Mile Creek at ATMD 55 km, and is 95 km from the Mary River estuary. It was built in 1965 for the purpose of town water supply, and upgraded in 1980 to increase storage capacity (i.e. 3.6 m was added to the original height of the dam). The catchment area for the dam is approximately 49 km^2, with surrounding land uses including agriculture, forestry, rural residential, and a variety of uses such as conservation, tourism and recreational activities.

The existing dam is an ungated zoned earth and rock fill dam. The spillway consists of anchored concreted slabs on compacted earth fill, with an uncontrolled ogee crest. The capacity of the dam is 8,018 ML at a full supply level (FSL) of 95.32 m AHD, creating an impoundment area of approximately 260 ha with a maximum depth of 10.5 m. The existing dam does not incorporate a fishway.

The Water licences held by Queensland Bulk Water Supply Authority (Seqwater) allow for taking a combined annual total of 5,000 ML from Lake Macdonald, when it is above the minimum operating volume of 22 ML / 87.7 m AHD. Daily environmental releases are made from Six Mile Creek Dam pursuant to the conditions of Seqwater's Water Licences, using in-flow / out-flow rules (as discussed in Chapter 6 – Water Resources).

7.3.2 Aquatic Habitat

Six Mile Creek is a low-gradient, low energy stream, with notophyll vine forest the dominant native riparian vegetation (DNRM 2004). Extensive deposits of large woody debris are an important natural feature of low energy streams, and are a common habitat element in Six Mile Creek (DNRM 2004). Medium length pools (i.e. between 6 and 12 channel widths in length) that are less than 2 m deep are common in Six Mile Creek, with riffles and shallow glides over sand also present (DNRM 2004).

With the exception of the Six Mile Creek Dam, disturbances along Six Mile Creek are relatively minor (DNRM 2004). Downstream of Lake Macdonald, flood flows have been reduced, low flows have been substantially reduced, and dry spells increased due to changes in the flow regime associated with the dam (DNRM 2004). As a result of the lower water levels in Six Mile Creek downstream of Lake Macdonald, large woody debris is more exposed (i.e. no longer providing as much submerged habitat for fish or turtles) and riffles have declined. Consequently, there is less suitable

habitat for fish and turtle passage along this section of Six Mile Creek (DNRM 2004), despite hydrological analysis by Hydrobiology (2008) suggesting that the hydrological regime is not significantly different between current and pre-development scenarios. Sediment transport processes in the lower reaches of Six Mile Creek are likely to have been altered by Lake Macdonald, which captures over 90% of the incoming sediment load (DNRM 2004).

Six Mile Creek is a stream order 5 watercourse along its downstream reaches, and mapping indicates:

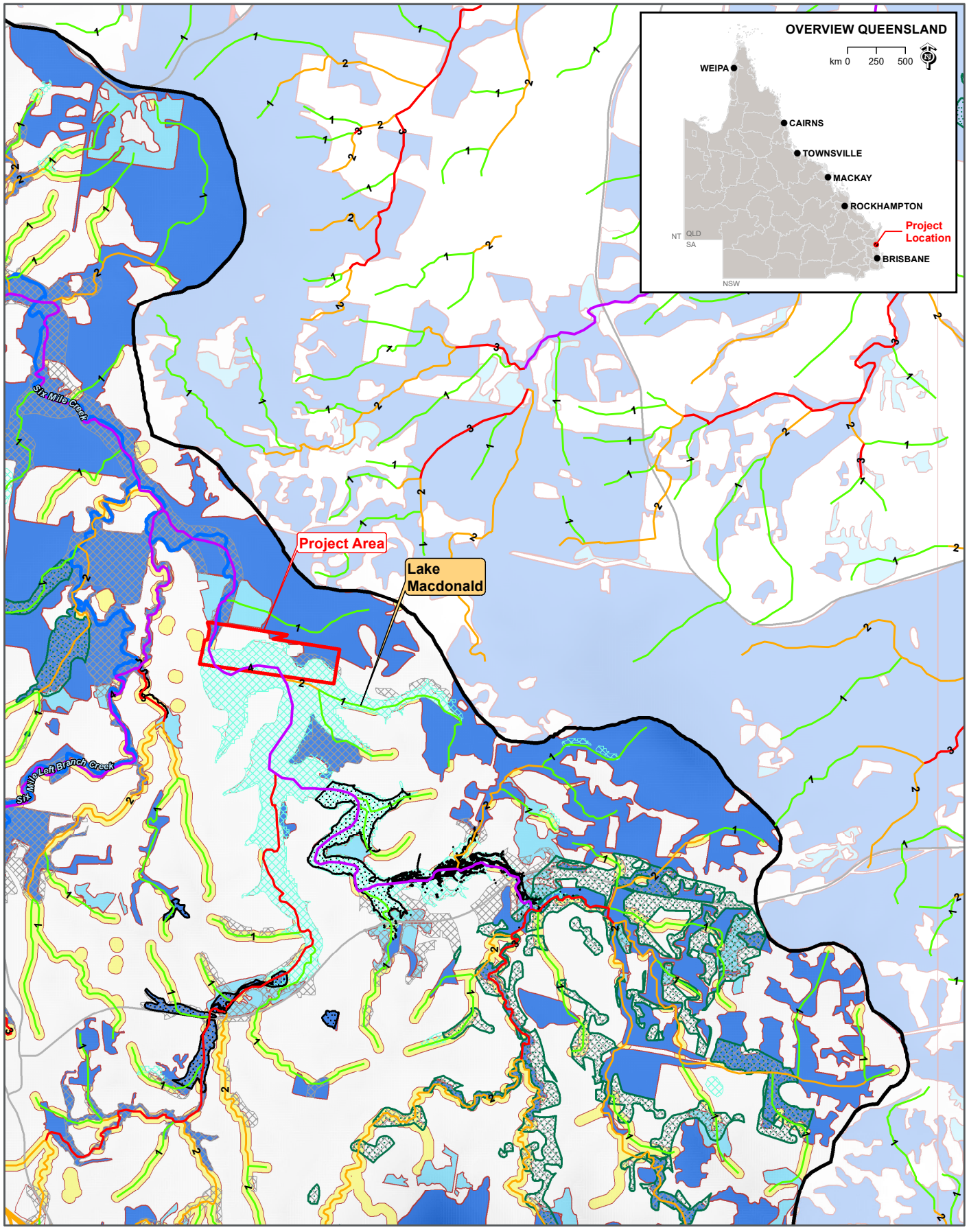
- Floodplain and GDEs occur along or near Six Mile Creek (Map 4.2 in Appendix G)
- The following MSES are present (Figure 7-3):
  - Waterways providing for fish passage (outside urban areas)
  - Wildlife habitat (suitable for platypus)
  - High Ecological Value (HEV) waters (waterways)
  - Regulated vegetation: category R vegetation, vegetation intersecting a watercourse, and vegetation within 100 m of a wetland
  - Riverine and lacustrine (i.e. Lake Macdonald) wetlands
- Very high and high conservation significance riverine areas in Six Mile Creek downstream of Lake Macdonald, and medium conservation significance riverine areas upstream of Lake Macdonald (Map 4.5 in Appendix G).

The detailed results of habitat surveys for each site from 2013 to 2018 are presented in Appendix G. Key habitat features of:

- **Six Mile Creek downstream of Lake Macdonald** include:
  - A well-defined channel with high steep banks, and undercut banks present at most sites
  - Substrate dominated by clay and silt, with gravel present at most sites and bedrock present at some sites
  - High variation in flow, with riffles, runs and shallow and deep pools present at most sites
  - Low abundance of submerged aquatic flora, except at site SMCDS01 immediately downstream of the dam, where there was some *Cabomba caroliniana* and *Nymphoides indica*
  - Abundant large woody debris and leaf packs at each site
  - Riparian vegetation is in good condition, providing shade and a supply of fine and large woody material
  - Presence of suitable breeding locations for Mary River cod, but very limited breeding habitat for Australian lungfish
  - Absence of suitable nesting habitat for Mary River and white-throated snapping turtle, and few places for turtle basking
  - An existing waterway barrier (i.e. rubble from the old road bridge) approximately 50 m downstream of the Six Mile Creek dam
- **Within Lake Macdonald** include:
  - A single flow habitat (deep pool)
  - High abundance of submerged aquatic flora, predominantly *Cabomba caroliniana* and *Nymphoides indica*, and beds of emergent Persicaria spp. near lake margins
  - A substrate dominated by silt, with some sand near banks
  - An absence of suitable breeding locations for Mary River cod and Australian lungfish
  - Absence of suitable nesting habitat for Mary River turtle and white-throated snapping turtle, and few places for turtle basking
  - Limited large woody debris
- **Six Mile Creek upstream of Lake Macdonald** include:
  - A well-defined channel with high steep banks, and undercut banks present at most sites
  - The flow habitats of some sites were influenced by impounded water, with site SMCUS03 having moderate diversity of flow habitats comprising riffles, runs and deep pools
  - SMCUS01, SMCUS02 and Cooroy Creek sites were choked by *Cabomba caroliniana*
  - The presence of potentially suitable breeding locations for Mary River cod, but very limited breeding habitat for Australian lungfish
  - Limited suitable nesting habitat for Mary River and white-throated snapping turtle, and
  - Turtle basking places present at most sites.

FIGURE 7-3: MATTERS OF STATE ENVIRONMENTAL SIGNIFICANCE
WILDLIFE AQUATIC HABITAT RELATING TO AQUATIC ECOLOGY

Six Mile Creek Dam Safety Upgrade Project



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2. Matters of state environmental significance - High ecological value waters - waterways - Queensland © State of Queensland (Department of Environment and Science) 2018

seqwater
WATER FOR LIFE

LEGEND

- Bruce Highway
- Secondary Road

Risk of Impact

- 1 - Low
- 2 - Moderate
- 3 - High
- 4 - Major

- Project Area
- Study Area
- MSES High Ecological Value Water Wetlands
- Potential breeding habitat for Platypus

Wetland Classifications

- Lacustrine System
- Riverine System

Regulated Vegetation Map

- Category A area
- Category B area
- Category C area
- Category R area
- Category X area
- Water

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7.3.3 Matters of National Environmental Significance

There are four aquatic MNES species that are known to occur, or that may occur, in Six Mile Creek and/or Lake Macdonald. These are Mary River cod, Australian lungfish, Mary River turtle, and white-throated snapping turtle. The ecology and distribution of these species are described in detail in Chapter 5 – MNES.

7.3.4 Aquatic Plants

Aquatic plants are absent or rare in Six Mile Creek downstream of Lake Macdonald, although they are common in the lake, with the noxious weed *Cabomba caroliniana* growing prolifically in the dam (DNRM 2004) and the noxious *Hygrophila costata* occurring in high cover along the lake margins. Various attempts to control Cabomba in Lake Macdonald have been made, particularly by Noosa Shire Council through the use of mechanical harvesting, but eradication of Cabomba is generally considered to be unviable with current control methods. Hygrophila infestations around Lake Macdonald have been effectively controlled by local stakeholder groups and Seqwater, and its occurrence is now sparse. A plan to eradicate remaining Hygrophila from Lake Macdonald and the upper catchment is currently being considered.

The diversity and growth forms of aquatic plants in the wider Mary River are greater than in Six Mile Creek, with the diversity of aquatic weeds also higher in the Mary River compared to Six Mile Creek (Mary River Pest Management Group 2010).

The results of the field surveys are shown in Table 7-4. In general, the overall diversity and cover of aquatic plant species and growth forms was low, with Lake Macdonald having the highest diversity of aquatic plant species both in the water and on the banks, and the highest diversity of growth forms in the water. Exceptions were Cabomba and water snowflake in Lake Macdonald, and Lomandra on banks of the downstream and upstream reaches of Six Mile Creek.

No listed threatened plant species were recorded, reflecting the absence of records of threatened aquatic plants in the Project area. Introduced species included Cabomba and cape lily, with Cabomba a restricted biosecurity matter.

Table 7-4: Aquatic plant survey results

SPECIES	COMMON NAME	GROWTH FORM	SIX MILE CREEK DS	LAKE MACDONALD	SIX MILE CREEK US
Plants in water (in-stream)					
Cabomba caroliniana	Cabomba [c]	submerged	I [a]	D	S
Nymphoides indica	water snowflake	floating-attached	I [a]	S	I
Ludwigia peploides	water primrose	emergent		I [b]	I
Philydrum lanuginosum	frog's mouth	emergent		I [b]	
Eleocharis sp.	spike rush	emergent		I [b]	
Nymphae caerulea	cape waterlily [c]	floating-attached		I	
Azolla sp.	Azolla	floating			I
Typha sp.	bull rush	emergent		I [b]	
Potamogeton javanicus	Javan pondweed	submerged		I	
Lemnoideae	duck weed	floating			I
Plants not in water (banks)					
Lomandra spp.	mat rush	_	D	I	S

SPECIES	COMMON NAME	GROWTH FORM	SIX MILE CREEK DS	LAKE MACDONALD	SIX MILE CREEK US
Carex spp.	Sedge	_	I		
Cyperus spp.	flat sedge	–	I	I	I
Persicaria spp.	knot weeds	–	I	I	I
Ludwigia octovalvis	willow primrose	–		I	
Schoenoplectus mucronatus	bog bulrush	–	I		

I = isolated; S = scattered; D = dense cover

[a] Cabomba was found in Six Mile Creek downstream of Lake Macdonald, but only within several hundred meters of the dam. Most of Six Mile Creek downstream was without instream aquatic plants, including Cabomba.

[b] These emergent species only occurred in shallow water along the edge of Lake Macdonald

[c] Denotes pest species

7.3.5 Macroinvertebrates

Macroinvertebrate communities are highly variable in Six Mile Creek, with taxonomic diversity low at some sites due to limited microhabitat diversity (DNRM 2004).

Survey results found low taxonomic diversity of macroinvertebrates in bed and edge habitat in Six Mile Creek, with taxa in bed habitat ranging from only eight at site SMCDS04 to 19 at site SMCDS02, and taxa in edge habitat ranging from 14 taxa at site SMCDS03 to 25 taxa at SMCDS04 (Table 7-5 and Table 7-6). The diversity of sensitive taxa, indicated by both PET richness, and the overall proportion of sensitive taxa, indicated by SIGNAL-2 Scores, was similar for bed and edge habitat, and often lower than the WQO, suggesting that sensitive taxa are not common in macroinvertebrate communities in Six Mile Creek. Fewer samples were collected upstream of, and within, Lake Macdonald than were collected downstream, but the macroinvertebrate indices for upstream and Lake Macdonald were generally in the range of indices recorded downstream of the dam.

Table 7-5: Mean macroinvertebrate indices in bed habitat at each site in February 2018

SITE	MACROINVERTEBRATE INDICES			
	ABUNDANCE	TAXONOMIC RICHNESS	PET RICHNESS	SIGNAL 2
Six Mile Creek downstream of Lake Macdonald				
SMCDS04	167	8	1	3.40
SMCDS03	169	15	4	4.11
SMCDS02	153	19	5	4.12
SMCDS01	190	14	3	3.48
Lake Macdonald				
DS Lake	131	10	2	3.83
Six Mile Creek upstream of Lake Macdonald				
SMCUS01	204	13	1	3.59

Grey shading indicates where a macroinvertebrate index does not comply with the WQO

Table 7-6: Mean macroinvertebrate indices in edge habitat at each site in February 2018

SITE	MACROINVERTEBRATE INDICES			
	ABUNDANCE	TAXONOMIC RICHNESS	PET RICHNESS	SIGNAL 2
Six Mile Creek downstream of Lake Macdonald				
SMCDS04	177	25	4	4.06
SMCDS03	125	14	4	3.82
SMCDS02	123	16	5	3.77
SMCDS01	232	19	3	3.60
Lake Macdonald				
DS Lake	163	15	4	3.31
Six Mile Creek upstream of Lake Macdonald				
SMCUS01	126	17	1	3.45

Grey shading indicates where a macroinvertebrate index does not comply with the WQO

7.3.6 Fish

The fish community in Six Mile Creek downstream of Lake Macdonald is generally in good condition and the creek provides significant breeding habitat for Mary River cod (DNRM 2004). Within Lake Macdonald, the impounded water is likely to favour some species native to Six Mile Creek (e.g. bony bream) as well as the recreational species (not native to the creek) that have been stocked in the dam (e.g. Australian bass, yellow belly).

A total of 26 native species, and five pest species, are known or likely to occur in Six Mile Creek, with a number of these species having been caught in the field surveys (Table 7-7). Mary River cod and Australian lungfish are both MNES species (refer to Chapter 5 – MNES for a detailed description of these species) and are also listed threatened species under the Queensland *Nature Conservation Act 1992* (NC Act).

Eastern Gambusia (*Gambusia holbrooki*) and tilapia (*Oreochromis mossambicus*) are restricted biosecurity matters under the Queensland *Biosecurity Act 2014*. Tilapia were only recently recorded for the first time in Six Mile Creek downstream of Lake Macdonald (January 2018). It is currently unknown if tilapia occur in Lake Macdonald, or if the dam wall has prevented this species extending further upstream.

A summary of the preferred habitat, reproductive ecology and migration patterns of fish species in Six Mile Creek is provided in Table 7-8. In general, the literature review found that:

- Larger bodied species, such as Mary River cod and Australian lungfish, have a preference for deep pool habitats with large woody debris.
- Estuarine tolerant species (e.g. striped gudgeon, empire gudgeon, mullet and estuary glassfish), are predominantly distributed within lowland sections of the Mary River, including lowland tributaries.
- Most species prefer fine substrates (sand/gravel) with low to moderate flow.
- Mary River cod spawn annually in spring, soon after the water temperature rises to 20°C. Spawning activity may be increased on a full moon.
- Australian lungfish spawn in slow-flowing shallow pools among aquatic plants between August and December, where they deposit eggs on plants or submerged matts of fine roots.
- Bullrout, sea mullet, Australian bass, Australian smelt, common gudgeon, and striped gudgeon spawn in winter and early spring, prior to increased water temperature and flows.
- Most other fish species spawn in summer with increased water temperature and water flow.

The fish species in Six Mile Creek have a range of migration and dispersal patterns, including species that must migrate to estuaries or the ocean to complete their life cycle (diadromous – including species with catadromous[1] and amphidromous[2] forms of diadromy), and species that migrate within freshwater reaches (potamodromous). Movement of fish species known or likely to occur in Six Mile Creek is as follows:

- Australian lungfish move larger distances in impounded reaches than in flowing reaches, as suitable spawning locations are less common in impounded waters, so movement distances linked with the annual breeding cycle are greater.
- Mary River cod have a tendency to move upstream and / or from the Mary River to tributaries during spring and summer when stream flow increases, and downstream during winter, often over distances spanning many kilometres (e.g. up to approximately 30 km; Simpson and Jackson, 1996a).
- The southern shortfin eel, longfin eel, Australian bass, empire gudgeon, flathead gudgeon and mullet species are diadromous, with spawning occurring in estuarine or marine waters.
- The flyspecked hardyhead, crimson-spotted rainbowfish, Agassiz's glassfish, carp gudgeon, dwarf flathead gudgeon, bony bream and Australian smelt are potamodromous. These species use various cues for migration, including increased water temperature and rise in river discharge.
- Mouth almighty, silverstreak hardyhead and eel-tailed catfish have limited migration.

[1] Fish that migrate down rivers to the sea to spawn.

[2] Fish that migrate from fresh to salt water or from salt to fresh water at some stage of the life cycle other than the breeding period.

Table 7-7: Fish species known from, or likely to occur in Six Mile Creek

SPECIES	COMMON NAME	CAUGHT DURING FIELD SURVEYS
Native Species		
Ambassidae		
Ambassis agassizii	Agassiz's glassfish	✓
Ambassis marianus	estuary glassfish	–
Anguillidae		
Anguilla australis	southern shortfin eel	✓
Anguilla reinhardtii	longfin eel	✓
Apogonidae		
Glossamia aprion	mouth almighty	✓
Atherinidae		
Craterocephalus marjoriae	silverstreak hardyhead	–
Craterocephalus stercusmuscarum	flyspecked hardyhead	✓
Eleotridae		
Gobiomorphus australis	striped gudgeon	–
Hypseleotris spp.	common gudgeons	✓
Hypseleotris compressa	empire gudgeon	–
Mogurnda adspersa	purple spotted gudgeon	✓
Philypnodon macrostomus	dwarf flathead gudgeon	✓
Philypnodon grandiceps	flathead gudgeon	✓
Melanotaeniidae		
Melanotaenia duboulayi	crimson-spotted rainbowfish	✓
Percichthyidae		
Maccullochella mariensis	Mary River cod	✓
Percalates novemaculeata	Australian bass	✓
Macquaria ambigua	yellowbelly	✓
Plotosidae		
Tandanus tandanus	eel-tailed catfish	✓
Neosilurus hyrtlii	Hyrtl's tandan	–
Pseudomugilidae		
Pseudomugil signifer	Pacific blue-eye	✓
Retropinnidae		

SPECIES	COMMON NAME	CAUGHT DURING FIELD SURVEYS
Retropinna semoni	Australian smelt	✓
Clupeidae		
Nematolosa erebi	bony bream	✓
Ceratodontidae		
Neoceratodus forsteri	Australian lungfish	✓
Mugilidae		
Trachystoma petardi	pinkeye mullet	–
Mugil cephalus	sea mullet	–
Tetrarogidae		
Notesthes robusta	bullrout	–
Terapontidae		
Leiopotherapon unicolor	spangled perch	✓
Osteoglossidae		
Scleropages leichardti	southern saratoga	✓
Pest Species		
Gambusia holbrooki	eastern Gambusia	✓
Xiphophorus maculatus	platy	–
Xiphophorus hellerii	swordtail	✓
Poecilia reticulata	guppy	–
Oreochromis mossambicus	tilapia	✓ [a]

[a] observed only

Table 7-8: Summary of habitat requirements of native fish species known or likely to occur in Six Mile Creek

SPECIES	COMMON NAME	CATCHMENT POSITION	PHYSICAL HABITAT	FLOW-HABITAT	REPRODUCTIVE ECOLOGY	MIGRATION PATTERN
Ambassis agassizii	Agassiz's glassfish	Mid to upper catchment	Submerged aquatic plants, fine substrates (sand/gravel) and open water	Low gradient, slow moving, moderate depth pools	Spring to autumn, triggered by rising temperatures	Potamodromous
Ambassis marianus	estuary glassfish	Lower catchment; brackish estuaries, tidal creeks and lower reaches	Mangrove roots, woody debris and aquatic vegetation	–	–	–
Anguilla australis	southern shortfin eel	Lower to mid catchment	Fine substrates (sand/gravel), leaf litter, woody debris, undercut banks and submerged roots	Shallow, still water pools	Outward migration during summer and autumn, spawning between June and September	Catadromous
Anguilla reinhardtii	longfin eel	Entire catchment, commonly lower to mid	No discernible habitat preference	Prefers flowing water including riffles and runs	Outward migration during summer and autumn, unknown spawning time	Catadromous
Glossamia aprion	mouth almighty	Lower to mid catchment	Large rivers, limited riparian cover, fine substrates (sand/gravel), submerged macrophytes	Deep slow-flowing pools	Spring and early summer	Limited migration
Craterocephalus marjoriae	silverstreak hardyhead	Entire catchment, commonly mid to upper	Intermediate substrates (gravel/cobble), submerged macrophytes, filamentous algae, leaf litter, undercut banks and submerged roots	Moderate depth and velocity, but also occurs in shallow riffles with high velocity	Late winter to summer, with increased water temperature	Limited migration
Craterocephalus stercusmuscarum	flyspecked hardyhead	Entire catchment	Macrophyte beds and in-stream cover	No discernible flow regime, prefers moderate current velocities, seen to congregate where streams flow into still water	Late winter to summer with increased water temperate	Potamodromous

SPECIES	COMMON NAME	CATCHMENT POSITION	PHYSICAL HABITAT	FLOW-HABITAT	REPRODUCTIVE ECOLOGY	MIGRATION PATTERN
Gobiomorphus australis	striped gudgeon	Lower to mid catchment including estuaries and dune lake systems	Fine substrates (sand/gravel), leaf-litter, undercut banks and submerged roots	Pools and runs with low velocity and moderate depth	Autumn and winter	Amphidromous
Hypseleotris spp.	common carp gudgeons	Entire catchment, commonly lower to mid	Fine to intermediate substrates (sand/gravel), submerged aquatic plants, undercut banks, submerged roots	Narrows streams with low flow and moderate depth (0.43 m)	Late winter to early autumn, prior to high flows	Potamodromous
Hypseleotris compressa	empire gudgeon	Lower catchment in coastal rivers and streams	Fine substrates (mud, sand, gravel), leaf litter, undercut banks and submerged roots	Moderate streams (5 m wide, with low flow and moderate depth (0.35 m)	January to May with increased water temperature	Amphidromous
Mogurnda adspersa	purple spotted gudgeon	Entire catchment, commonly coastal uplands	Fine to intermediate substrates (sand, gravel, cobble), aquatic plants, filamentous algae, leaf litter, submerged roots and undercut banks	Pools with low velocity and low to moderate depth	Spring to late summer	Limited migration
Philypnodon macrostomus	dwarf flathead gudgeon	Entire catchment, commonly lower to mid-upper catchment	Intermediate substrates (gravel, cobble), submerged plants, leaf litter, undercut banks, submerged roots	Low flow, moderate depth (0.31 m) but can occur in shallow, high velocity riffle habitats	Spring to autumn, with increasing water temperature	Amphidromous
Philypnodon grandiceps	flathead gudgeon	Entire catchment, commonly lower to mid catchment	Intermediate to coarse sediment (gravel, cobbles, bedrock), aquatic plants, filamentous algae, leaf litter, submerged roots, undercut banks	Low flow, moderate depth (0.4 m), but has been classified as a riffle-dwelling species	Spring to autumn, with increasing water temperature	Amphidromous
Melanotaenia duboulayi	crimson-spotted rainbowfish	Entire catchment, commonly mid catchment	Fine to intermediate substrate (sand, gravel), submerged plants, filamentous algae, leaf	Low-moderate flow, moderate depth (0.43 m), but occasionally in shallow	Late winter to summer with increasing water temperature	Potamodromous

SPECIES	COMMON NAME	CATCHMENT POSITION	PHYSICAL HABITAT	FLOW-HABITAT	REPRODUCTIVE ECOLOGY	MIGRATION PATTERN
			litter, undercut banks, submerged roots	riffles with high water velocity		
Percalates novemaculeata	Australian bass	Entire catchment, males predominantly estuarine and females in lagoons and upstream	Submerged woody debris, undercut banks and overhanging vegetation	Slow, deep (>2 m) pools	June to August with elevated discharge	Catadromous
Maccullochella mariensis	Mary River cod	Entire catchment, but now thought to be restricted to three isolated mid catchment regions	Mud/clay substrate, woody debris and log jams, extensive overhanging vegetation, undercut banks, rock ledges	Slow, deep pools	Annually around spring when temperatures rise above 20°C	Potamodromous
Tandanus tandanus	eel-tailed catfish	Entire catchment, mostly mid to upper catchment	Variety of habitats but prefers intact low to moderate riparian zone, diverse substrates (sand, gravel, cobble), leaf litter, undercut banks	Low flow streams with moderate depths (0.4 m)	Spring and summer with increasing temperature	Limited migration
Neosilurus hyrtlii	Hyrtl's tandan	Entire catchment	Uses virtually every aquatic habitat except estuarine reaches, commonly from areas with muddy or sandy substrates, leaf litter, submerged plants and blue-green algae	Slow, deep (>2 m) pools	Summer wet season, with increasing water levels	Potamodromous
Pseudomugil signifer	Pacific blue-eye	Entire catchment, commonly in the lower catchment	Intermediate substrates (gravel, cobble), leaf litter, submerged roots, undercut banks, submerged plants and filamentous algae	Common in streams of intermediate width (6-10m) and low to moderate flow.	Late winter to late summer, with increasing water temperature	No migration pattern is known
Retropinna semoni	Australian smelt	Entire catchment, commonly lower to mid catchment	Intermediate to coarse substrate (gravel, cobble), aquatic plants, filamentous algae	Shallow (0.23 m), high velocity riffles and runs, but is found in deeper slow flowing pools	Winter to summer, with low water temperatures	Potamodromous

SPECIES	COMMON NAME	CATCHMENT POSITION	PHYSICAL HABITAT	FLOW-HABITAT	REPRODUCTIVE ECOLOGY	MIGRATION PATTERN
				during periods of low flow		
Nematolosa erebi	bony bream	Lower to mid catchment, although known to survive in upper catchment conditions when translocated	No discernible habitat known, instead thought to refuge with fellow fish	Most common in lowland channel lagoons, with juvenile fish common in open shallow areas (30-150 cm) and adults in deeper waters	All year except June to August (the coldest months)	Potamodromous
Neoceratodus forsteri	Australian lungfish	Lower to mid catchment, but restricted to freshwater	Mud, sand and gravel substrates, overhanging vegetation, submerged woody debris and dense macrophyte beds. Tends to avoid open water	Slow-flowing rivers and still water reservoirs and deep pools	August to December with peak activity within three months of the winter solstice.	Potamodromous
Trachystoma petardi	pinkeye mullet	Lower catchment, predominantly in estuarine waters	–	Deep pools or gently flowing sections of rivers	Summer	Catadromous
Mugil cephalus	sea mullet	Lower catchment, predominantly in estuarine waters	Varies on life history stage, larvae are initially pelagic in estuarine water, juveniles prefer shallow water with sandy substrate and adults have no discernible preference	Predominantly tidally influence slow-flowing rivers, but can migrate upstream into fast-flowing tributaries	Autumn to winter, stimulated by decreased water temperature	Catadromous
Notesthes robusta	bullrout	Lower catchment, predominantly within 50km of the river mouth	Intermediate substrate (gravel/cobble) and in-stream cover	Riffle/run habitats with a depth of 0.5 m and flow less than 0.3 m/s	Possibly winter to spring	Catadromous
Leiopotherapon unicolor	spangled perch	Lower to mid-upper catchment,	Fine substrate (sand and gravel), predominantly near undercut banks and submerged woody debris	Little to no flow at depths between 0.3 to 0.6 m	Summer during the wet season with rising water temperature	Potamodromous

Sources: Fishbase 2010, Pusey et al. 2004, DAF 2015, DoE 2015

Detailed results of the fish surveys for each site are presented in Appendix G. The key results from the fish surveys were:

- Several species, including Pacific blue eye, were only present in Six Mile Creek downstream of Lake Macdonald, suggesting that the dam prevents these species from migrating further upstream
- Several diadromous species expected to be present in Six Mile Creek were absent (e.g. sea mullet, pink eye mullet, estuary glassfish, striped gudgeon, empire gudgeon), which may reflect the cumulative impacts of barriers to fish passage in the lower Mary River between the estuary and Six Mile Creek
- Mary River cod and Australian lungfish were only caught in Six Mile Creek downstream of Lake Macdonald
- Common gudgeons were the most abundant species, including in Lake Macdonald
- There is a seasonal pattern in abundance, with abundance of most species higher in spring compared to summer
- The abundance of pest fish (eastern Gambusia and swordtails) was highest in Six Mile Creek upstream of Lake Macdonald
- Most of the species caught had healthy populations comprised of juveniles, sub-adults and adults
- During periods of low flow fish may become isolated in the tailwater pool downstream of Lake Macdonald.

The total length of each fish caught in each survey is shown by species in Appendix G. Results show a:

- Gradual increase in fish lengths for most species, indicating healthy populations.
- Steep increase in the length of bony bream in Lake Macdonald, suggesting this species can grow to a larger size in reservoir habitat, but there were no other notable size differences between waterway and reservoir sections of Six Mile Creek for any other species.
- Trend with a strong inflection point (i.e. gradual incline that changes to a steep incline) for some species, suggesting the presence of adults of different size (i.e. some relatively very large individuals were present). This may be related to the age of the fish or the habitat within which it was caught (e.g. bony bream) or it may be linked to sexual dimorphism of adult fish (i.e. where adult males are larger than adult females for carp gudgeons, and adult females are larger than adult males for eastern Gambusia; Allen et al., 2002).

Spawning Mary River cod have been recorded from Six Mile Creek downstream of Lake Macdonald (Dunlop 2016). Consequently, this reach of Six Mile Creek supports a key population of Mary River cod, although inter-annual recruitment success is likely to be variable. Reproduction by Mary River cod in and upstream of Lake Macdonald has not been assessed, although at least 112,730 Mary River cod fingerlings were released to Lake Macdonald between 1983 and 2015 (MRCCA 2016). Reproduction by Australian lungfish in Six Mile Creek is likely to be very limited as preferred breeding habitats are absent, and it is expected that there would be no reproduction in Lake Macdonald (see Kind 2002) or in Six Mile Creek upstream of Lake Macdonald.

7.3.7 Turtles

The Mary River has high diversity (six species) and endemism (two regionally endemic species) of freshwater turtles (Limpus 2008):

- Mary River turtle – endemic to the Mary River Basin
- White-throated snapping turtle – endemic to the Mary, Burnett and Fitzroy River Basins
- Krefft's river turtle (*Emydura macquarii krefftii*) – widespread
- Saw-shelled turtle (*Wollumbinia latisternum*) – widespread
- Eastern long-necked turtle (*Chelodina longicollis*) – widespread, and
- Broad-shelled river turtled (*Chelodina expansa*) – widespread.

Mary River turtle (endangered) and white-throated snapping turtle (critically endangered) are MNES, listed as threatened species under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and also under the NC Act. A detailed description of these species is provided Chapter 5 – MNES. Predation of eggs from nesting banks is the most critical threat to the survival of these two species, causing a deficiency of immature turtles and very low recruitment rates in both species, although past harvesting of eggs from Mary River turtle nests has a legacy in the continuing decline of this species (Limpus 2008).

While Six Mile Creek was not surveyed for turtles by Limpus (2008), Mary River turtle and white-throated snapping turtle are known to occur in 'permanent stream and large pool habitats' (Limpus 2008, p.17 and p. 31), whereas the Krefft's river turtle is commonly found in permanent and semi-permanent waterways and man-made waterbodies on

ephemeral streams (Limpus 2008, p. 45). Mary River turtle and white-throated snapping turtle has been found in several of the larger tributaries of the Mary River, including Tinana Creek, Yabba Creek and Obi Obi Creek. White-throated snapping turtle has also been found in several tributaries and tended to extend further upstream in both tributary streams and the Mary River compared to Mary River turtle (Limpus 2008). It is therefore possible that both Mary River turtle and white-throated snapping turtle occur infrequently in the lower reaches of Six Mile Creek, with white throated-snapping turtle possibility occurring further upstream than Mary River turtle.

Breeding banks for Mary River turtle and white-throated snapping turtle are known along two reaches of the Mary River proper (the first near Tiaro and the second between Traveston and Kenilworth) and in Tinana Creek, and white-throated snapping turtle breed in Yabba Creek (Limpus 2008). Previous survey work for the Project in August and October 2015 found that it is unlikely that there is suitable breeding habitat for either species on Six Mile Creek (frc environmental, 2016).

Four of the six turtle species known from the Mary River catchment were caught during the baseline surveys (Table 7-9). Only saw-shelled turtle was recorded in Six Mile Creek downstream of Lake Macdonald, with eastern long-necked turtle and Krefft's river turtle recorded from Lake Macdonald, and all four species recorded from upstream of Lake Macdonald (Appendix G). Saw-shelled turtle and Krefft's river turtle were the most abundant turtle species. Only two juvenile saw-shelled turtles were caught; all other individuals were adults (Appendix G).

Table 7-9: Turtles caught during field surveys

SPECIES	COMMON NAME	SIX MILE CREEK DS	LAKE MACDONALD	SIX MILE CREEK US
Emydura macquarii krefftii)	Krefft's river turtle		✓	✓
Wollumbinia latisternum	Saw-shelled turtle	✓		✓
Chelodina longicollis	Eastern long-necked turtle		✓	✓
Chelodina expansa	Broad-shelled river turtle			✓

7.3.8 Platypus

Platypus (*Ornithorhynchus anatinus*) is a long-lived (up to 17 years), small, egg-laying, amphibious mammal that is widely distributed in eastern Australia (Grant 1989). It inhabits perennial freshwater streams and connected lentic habitats (including impounded waters), where it spends about 50% of time in water (foraging, moving) and the remaining 50% in one of several short, simple resting burrows (Grant 1989).

Platypus feeds predominantly on benthic invertebrates, with foraging typically occurring at night or dusk, with some individuals foraging during the day in winter. Foraging movements generally within a 1.5 km range, although movements of over 3 km have been recorded, and juveniles are speculated to move over larger distances such as when dispersing from natal areas (Grant 1989).

The breeding season is typically spring, with breeding occurring earlier in norther regions of the species' distribution compared to southern regions. Eggs laid, and young raised, within long (up to 30 m), complex breeding burrows that are maintained by breeding females. Young are weaned after approximately four months and emerge from the burrow in late summer (Grant 1989).

Platypus is a 'Special Least Concern' species under the NC Act, but is not threatened at National or State levels.

There are confirmed platypus records from Six Mile Creek downstream, within and upstream of Six Mile Dam, including mid-area of Lake Macdonald and within impounded sections of both the Six Mile Creek and Cooroy Creek arms of Lake Macdonald.

7.3.9 Stygofauna

Stygofauna are subterranean aquatic animals that live in the pores, voids and cavities of aquifers and other groundwater ecosystems. Many species of stygofauna have specialised adaptations to underground life and communities are typically dominated by crustaceans, including copepods, amphipods, isopods and syncarids.

Stygofauna have no conservation listing in Queensland. The following are listed under Commonwealth EPBC Act:

- The Cape Range Remiped (*Kumonga exleyi*) in Western Australia, which is listed as Vulnerable
- Stygofauna communities associated with Great Artesian Springs (i.e. the community of native species dependent on natural discharge of groundwater from the Great Artesian Basin), which are listed as Endangered.

The Project area is not within the Great Artesian Basin, and is outside the known range of the Cape Range Remiped, therefore listed species of stygofauna do not occur within the Project area. Further information on stygofauna is presented in Appendix G.

At the family level, stygofauna are widespread and many families that include stygofaunal species also include surface water and marine species (e.g. copepods, rotifers and mites). However, at the species level many taxa have a narrow distributional range (i.e. stygofauna communities contain species that occur exclusively within a small area); thus stygofauna communities are thought to have high endemism (Boulton et al. 2010; Harvey et al. 2011). For example, about one quarter (i.e. 23%) of the stygofauna species that were sampled on two or more occasions in a long-term study of stygofauna in the Pilbara region were sampled from within the same sub-region, and the median area of distribution of these stygofaunal species was 683 km^2 (Halse et al. 2014), with almost all stygofaunal species having distributions of less than 1,000 km^2 (Eberhard et al. 2009). A species of Parabathynellidae was recorded from 3 bores in the Burdekin River Alluvial Aquifer in Queensland, with two of these bores located approximately 20 km apart (Cook et al. 2012), suggesting a potential distribution of approximately 400 km^2. Additionally, studies in both Western Australia and Queensland have found evidence that sub-catchment boundaries can demarcate locations of turn-over of stygofaunal species (Finston et al. 2007; Little et al. 2016). Therefore, areas of approximately 400 – 600 km^2 within a single sub-catchment may represent reasonable estimates of distribution of most stygofaunal species, acknowledging that site-specific factors (e.g. highly confined aquifers) may impose further restrictions on distribution in some cases, or create strong population subdivision within species on smaller spatial scales (Cook et al. 2012; Little et al. 2016).

A total of 24 described families and 23 described genera have been recorded from Queensland across numerous bioregional areas (Glanville et al. 2016), with representatives of these taxa known from South East Queensland (Glanville et al. 2016; Little et al. 2016). This suggests that stygofauna are likely to be present in the Project area where the habitat of groundwater ecosystems is suitable for their occurrence. The suitability of a groundwater ecosystem to provide habitat for stygofauna is dependent on several environmental factors including:

- Geology – stygofauna have the potential to occur in aquifers composed of any geological unit with sufficient pore space to complete their life cycle (Tomlinson & Boulton 2008); thus, stygofauna are most common in alluvium, granite, gravel, sand, sandstone, silt, and volcanic geological units (Glanville et al. 2016). Stygofauna are less likely in geological units with relatively small pore spaces, such as those dominated by mudstone, siltstone and clays.
- Groundwater hydrology – in alluvial aquifers in eastern Australia the average number of stygofauna taxa was higher within 6 m from the water table height, and where the water table height was less than approximately 15 m below the ground (Hancock & Boulton 2008), although stygofauna have been recorded from over 60 m below ground (Glanville et al. 2016), indicating that deep groundwater ecosystems can also support stygofaunal communities.
- Groundwater quality:
  - The mean electrical conductivity of water from which stygofauna have been sampled is less than 4,000 µS/cm, although they have been recorded from a broad range of electrical conductivities (i.e. 11.5 – 54,800 µS/cm) (Glanville et al. 2016). Tolerance to high electrical conductivity is likely to vary among taxa, with only crustaceans (i.e. copepods and syncarids) reported from the upper end of this range (Glanville et al. 2016).
  - The minimum concentration of dissolved oxygen needed to support stygofauna communities is unknown. Some taxonomic groups are likely to be more tolerant of very low dissolved oxygen, and others more tolerant of very high dissolved oxygen (Halse et al. 2014). However, bores with the highest diversity of

stygofauna had dissolved oxygen levels ranging from approximately 20 to 60% saturation (Halse et al. 2014).
  - Stygofauna have been recorded from groundwater with pH ranging from 3.5 to 10.3, with diversity highest when pH is between 6.5 and 7.5 (average of 7.0) (Hancock & Boulton 2008).
  - Total dissolved solids (TDS) can strongly influence the diversity of stygofauna, with stygofauna almost always absent where TDS is higher than 15 mg/L (Halse et al. 2014).
  - Other water quality parameters, such as ionic composition, may also influence the diversity and taxonomic composition of stygofauna (Halse et al. 2014).

The groundwater study for the Six Mile Creek Dam Upgrade Project (SLR 2018) indicated that the:

- Geological units underlying Lake Macdonald, include quaternary alluvium approximately 3 – 21 m deep with high clay content overlaying weathered Triassic Myrtle Creek beds composed of weathered sandstone. Outcrops of Triassic Kin Kin bedrock composed of shale and mudstone occur to the east of Six Mile Creek Dam.
- Hydrology of the underlying geological units is characterised by:
  - Low hydraulic conductivity in the alluvium due to high clay content
  - Higher hydraulic conductivity of underlying sandstone
- Water quality of groundwater of:
  - Alluvium (SMEC 2018)
    - pH: 5.39 – 6.59
    - Dissolved oxygen: 57.4 – 62.3 mg/L
    - Electrical conductivity: 86 – 140 µS/cm
    - TDS: 59 – 160 mg/L
  - Kin Kin sandstone considered potable to slightly brackish (SLR 2018).

In summary, the desktop assessment indicated that the alluvium of the Project area is unlikely to be suitable for stygofauna due to high clay content, low hydraulic conductivity and high TDS, and the Kin Kin sandstone is suitable for stygofauna due to the higher hydraulic conductivity.

7.3.10 Aquatic Ecology Values Assessment

Aquatic MNES (i.e. Mary River cod and Australian lungfish) and platypus are known from Six Mile Creek downstream of Lake Macdonald, and it is possible that Mary River turtle and white-throated snapping turtle occur in the lower reaches of Six Mile Creek. Mary River cod are known to breed in Six Mile Creek downstream of Lake Macdonald. MSES downstream of Lake Macdonald (other than fish passage) include: several categories of regulated vegetation (i.e. category R vegetation and vegetation intersecting a watercourse) and HEV (watercourse) waters (Appendix G).

Within Lake Macdonald, and upstream of Lake Macdonald, platypus are known to occur and likely breed, Mary River cod and Australian lungfish may occur but are unlikely to be breeding, and it is likely that Mary River turtle or white-throated snapping turtle would be rare or absent from Lake Macdonald or upstream of Lake Macdonald. MSES upstream of Lake Macdonald (other than fish passage) include: several categories of regulated vegetation (i.e. category R vegetation) and HEV (watercourse) waters (Appendix G).

Using the criteria presented in Table 7-2, the assigned ecological value of:

- Six Mile Creek downstream of Lake Macdonald is very high
- Lake Macdonald is high
- Six Mile Creek upstream of Lake Macdonald is high, and
- Groundwater ecosystems in the Project area is low (i.e. no habitat for conservation significant species).

7.4 Impact Assessment

7.4.1 Project Summary

The Project will incorporate the demolition of the existing spillway and embankments and the construction of a new spillway and embankments to improve the safety and performance of the dam to meet current Queensland dam safety regulations. The new spillway will be an ungated dual height labyrinth weir, with the capacity, FSL and inundation area remaining the same as the existing dam following completion of the Project. The major phases of the Project that may impact aquatic ecology are:

- Drawdown – the lowering of Lake Macdonald over 12 weeks to RL 89 m AHD
- Construction – the demolition of the existing spillway and embankments and the construction of a new spillway and embankments
- Refill and Operation – the filling of the dam by natural inflows and normal dam operations.

7.4.2 Potential Impacts

Aquatic Habitat

Aquatic habitat in the lake will be adversely affected by lowered water levels during the drawdown phase, with the amount of aquatic habitat (i.e. volume of water) in Lake Macdonald reduced to approximately 2.8% of FSL (27 hectares) for the first two months of construction, and allowed to increase to approximately 5.1% of FSL (42 hectares) for the remainder of the construction period. This is a significant temporary reduction in aquatic habitat that will be reversed during the refill and operational phases of the Project.

There may also be potential adverse impacts to aquatic habitat downstream of the lake due to water quality, sedimentation and hydrological changes during drawdown and construction phases:

- **Water quality** – Potential changes to water quality include increased turbidity, suspended solids, nutrient and metal concentrations, decreased pH and dissolved oxygen, and contamination from spills (refer to Chapter 6 – Water Resources).
- **Sedimentation** – Fine sediments accumulate on the bed of reservoirs (e.g. >90% of sediment is captured in Six Mile Creek Dam, DNRM 2014), which could be mobilised during drawdown and construction phases and deposited downstream (i.e. sedimentation). Sedimentation smothers benthic habitats, including in-filling pools and interstitial spaces of coarse substrate (e.g. gravels and cobbles), causing cascading impacts to primary producers (i.e. aquatic plants and benthic algae), macroinvertebrates and fishes (Wood and Armitage 1997).
- **Potential hydrological impacts** – The drawdown phase will create a 'flow event' that is of similar volume to a 1 in 2-year peak flow event, but the duration of this flow will be significantly longer than a natural flow event and the flow rate will not exceed 10 cumecs. The frequency of low flows will likely increase from current conditions during the construction period, due to reduced capacity to store water in the lake as well as no extraction of water for treatment. Thus a greater proportion of catchment in-flows to Lake Macdonald will flow downstream to Six Mile Creek during construction. However, the magnitude, frequency, duration and timing of large flows should not change substantially from current, because the nature of Lake Macdonald and its catchment are such that attenuation of high flows by the current dam are minimal.

Aquatic Fauna

General Impacts

Aquatic fauna may become injured in pumping equipment during the lake drawdown, which could make them susceptible to pathogens and disease, or be fatally injured, trapped and subsequently drown. Impact injury may also occur as a result of spilling flows over the low flow notch on the coffer dam during construction, and over the spillway during the refilling and operation.

Aquatic fauna in Lake Macdonald may become stranded in isolated pools during the lake drawdown once water levels have lowered, and following large flow events during the construction phase (i.e. when water levels rise and then drain following significant rainfall), which may increase predation (e.g. predation of smaller fish by larger fish and / or birds), and / or crowding. Crowding may result in reduced dissolved oxygen concentrations in water, increased competition for food and shelter, and increased stress on fauna. As small isolated pools evaporate, or if areas are dewatered rapidly, there is a risk that aquatic fauna could become stranded on dry areas and perish. Turtles and platypus may also have difficulty moving to the nearest available water through exposed lake bed sediments (i.e. mud) and exposed aquatic vegetation. Some turtle species have an innate biological response to 'walk out' of waterbodies

as water levels lower; however, alternate waters may not be sufficiently proximate, and / or movement to alternate water may involve crossing roads and encountering other hazards.

During refilling and operation, injury or mortality to aquatic fauna could occur by downstream passage over the labyrinth spillway, with the vertical drop to the surface over a vertical fall spillway to the surface below being the predominant source of risk (Berghuis 2017). A vertical fall from a spillway to a deep plunge pool or stilling basin can cause significant injuries to fish when the fall higher is greater than 13 m (Berghuis 2017), with vertical falls to hard surfaces (e.g. concrete, rock) or shallow water likely to result in serious injury at much lower fall heights. The proposed dual height labyrinth spillway incorporates a plunge pool on the downstream face, to manage the potential impact of vertical falls. DAF guidance on plunge pool depths of at least 30% of the vertical fall have been used as a starting point and refined through modelling. Furthermore, tail water levels rise rapidly during spilling flows at Six Mile Creek Dam. Thus, plunge pool walls will be drowned out in large flow events to create a greater plunge pool depth with greater flows. Entrapment of fish in the plunge pools is also possible as spillway flows subside, where fish may be susceptible to predation and poor tailwater quality.

Impacts to Fish Passage

Almost all freshwater fish species migrate at some spatial scale (Harris et al. in press), with migration being the regular cyclic alteration between different habitats used for spawning, feeding or survival (Northcote 1998). Migration is a key ecological process that enables species to complete their life history by:

- Providing access to foraging, residing and spawning / breeding habitats, which may occur in geographically distinct segments of a river system
- Avoiding predation
- Reducing population density and intra-specific competition
- Enabling individuals to find refuge from seasonal or inter-annual harsh conditions, such as dry seasons and droughts.

Migration also maintains diverse and abundant fish communities, with both diversity and abundance of fish known to decrease where natural migration patterns are impacted; barriers to fish migration represent a significant threatening process for freshwater fish globally (Harris et al. in press). Maintenance of naturally diverse fish communities (via maintenance of fish passage and other factors, such as habitat quality and natural flow regime) maintains natural ecological processes at the location of the fish community (e.g. natural tropic interactions and food web structure) and contributes significantly to maintaining the EVs of the watercourse.

A permanent waterway barrier in a downstream reach may cause significant changes to fish communities along the whole river if diadromous migration is impeded. Multiple waterway barriers may cause cumulative impacts and can significantly change aquatic communities. Secondary ecological impacts such increased rates of benthic algal growth, sedimentation and accumulation of organic matter may result from the exclusion of migratory fish and shrimps due to waterway barrier works.

Six Mile Creek is mapped as a 'major risk of impact' (purple) waterway in DAF's waterway barrier works risk layer, indicating that permanent waterway barriers, such as dams, are likely to have a significant impact on fish passage. Fish passage is currently not provided at Six Mile Creek Dam. The absence of Pacific blue-eyes (a diadromous species) upstream of the dam indicates a likely impact to fish passage (frc environmental, 2016). Many species that undertake diadromous migration are present in relatively low abundance in Six Mile Creek, and a number of diadromous species that would be expected to occur have not been caught in Six Mile Creek. This suggests the possibility of cumulative impacts to fish passage between the estuary and Six Mile Creek by barriers in the lower Mary River (e.g. Gympie Weir) (see Walker 2008). The upgraded Six Mile Creek Dam will form a waterway barrier with associated impacts to passage. However, as there is no passage on the existing dam, impacts from the upgraded dam are not expected to differ from existing impacts.

Aquatic Flora

The drawdown of Lake Macdonald will expose aquatic plants above RL 89.0 m AHD, with those species dependent on standing water expected to perish in these areas.

Biosecurity

An invasive species is a species that is found beyond its natural distribution, and which threatens valued environmental, agricultural or other societal resources. Invasive species that have, or have the potential to have,

significant adverse impacts on the ecological, agricultural or economic resources of Queensland are declared under the *Biosecurity Act 2014*. The damage caused by invasive species includes:

- Competitive impacts, where the invasive species can reproduce more rapidly, or otherwise out-compete native species, to the extent that a native species declines or is threatened. For example, fish such as eastern gambusia and tilapia displace native fish, while aquatic weeds such as water hyacinth (*Eichhornia crassipes*) and Cabomba can displace native aquatic plants.
- Degradation of habitat, where feeding or other behaviours result in the degradation of habitat that supports native species. For example, aquatic weeds choke waterways and can reduce the concentration of dissolved oxygen in the water, making it unsuitable for native fauna; and tilapia disturb benthic habitats through their breeding behaviour.
- Predatory impacts, where an invasive species reduces the population size and / or threatens the survival of native species by predation.
- Herbivory impacts, where an invasive species consumes native plants, causing a population decline.

The Project has the potential to spread restricted biosecurity matters, most notably:

- Upstream movement of tilapia during the construction period at times when the coffer dam is over-topped by large flows
- Spread of aquatic plant fragments during fauna relocation during the drawdown phase.

Stygofauna

The Project has the potential to impact local stygofauna communities in underlying shallow alluvial aquifers by:

- Reducing the rate of aquifer recharge from direct infiltration from Lake Macdonald during dewatering and construction phases, which may result in highly localised reductions in groundwater levels in the order of 8 – 14 m below ground level (SLR 2018), thereby reducing habitat availability for stygofauna in shallow groundwater systems, and
- Contaminating groundwater quality via spills of fuels and oils, which may enter shallow groundwater ecosystems and cause lethal or sub-lethal impacts to stygofauna.

Matters of National Environmental Significance

Potential impacts to MNES species are described in detail in Chapter 5 – MNES, along with an assessment against the EPBC Act Significant Impact Criteria.

In summary, potential impacts to MNES species are anticipated to primarily occur during the drawdown and construction stages of the Project, as described above for other aquatic fauna, and comprise:

- Injury due to pumping equipment
- Stranding in isolated pools during drawdown
- Temporary reduction in quantity and quality of habitat
- Crowding and reduced resources in remaining habitat.

During refill and operation, injury or mortality to MNES species could occur by downstream passage over the labyrinth spillway.

Most sources of impact have been assessed as having a low risk of impact when the appropriate mitigations are applied (Table 7-10). However, the temporary loss of aquatic habitat in Lake Macdonald on aquatic fauna, including MNES species, was still assessed as having a moderate residual impact after mitigation measures were applied.

Matters of State Environmental Significance

Suitable habitat for platypus is mapped as wildlife habitat on the MSES spatial layer. Mapped areas are located along Six Mile Creek upstream of Lake Macdonald and platypus have been observed in the creek upstream of the lake. Following the lake drawdown, this area will rely on inflows from Six Mile Creek. If platypus are present, this may temporarily remove or restrict access to suitable breeding and foraging habitat for the duration of construction.

Six Mile Creek and Lake Macdonald are classified as waterways providing for fish passage, HEV waters (waterways), and riverine and lacustrine wetlands. Potential impacts to the ecological value of these MSES waters incorporate those described in the sections above. Where the above impacts occur, the ecological value of these MSES may be impaired.

As such, measures applied to mitigate the impacts identified above (as described in section 7.5), will also mitigate potential impacts to the value of MSES waters.

Impacts to vegetation associated with waterways and wetlands, including MSES, have been assessed in detail in Chapter 8 – Terrestrial Ecology.

7.5 Impact Mitigation and Management

Method

The risks of, and mitigations for, the potential impacts of the Project on the EVs of Six Mile Creek were assessed using a risk-based approach. This approach is described in detail in Appendix G.

Management Objectives

Appropriate mitigation measures should be implemented for the Project to achieve the following objectives:

- Prevent or reduce potential impacts to aquatic habitat, including water quality
- Prevent or reduce potential impacts to aquatic fauna, in particular listed threatened species
- Prevent or reduce the potential impacts of the Project on the establishment and spread of aquatic biosecurity matters
- Prevent or reduce the potential impacts to stygofauna in the Project area.

Suggested mitigation measures for potential impacts are provided in Table 7-10, however alternative measures may also be appropriate to achieve the objectives identified above.

Fish Passage

Fish passage is currently not provided at the Six Mile Creek dam. Investigations were undertaken into fishway options for the Project (e.g. frc environmental, 2016; Berghuis 2018). The investigations found that there were limited options for implementing fish passage in the new dam, due to constraints such as conflicts with existing infrastructure and limited space, as well as limitations on water to run a fishway. A mechanical fishway was assessed as the most viable fishway option. It is also recognised that Mozambique tilapia, a restricted biosecurity matter, is known to be present downstream of the dam but not upstream. As such, General Biosecurity Obligations (GBO) require controls to prevent upstream dispersal of tilapia. Preliminary advice from DAF indicates that the risk of aiding upstream dispersal of tilapia outweighs the benefit of providing fish passage for native species (DAF 2018). Therefore, upstream fish passage will not be provided at the upgraded dam. Downstream fish passage was assessed by Berghuis (2018); this report is provided in Appendix O.

As provision of upstream fish passage at Six Mile Creek Dam was assessed as of limited benefit, off-site fish passage options were investigated as part of the Project. Off-site fish passage mitigations could be achieved through remediation of another higher priority barrier identified in the Mary River catchment, preferably with a direct and geographically close link to the Six Mile Creek system – such as the Gundiah Road crossing or Gympie gauging weir.

Gympie gauging weir is viewed as the optimal off-site mitigation action due to its proximity to the confluence of Six Mile Creek with the Mary River, and the associated improvements (over a wide range of flows up to drown-out) within Six Mile Creek and the upper Mary River catchment. The Gympie gauging weir is also a Seqwater asset and has previously been subject to assessment for a fishway and turtle passage (biopassage). A biopassage detailed design is available for the gauging weir.

Many species that undertake diadromous migration are present in relatively low abundance in Six Mile Creek, and a number of diadromous species that would be expected to occur have not been caught (e.g. sea mullet, pink eye mullet, empire gudgeon, striped gudgeon), suggesting the possibility of cumulative impacts to fish passage between the estuary and Six Mile Creek by barriers in the lower Mary River (e.g. Gympie Gauging Weir) (see Walker 2008). Providing fish passage at barriers in the lower Mary River will therefore improve the native fish community in Six Mile Creek below the dam, as well as in other sections of the broader Mary River system.

Table 7-10: Mitigation and management measures proposed to manage aquatic ecological impacts

ECOLOGICL ASPECT	PROJECT PHASE	POTENTIAL IMPACT	IMPACT RISK BEFORE MITIGATION	MITIGATION AND MANAGEMENT	RESIDUAL IMPACT RISK
Aquatic habitat (including water quality)	Pre-construction – lake drawdown	Significant temporary reduction in availability of aquatic habitat (i.e. volume of water), with Lake Macdonald reduced to approximately 2.8% of FSL before construction and for the first two months of construction.	High	Develop and implement a management plan for the lake drawdown that includes a comprehensive aquatic fauna salvage operation in accordance with DAF's Fish Salvage Guidelines (DPI 2004).	Moderate
		Mobilisation of fine sediment in Lake Macdonald during drawdown leading to sedimentation in Six Mile Creek.	Moderate	Minimise disturbance and downstream transfer of unconsolidated bed sediments, for example by using a pontoon based pump station. Stabilise exposed sediments as soon as possible, for example by seeding the exposed Lake Macdonald bed with non-invasive grasses following initial drawdown.	Low
		Changes to hydrological conditions – prolonged release of water during drawdown.	Moderate	Avoid releases during natural low flow periods, for example undertake drawdown when flows of moderate magnitude commonly occur. Select drawdown discharge rate that will not exceed the bank full width of Six Mile Creek downstream of the dam. Avoid changes to hydrology during the breeding seasons for MNES species known to be in Six Mile Creek downstream of the dam, for	Low

ECOLOGICL ASPECT	PROJECT PHASE	POTENTIAL IMPACT	IMPACT RISK BEFORE MITIGATION	MITIGATION AND MANAGEMENT	RESIDUAL IMPACT RISK
				example undertake drawdown outside the Mary River cod and Australian lungfish breeding seasons.	
	Construction	Significant temporary reduction in availability of aquatic habitat with Lake Macdonald reduced to approximately 5.1% of FSL for the main construction period.	High	Develop and implement a management plan for the lake drawdown that includes a comprehensive aquatic fauna salvage operation. Where possible, augment aquatic habitat within Lake Macdonald (e.g. by adding physical habitat structures; controlling aquatic weeds) to improve the long-term aquatic habitat values from current condition.	Moderate
		Mobilisation of exposed sediment in Lake Macdonald during flow events leading to sedimentation in Six Mile Creek.	Moderate	Avoid or manage areas of potential erosion, for example by implementing an ESCP in accordance with applicable industry standards, and monitoring the efficacy of management measures. Stabilise exposed sediments as soon as possible, for example by seeding the exposed Lake Macdonald bed with non-invasive grasses following initial drawdown. Investigate benefits of slowing flow and reduce erosion in the upper reaches of the lake, for example by using physical barriers (e.g. staggered baffles) at key upstream locations.	Low

ECOLOGICL ASPECT	PROJECT PHASE	POTENTIAL IMPACT	IMPACT RISK BEFORE MITIGATION	MITIGATION AND MANAGEMENT	RESIDUAL IMPACT RISK
		Changes to hydrological conditions – changes to the frequency low flows downstream of the coffer dam.	Moderate	Maintain the existing downstream flow regime during the construction period, for example by allowing inflows to pass the construction area, pumping water downstream at a rate consistent with inflows. Maintain environmental flows as per the Mary River ROP.	Low
		Reduction in quality of habitat present in Lake Macdonald due to decreased water quality (risk of lower dissolved oxygen and pH, higher turbidity, nutrients and metals, and contaminants) and reduced resource availability (i.e. food and shelter).	Moderate	Implement water quality management measures such as those identified in Chapter 6 – Water Resources. Consider implementing a feeding plan if scarce food resources are determined to be a limiting factor in habitat condition. Limit access stock to the lake where possible, for example through the installation of fencing.	Low
Biosecurity (aquatic flora and fauna)	Pre-construction – lake drawdown	Spread of aquatic plant fragments during fauna relocation during the lake drawdown.	Moderate	Minimise potential spread of aquatic weeds, for example by implementing identification training for all relevant personnel, only relocating aquatic fauna to waterbodies that are already infested with Cabomba, and/or requiring that vehicles, machinery, equipment and temporary infrastructure are subject to weed hygiene protocols.	Low
	Construction	Spread of pest fish, including upstream movement of tilapia	Moderate	To the extent that is possible, reduce the opportunities for upstream movement by tilapia, for example by managing the water	Low

ECOLOGICL ASPECT	PROJECT PHASE	POTENTIAL IMPACT	IMPACT RISK BEFORE MITIGATION	MITIGATION AND MANAGEMENT	RESIDUAL IMPACT RISK
				level in the lake to reduce the potential for drown out / overtopping (i.e. via pumping) and not using or pumping water from Six Mile Creek downstream of the dam for construction or machinery.. Euthanise pest fish humanely in accordance with methods approved by animal ethics, for example, if possible, sort fish during any salvage effort before relocation and euthanise pest fish.	
		Spread of restricted aquatic plants	Moderate	Minimise potential spread of aquatic weeds, for example by implementing pest identification training for all relevant construction personnel, only relocating aquatic fauna to waterbodies that are already infested with Cabomba, and/or requiring that vehicles, machinery, equipment and temporary infrastructure are subject to weed hygiene protocols. Where possible, remove Hygrophila and Cabomba from Lake Macdonald.	Low
		Increase in pest species in and around Lake Macdonald – cane toad	Moderate	Control potential increases in cane toad populations, for example by installing cane toad traps, as manufactured by the Mary River Catchment Coordinating Committee.	Low

ECOLOGICL ASPECT	PROJECT PHASE	POTENTIAL IMPACT	IMPACT RISK BEFORE MITIGATION	MITIGATION AND MANAGEMENT	RESIDUAL IMPACT RISK
MNES species: **Mary River cod** **Australian lungfish** **Mary River turtle** **White-throated snapping turtle**	Pre-construction – lake drawdown	May become injured in pumping equipment, leading to illness, or be fatally injured or trapped and subsequently drown.	Moderate	Prevent MNES species from being entrained and injured or trapped by using suitably designed screens, ensuring water velocity at pipe intake is less than the burst swimming speed of fish known from Lake Macdonald (i.e. <0.1 m/s; see Boys et al. 2012), and/or monitoring measures implemented to ensure they are functioning correctly.	Low
		May become stranded in small isolated pools in Lake Macdonald leading to illness, injury, and/or death.	High	Enable MNES species to move to areas where water will persist for the duration of the Project, for example by lowering water levels slowly during the initial weeks of drawdown. Develop and implement a management plan for the lake drawdown that includes a comprehensive salvage operation in accordance with DAF's Fish Salvage Guidelines (DPI 2004) that targets MNES species and incorporates: • Quantitative objectives • Salvage and relocation until such time that the quantitative salvage objectives have been achieved • Selection of relocation sites with consideration of biosecurity management, carrying capacity, and ease of re-introduction back to Lake Macdonald	Low

ECOLOGICL ASPECT	PROJECT PHASE	POTENTIAL IMPACT	IMPACT RISK BEFORE MITIGATION	MITIGATION AND MANAGEMENT	RESIDUAL IMPACT RISK
				• Release requirements to avoid over-stocking / crowding, and monitoring the success of relocation. Monitoring key water quality parameters and observing fauna in Lake Macdonald during construction to trigger incidental salvage of MNES species, or other mitigation measures (e.g. a feeding program), as required.	
		Temporary reduction of habitat	High	Develop and implement a management plan for the lake drawdown that includes a comprehensive salvage operation that targets MNES species in accordance with DAF's Fish Salvage Guidelines (DPI 2004). Regularly monitor the lake for these MNES species to enable a care or relocation response if necessary. Conduct the drawdown program outside of breeding seasons of MNES species, where practical.	Moderate
	Construction	May become injured in pumping equipment, leading to illness, or be fatally injured or trapped and subsequently drown.	Moderate	Prevent MNES species from being entrained and injured or trapped by using suitably designed screens and/or, ensuring water velocity at pipe intake is less than the burst swimming speed of fish known from Lake Macdonald (i.e. <0.1 m/s; see Boys et al. 2012).	Low

ECOLOGICL ASPECT	PROJECT PHASE	POTENTIAL IMPACT	IMPACT RISK BEFORE MITIGATION	MITIGATION AND MANAGEMENT	RESIDUAL IMPACT RISK
				Monitor measures implemented to ensure they are functioning correctly.	
		May become stranded in small isolated pools in Lake Macdonald leading to illness, injury, and/or death.	High	Develop and implement a management plan for the lake drawdown that includes a comprehensive salvage operation in accordance with DAF's Fish Salvage Guidelines (DPI 2004) that targets MNES species and incorporates incidental relocation after high flow events. Monitor key water quality parameters and observe fauna in Lake Macdonald during construction to trigger incidental salvage, or other mitigation measures (e.g. a feeding program), as required.	Moderate
		Temporary reduction of habitat	High	Develop and implement a management plan for the lake drawdown that includes a comprehensive salvage operation that targets MNES species in accordance with DAF's Fish Salvage Guidelines (DPI 2004). Monitor the lake for these species to enable a care or relocation response if necessary.	Moderate
	Post-construction	Communities do not recover to pre-Project condition.	Moderate	Return relocated MNES species to lake and re-stock (e.g. through stocking groups), where practical, once water quality assessments have confirmed suitability.	Low

ECOLOGICL ASPECT	PROJECT PHASE	POTENTIAL IMPACT	IMPACT RISK BEFORE MITIGATION	MITIGATION AND MANAGEMENT	RESIDUAL IMPACT RISK
				Monitor fauna response and condition to enable a response if necessary. Where possible, augment habitat for these MNES species within Lake Macdonald (e.g. by adding physical habitat structures; controlling aquatic weeds).	
Platypus	Pre-construction – lake drawdown	Platypus may become injured in pumping equipment or be fatally injured, or trapped and subsequently drown.	Moderate	Prevent platypus from being entrained and injured or trapped by using suitably designed screens. Monitor measures implemented to ensure they are functioning correctly.	Low
		Platypus in Lake Macdonald may become stranded in small isolated pools or burrows, leading to illness, injury, and/or death.	High	Enable platypus to move to areas where water will persist for the duration of the Project, for example by lowering water levels slowly during the initial weeks of drawdown and ensuring suitable refuge pools remain (e.g. by shaping the bed of the lake and/or Six Mile Creek upstream of the lake). Develop and implement a management plan for the lake drawdown that includes a comprehensive aquatic fauna salvage operation that includes a contingency for platypus even though the relocation of platypus is not preferred.	Moderate
		Temporary reduction of habitat	High	No bank disturbance should be undertaken until a suitably qualified person has checked the	Moderate

ECOLOGICL ASPECT	PROJECT PHASE	POTENTIAL IMPACT	IMPACT RISK BEFORE MITIGATION	MITIGATION AND MANAGEMENT	RESIDUAL IMPACT RISK
				banks for threatened fauna and fauna burrows in the construction area. Inspections of Six Mile Creek upstream should also be conducted. If any burrows are identified, implement a 3 m x 3 m exclusion zone with flagging tape until approval to impact the burrow has been granted by the suitably qualified person. Monitor platypus response and condition to enable a care or relocation response if necessary. Conduct the drawdown program outside of platypus breeding season (August to October).	
	Construction	Platypus may become injured or trapped in pumping equipment used to manage water levels in the lake.	Moderate	Prevent platypus from being entrained and injured or trapped by using suitably designed screens. Monitor measures implemented to ensure they are functioning correctly.	Low
		Platypus in Lake Macdonald may become stranded in small isolated pools or burrows when water recedes following high flow events, leading to illness, injury, and/or death.	High	Enable platypus to move to areas where water will persist for the duration of the Project, where possible, for example by lowering water levels slowly during the initial weeks of drawdown and ensuring suitable refuge pools remain (e.g. by shaping the bed of the lake and/or Six Mile Creek upstream of the lake). Develop and implement a management plan for the lake	Moderate

ECOLOGICL ASPECT	PROJECT PHASE	POTENTIAL IMPACT	IMPACT RISK BEFORE MITIGATION	MITIGATION AND MANAGEMENT	RESIDUAL IMPACT RISK
				drawdown that includes a comprehensive aquatic fauna salvage operation that includes a contingency for platypus even though the relocation of platypus is not preferred.	
		Temporary reduction of habitat	High	No bank disturbance should be undertaken until a suitably qualified person has checked the banks for threatened fauna and fauna burrows in the construction area. Inspections of Six Mile Creek upstream should also be conducted. If any burrows are identified, implement a 3 m x 3 m exclusion zone with flagging tape until approval to impact the burrow has been granted by the suitably qualified person. Monitor platypus response and condition to enable a relocation or care action if necessary.	Moderate
	Post-construction	Platypus community does not recover to pre-Project condition.	Moderate	Return relocated platypus to lake (if any were removed during construction). Monitor platypus response and condition to enable a response if necessary.	Low
Other aquatic fauna	Pre-construction – lake drawdown	Aquatic fauna may become injured in pumping equipment, which could make them susceptible to pathogens and disease, or be	High	Prevent aquatic fauna from being entrained and injured or trapped by pumping equipment, for example by using suitably designed screens, ensuring water velocity at pipe intake is less than	Low

ECOLOGICL ASPECT	PROJECT PHASE	POTENTIAL IMPACT	IMPACT RISK BEFORE MITIGATION	MITIGATION AND MANAGEMENT	RESIDUAL IMPACT RISK
		fatally injured, trapped and subsequently drown.		the burst swimming speed of fish known from Lake Macdonald (i.e. < 0.5 m/s; see Kapitzke 2010), and/or monitoring measures implemented to ensure they are functioning correctly.	
		Aquatic fauna in Lake Macdonald may become stranded in small isolated pools, which may increase predation (e.g. by larger fish and/or birds), crowding, and/or death.	High	Enable aquatic fauna to move to areas where water will persist for the duration of the Project, for example by lowering water levels slowly during the initial weeks of drawdown. Develop and implement a management plan for the lake drawdown that includes a comprehensive aquatic fauna salvage operation.	Moderate
		Movement by some turtle species to alternate waterbodies may involve crossing roads and encountering other hazards.	Moderate	Prevent turtles dispersing over roads, for example by installing temporary fencing, similar to coarse sediment barriers, between Lake Macdonald and roads. Daily surveillance and salvage of turtles during the drawdown phase and weekly during the construction phase. Develop and implement a management plan for the lake drawdown that includes a comprehensive aquatic fauna salvage operation.	Low
	Construction	Aquatic fauna may become injured in pumping equipment, which could make them susceptible to	High	Prevent aquatic fauna from being entrained and injured or trapped by pumping equipment, for example by using suitably	Low

ECOLOGICL ASPECT	PROJECT PHASE	POTENTIAL IMPACT	IMPACT RISK BEFORE MITIGATION	MITIGATION AND MANAGEMENT	RESIDUAL IMPACT RISK
		pathogens and disease, or be fatally injured, trapped and subsequently drown.		designed screens, ensuring water velocity at pipe intake is less than the burst swimming speed of fish known from Lake Macdonald (i.e. < 0.5 m/s; see Kapitzke 2010), and/or monitoring measures implemented to ensure they are functioning correctly.	
		Aquatic fauna in Lake Macdonald may become stranded in small isolated pools following large flow events during the construction phase (i.e. when water levels rise and then lower again following significant rainfall), which may increase predation (e.g. by larger fish and/or birds), crowding, and/or death.	High	Where possible, maintain suitable habitat for fauna, for example by managing water quality and regular monitoring of conditions. Develop and implement a management plan for the lake drawdown that includes a comprehensive aquatic fauna salvage operation in accordance with DAF's Fish Salvage Guidelines (DPI 2004).	Moderate
	Post-construction	Aquatic faunal community does not recover to pre-Project condition.	Moderate	Restore Lake Macdonald, where possible, for example by re-stocking fish and turtle species, once water quality assessments have confirmed suitability. Where possible, augment aquatic habitat within Lake Macdonald (e.g. by adding physical habitat structures; controlling aquatic weeds) to improve the long-term aquatic habitat values of Lake Macdonald from current condition.	Low
Aquatic plants	Construction	Lowering the lake will expose aquatic plants above 89.0 m AHD and species dependent	Low	Water will be retained in Lake Macdonald below 89.0 m AHD,	Low

ECOLOGICL ASPECT	PROJECT PHASE	POTENTIAL IMPACT	IMPACT RISK BEFORE MITIGATION	MITIGATION AND MANAGEMENT	RESIDUAL IMPACT RISK
		on standing water are expected to perish in exposed areas.		providing refuge habitat for aquatic plants. Where possible, manage the extent and abundance of exotic aquatic plants while the lake is lowered.	
Fish passage	Construction	Upstream fish passage will not be provided due to biosecurity concerns.	High	Provide an off-site mitigation to improve fish passage at Gympie Gauging Weir.	Low
		Fauna may pass over the coffer dam at the low flow notch and in high flow events, potentially leading to injury or death.	Moderate	Manage the likelihood of overtopping events, for example by allowing inflows to pass the construction area, pumping water downstream at a rate consistent with inflows, and/or using water piped from the Mary River to the water treatment plant.	Low
	Operation	Upstream fish passage will not be provided due to biosecurity concerns.	High	Provide an off-site mitigation to improve fish passage at Gympie Gauging Weir.	Low
		Injury or mortality to stream fauna could occur by downstream passage over the labyrinth spillway	High	Reduce the risk of injury and mortality to aquatic fauna over the spillway and stranding of fauna in plunge pools, for example by ensuring the design of the spillway includes sufficiently deep plunge pools and incorporating recommendations from a fish biologist (Berghuis 2017).	Low*
		Entrapment of fish in the plunge pools as overtopping flows subside, where they may be susceptible to	Moderate	Reduce the risk of injury and mortality to aquatic fauna over the spillway and stranding of fauna in plunge pools, for example by	Low*

ECOLOGICL ASPECT	PROJECT PHASE	POTENTIAL IMPACT	IMPACT RISK BEFORE MITIGATION	MITIGATION AND MANAGEMENT	RESIDUAL IMPACT RISK
		predation and poor tailwater quality.		including sufficient drainage from plunge pools to minimise entrapment, as per recommendations from a fish biologist (Berghuis 2017).	
Stygofauna	Construction	Reduced aquifer recharge rate during drawdown and construction, reducing habitat availability for stygofauna in shallow groundwater systems, and Contamination of groundwater quality via spills of fuels and oils.	Low	Reduce the likelihood of chemical spills or leaks, for example through: • Storing fuels, oils and other chemicals in bunded areas in accordance with Australian Standard 1940 (2004) – The storage and handling of flammable and combustible liquids • Establishing bunded areas away from water bodies, preferable above the Q100 level • Only refuelling in bunded areas • Making spill kits available to enable a rapid response to a spill if one was to occur.	Low

* The risk assessment for downstream passage over the spillway is preliminary and based on a fisheries biologist completing a separate assessment and providing on-going input into the spillway design to minimise potential impacts.

7.6 Summary

Two threatened fish and two freshwater turtle species listed under the EPBC Act (i.e. aquatic MNES) are known from the Mary River and Six Mile Creek:

- White-throated snapping turtle – critically endangered
- Mary River cod – endangered
- Mary River turtle – endangered
- Australian lungfish – vulnerable.

Mary River cod and Australian lungfish are known from Six Mile Creek downstream of Lake Macdonald, and it is possible that Mary River turtle and white-throated snapping turtle sometimes occur in the lower reaches of Six Mile Creek. Mary River cod are known to breed in Six Mile Creek downstream of Lake Macdonald. Within Lake Macdonald, and upstream of Lake Macdonald, platypus are known to occur, Mary River cod and Australian lungfish may occur but are unlikely to be breeding, and Mary River turtle or white-throated snapping turtle are likely to be rare or absent. Matters of State Environmental Significance downstream and upstream of Lake Macdonald (other than fish passage) include: several categories of regulated vegetation and HEV (watercourse) waters.

The desktop assessment indicated that the alluvium of the Project area is unlikely to be suitable for stygofauna due to high clay content, low hydraulic conductivity and high total dissolved solids, and the Kin Kin sandstone is suitable for stygofauna due to the higher hydraulic conductivity.

The following potential impacts from the Project to the aquatic values of Six Mile Creek and Lake Macdonald were identified:

- Impacts to water quality in Lake Macdonald and downstream of the lake
- Impacts to aquatic habitat in Lake Macdonald and downstream
- Impacts to aquatic fauna (injury, mortality or stranding) in Lake Macdonald
- Impacts to aquatic flora in Lake Macdonald and downstream of the lake
- Spread of biosecurity matters downstream of Lake Macdonald
- Impacts to stygofauna communities in shallow groundwater systems
- Barriers to fish passage at the dam wall.

The risks of, and mitigations for, each of the identified potential sources of adverse impact of the Project on the Environmental Values of Six Mile Creek were assessed using a risk-based approach. Potential direct and indirect impacts of the Project are likely to affect both Lake Macdonald and Six Mile Creek downstream. As the Project is replacing an existing dam wall the long-term impact will be no change from current condition. Most sources of impact during the Project were assessed as having a low risk of impact when appropriate mitigations are applied. Most potential impacts will be temporary (i.e. for the duration of the drawdown and construction periods; approximately 2 to 3 years in total), and if appropriate mitigations are applied there will be no ongoing impacts to the aquatic environmental values of Lake Macdonald or Six Mile Creek.

However, the temporary loss of aquatic habitat in Lake Macdonald due to the drawdown of the lake for safety during construction still resulted in a moderate residual impact after mitigation measures were applied. There will be a temporary loss of approximately 97.2% of aquatic habitat (by water volume) in Lake Macdonald, which requires additional mitigation in the form of a comprehensive aquatic fauna salvage operation. This is an unavoidable risk given the safety requirements of the Project.

MNES were also assessed against the Significant Impact Criteria for critically endangered, endangered and vulnerable aquatic species. This assessment is provided in Chapter 5 – MNES.

Fish passage is currently not provided at the Six Mile Creek dam. While fishway options have been considered for the Six Mile Creek Dam upgrade (e.g. frc environmental, 2016; Seqwater 2018), preliminary advice from DAF indicates that several factors outweigh the benefit of providing fish passage over the upgraded dam, including site constraints, the risk of aiding upstream dispersal by the noxious fish, tilapia, and the anticipated regional benefits of the proposed off-site mitigation option. Off-site mitigation measures for fish passage are therefore proposed; specifically, the provision of fish passage at Gympie Weir.