Member of the Surbana Jurong Group

SMEC INTERNAL REF. 30035740

Flora & Fauna (Dewatering) Management Plan

Lake Macdonald (Six Mile Creek) Dam Improvement Project

Client Reference No. 05327
Prepared for: Seqwater
22 April 2025

Through our specialist expertise, we deliver advanced environmental solutions for our clients and partners.

Leveraging our 70-year history of delivering nation-building infrastructure, we provide technical expertise and advanced engineering services to resolve complex challenges.

Through our network of global specialists collaborating with local partners, we connect you with the best teams and capabilities to deliver innovative and sustainable solutions.

We’re redefining exceptional

Document Control

Document Type	Flora & Fauna (Dewatering) Management Plan
Project Title	Lake Macdonald (Six Mile Creek) Dam Improvement Project
Project Number	30035740
Revision Number	Rev 05
Project Use	Issued for Use (IFU)

Important Notice

Contents

Appendices

Figures

Tables

Executive Summary

This Adaptive Management Plan, herein referred as the 'plan,' has been prepared to manage potential impacts associated with water lowering for the Lake Macdonald (Six Mile Creek) Dam Improvement Project. Located in the Noosa hinterland, Lake Macdonald (Six Mile Creek) Dam, alternatively referred to as Lake Macdonald, serves as one of two principal raw water sources providing potable drinking water to the residents of Noosa Shire. The dam improvement project will enhance the dam's ability to manage severe weather and earthquake events, improve spillway discharge capacity, and enhance earthquake stability, all while maintaining water supply security.

The improvement works involve removing the existing spillway and embankments, and the construction of a new spillway and embankments on weathered rock. This process necessitates lowering the water level in Lake Macdonald to RL 93 m AHD (~42% of full supply volume) to facilitate construction of a temporary coffer-dam, demolition of the existing structure and construction of its replacement. The reduced water level will be maintained for approximately 48 months, subject to inflows and weather.

This plan, a revision of the 2020 draft, has been updated to accommodate changes in design/methodology, with a significant shift in focus on the lake level. In 2020, the construction methodology necessitated lowering the lake to RL 88.5 m AHD (essentially empty), whereas the updated 2023 methodology maintains 42% of the lake volume, significantly reducing stressors on aquatic fauna and minimising the need for lake de-stocking. Technical studies have been revised to account for the passage of time, incorporating recent aquatic ecology field surveys that inform and update this plan, in addition to revisions made to species management plans.

Two aquatic fauna species listed as Matters of National Environmental Significance (MNES) have been identified in Lake Macdonald and Six Mile Creek: the Mary River cod (*Maccullochella mariensis*) and the giant barred frog (*Mixophyes iterates*). Additionally, three other MNES species may inhabit the area: the Australian lungfish (*Neoceratodus forsteri*), the Mary River turtle (*Elusor macrurus*), and the white-throated snapping turtle (*Elseya albagula*). These species are also recognised as Matters of State Environmental Significance (MSES), with two additional MSES species known to exist in Lake Macdonald: the platypus (*Ornithorhynchus anatinus*) and the tusked frog (*Adelotus brevis*).

This plan aims to mitigate environmental impacts from lowering Lake Macdonald and safeguard MNES and MSES species while facilitating the essential safety upgrades of Six Mile Creek Dam. Its primary goal is to prevent significant harm and manage potential effects on aquatic ecosystems downstream of the dam. Other types of impacts, such as effects on recreational activities, are addressed in the Project's Impact Assessment Report (IAR), which was approved with conditions by the Queensland Coordinator-General on 20 May 2019. The Commonwealth Minister for the Environment approved the Project, with conditions, as a controlled action on 7 November 2019.

This plan has been prepared in accordance with conditions in the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) Approval (EPBC 2017/8078) and the Queensland Coordinator-General's evaluation report on the IAR (May 2019). The plan includes:

- A description of how and when the lake will be lowered
- A summary of baseline aquatic ecosystem conditions based on information in the Impact Assessment Report and subsequent surveys
- Discussion of potential impacts associated with the lake lowering
- Environmental objectives, performance criteria, management measures, monitoring and reporting requirements, and corrective actions to minimise potential impacts from the lake lowering, including a fauna salvage and relocation program
- A risk assessment and implementation schedule
- Key roles and responsibilities
- Data management, reporting, and audit requirements
- Required permits and qualifications.

1. Introduction

This plan is a revision of a plan drafted in 2020, updated to reflect a design/method change. Of most importance to this revision is a change to the lake level to be maintained during the improvement project. In 2020, the construction methodology required the lowering of the lake to RL 88.5 m AHD – almost empty. This scenario necessitated the removal of the vast bulk of the biomass from the lake. The revised 2023 methodology provides for maintenance of the lake level at RL 93 m AHD (approximately 42% of full supply), and maintenance of the lake as a live storage (i.e. still contributing to regional potable water supply). Under the new scenario, the stressors on aquatic fauna are greatly reduced and the requirements for de-stocking of the lake significantly diminished.

1.1 Background

Lake Macdonald (Six Mile Creek) Dam, commonly and from herein referred to as Lake Macdonald, is located on the Sunshine Coast. It is one of two principal raw water sources that supply potable drinking water to the residents of Noosa Shire. The dam requires an upgrade to meet modern safety standards and the performance requirements of the Queensland dam safety regulations into the future (the Project).

The improvement of Lake Macdonald Dam will allow the dam to better manage severe weather and earthquake events; it includes improving the spillway discharge capacity and earthquake stability while maintaining water supply security. The Project will not change the scale of the existing water impoundment, with the dam's full supply level and inundation area remaining the same post-upgrade and the proposed dam infrastructure largely occupying the existing footprint.

The Project comprises the removal of the existing spillway and embankments and the construction of a new spillway and embankments on weathered rock. This will require the lowering of water stored in Lake Macdonald to facilitate construction of a temporary coffer dam, demolition of the existing dam and construction of a replacement dam. The water level will be lowered to RL 93.0 m AHD for the duration of construction which will be approximately 3 to 4 years (subject to inflows and weather). Lake Macdonald will continue to be relied upon for water supply during the construction period and further operationally related drawdowns will occur. The indicative program for the Project is shown below in Table 1-1.

Table 1-1: Indicative Program for the Project

Phase	Timing
Supplementary business case and investment approval	End 2023
Construction Contract Award	Early 2024
Community Engagement Action Plan Launch	Early 2024
Mobilise to site and commence early and preparatory works	Q4 2024 to Q2 2025
Construction	2025-2030*

*Weather and construction conditions permitting

1.2 Site Description

Lake Macdonald is located on Six Mile Creek, approximately 10 km from the centre of Cooroy in the Noosa hinterland. The dam was constructed in the early 1960s and raised in 1979. When full it holds 8,018 ML of water, with a surface area of 260 ha and a total catchment area of 49 km^2. Lake Macdonald and its location are shown in Figure 1–1.

Lake Macdonald is primarily a water storage with no flood mitigation objectives; however the dam provides some flood attenuation and the conditions of the water licence for the dam include environmental flow release requirements. The lake is also used as a recreation facility by the community, supporting rowing, paddling, fishing, and foreshore recreation, including the Noosa Botanical Gardens.

A number of protected species are known to occur or potentially occur in and around Six Mile Creek and Lake Macdonald. In particular, five species that are listed as Matters of National Environmental Significance (MNES) and listed as Matters of State Environmental Significance (MSES), may occur in Lake Macdonald and Six Mile Creek: Mary

River cod (*Maccullochella mariensis*), Australian lungfish (*Neoceratodus forsteri*), Mary River turtle (*Elusor macrurus*), white-throated snapping turtle (*Elseya albagula*), and giant barred frog (*Mixophyes iterates*). Two additional MSES species, tusked frog (*Adelotus brevis)* and platypus (*Ornithorhynchus anatinus*), were recorded within Lake Macdonald and the upper reaches of the lake, with the platypus also recorded in Six Mile Creek.

1.3 Purpose and Objectives

The purpose of this plan is to manage the environmental impacts associated with the lowering of Lake Macdonald to facilitate construction of the upgraded Lake Macdonald (Six Mile Creek) Dam, and to protect the Mary River cod, Australian lungfish, Mary River turtle, white-throated snapping turtle, giant barred frog, tusked frog, and platypus. The primary objective of the plan is to minimise the risk of material environmental harm due to the lowering. As the water level in Lake Macdonald will need to be lowered to undertake the construction of the Project, the plan has been developed to manage potential impacts on aquatic ecosystems in:

- Lake Macdonald
- Six Mile Creek downstream of Lake Macdonald.

Other types of impacts, such as impacts to recreational activities, are addressed in the Project's Impact Assessment Report (IAR).

This plan has been prepared in accordance with conditions in the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) Approval (EPBC 2017/8078) and the Queensland Coordinator-General's evaluation report on the IAR (May 2019) – noting that the design/methodology has evolved over that period.

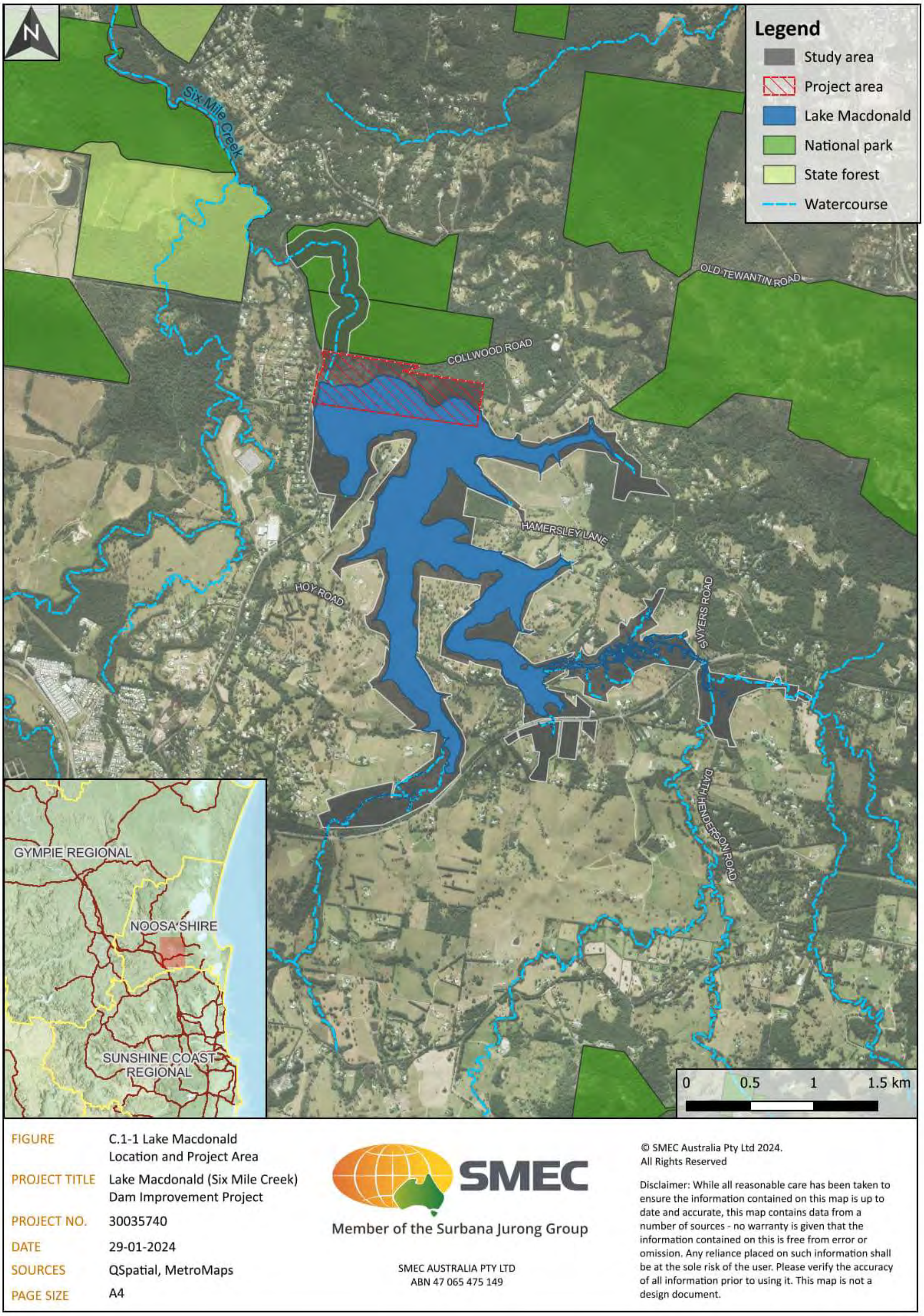


Figure 1–1: Lake Macdonald location and Project area

1.4 Plan Preparation

This plan was originally prepared in 2019/2020 by the following suitably qualified persons:

- Steven Cox
  - Senior Planning Approvals Advisor, Seqwater
  - Bachelor of Applied Science (Chemistry – Honours), Queensland University of Technology, 2006
  - 14+ years' experience in environmental science and planning roles
- Nirvana Searle
  - Associate Environmental Scientist, SMEC
  - Bachelor of Applied Science (Environmental Science - Honours), University of Canberra 1997
  - 18+ years' experience in aquatic ecologist roles
  - Certified Environmental Practitioner, Environment Institute of Australia and New Zealand
- Dr Ben Cook
  - Senior Principal Ecologist, frc environmental
  - Doctor of Philosophy (PhD), Aquatic Biology, Griffith University 2006
  - Bachelor of Science (Environmental Science - Honours), Griffith University 2000
  - Bachelor of Applied Science (Environmental Management), University of Queensland 1998
  - 20+ years' experience in academic and applied aquatic ecologist roles
- Dr Ben Pearson
  - Geomorphologist, Hydrobiology
  - Doctor of Philosophy (PhD), Geomorphology, James Cook University 2006
  - Bachelor of Applied Science (Environmental Management), James Cook University 1999
  - 20+ years' experience in academic and applied aquatic ecologist roles.

This plan was revised between 2023 and 2025 with major changes to the detailed design by the following suitably qualified persons:

- Kylie Mill
  - Senior Advisor Planning Approvals, Seqwater
  - Bachelor of Built Environment (Distinction) Urban and Regional Planning (Queensland University of Technology)
  - 25+ years' experience in major projects and planning roles.
- CP Soin
  - Manager Environment, SMEC
  - Bachelor of Environmental Management (Major in Sustainable Development), University of Queensland 2007
  - Master of Development Practice (Double major in Politics of Global Development and Development Planning), University of Queensland 2010
  - 16+ years' experience in major projects and planning roles
- Jordan Diflo
  - Associate Scientist Environment, SMEC
  - Bachelor of Environmental Science from University of the Sunshine Coast 2013.

   - 10 years' experience in environmental science and planning roles
- Dr James Bone
   - Senior Associate Scientist Ecology, SMEC
   - PhD Environmental Science, Griffith University,
   - Bachelor of Science (First Class Honours), Griffith University
   - 10+ years' experience in applied aquatic ecologist roles
- Craig Thamm
   - Bachelor of Engineering (Environment) Hons, Advanced Diploma WH&S
   - 29+ years' experience
- Kris Pitman
   - Principal Fish Ecologist, Fishology Consulting
   - Bachelor of Science (Hons) Southern Cross University
   - 21+ years' experience
- Dr Ben Cook
   - Senior Principal Ecologist, frc environmental
   - Doctor of Philosophy (PhD), Aquatic Biology, Griffith University 2006
   - Bachelor of Science (Environmental Science - Honours), Griffith University 2000
   - Bachelor of Applied Science (Environmental Management), University of Queensland 1998
   - 20+ years' experience in academic and applied aquatic ecologist roles.

In addition to the principal plan preparers, the development of the plan has been informed by representatives of the construction team to ensure that the methods and measures described herein are able to be implemented.

1.5 Content Relevant to EPBC Act Approval Conditions

EPBC Act approval conditions relevant to the lake lowering are identified in Table 1-2 , along with where these are addressed in this plan and a summary of key commitments.

Supporting information for this plan is provided in the Six Mile Creek Dam Safety Upgrade Project Impact Assessment Report (IAR), the IAR supplementary document, and the Project's Environmental Management Plan and High Risk Species Management Program.

Table 1-2: EPBC Act approval conditions and location addressed in plan

Condition Reference	Condition Requirement	Report Reference	Summary of Key Commitments
Department of the Environment and Energy – Approval Decision (EPBC 2017/8078)			
Part A	**CONDITIONS SPECIFIC TO THE ACTION**		
1	The approval holder must:		
	a) not undertake construction outside the project area	Refer to Construction Environmental Management Plan for Project	No construction will occur outside the Project area.
	b) not undertake clearing outside the clearing extent	Refer to Impact Assessment Report (IAR) Table 5-3 Table 6-1	Clearing of riparian vegetation will be restricted to the footprint approved under the IAR
	c) not undertake the lake drawdown between 1 September and 28 February	Section 2.2	Lake drawdown will not occur between 1 September and 28 February.
	d) not undertake the lake drawdown in a manner that exceeds bank-full height.	Section 2.4 Table 5-2 Table 3-1	Discharge during dewatering will not exceed 5 m^3/s with initial dewatering being undertaken over a period of not less than 4 weeks (assuming lake full at commencement).
2	Prior to the commencement of the action, and to inform the Adaptive Management Plan required under condition three (3), the approval holder must:		
	a) identify and map habitat of protected matter(s) within Lake Macdonald and downstream in Six Mile Creek	Appendix G	Habitat assessment and mapping was completed in July 2020.
	b) develop trigger levels and specify limits, at which to initiate adaptive management of the lake drawdown and construction activities, for water quality parameters including (but not limited to) temperature, pH, dissolved oxygen, turbidity, total suspended solids, nitrogen and phosphorus.	Section 3.3 Table 3-1	Water quality trigger levels (low and high) and limits have been identified based on baseline data and water quality objectives defined in the *Environmental Protection (Water and Wetland Biodiversity) Policy 2019*. Compliance with these triggers will be used to initiate adaptive management of Project activities and management measures.
Adaptive Management Plan			
3	For the protection of protected matter(s) within Lake Macdonald and downstream in Six Mile Creek, the approval holder must submit an Adaptive Management Plan, prepared by a suitably qualified and	This plan Section 1.7	This document will be submitted to DCCEEW for approval by the Minister before implementation. This plan will be implemented for the duration of the Project.

Condition Reference	Condition Requirement	Report Reference	Summary of Key Commitments
	experienced person, for the Minister's approval. The approval holder must not commence the action until the Adaptive Management Plan has been approved by the Minister in writing. The approved Adaptive Management Plan must be implemented for the duration of the action.		
4	The Adaptive Management Plan must be reviewed by an independent expert in relation to each of the protected matter(s). The review must be provided to the Department at the time the Adaptive Management Plan is submitted for the Minister's approval	Section 13 Table 13-1 Table 13-2	This document has been reviewed by independent experts for each of the protected matters (i.e. Mary River cod, Australian lungfish, giant barred frog, Mary River turtle, and white-throated snapping turtle).
5	The Adaptive Management Plan must be consistent with the Department's Environmental Management Plan Guidelines (2014), and must include:		
	a) details of how the construction and lake drawdown (during both the gradual 12-week lowering scenario and the rapid release scenario) will be managed to avoid, mitigate, and manage: i. negative impacts on the habitat of protected matter(s) identified and mapped as required under condition two (2)	Section 2 risks associated with water quantity Section 3 risks associated with water quality Section 4 risks associated with erosion and sediment Section 5.3	The initial lake lowering will be undertaken over a period of not less than 4 weeks with release rates determined by lowering requirement and inflow into the storage at the time. Performance criteria for habitat have been set and if exceeded will trigger a review of releases and management measures. Adjustments to drawdown releases (reduce or cease) may be made if a potential impact is detected. The requirement for, and the nature of, the adjustment will be dependent on the identified impact.
	ii. the exceedance of trigger levels to initiate adaptive management, and exceedance of specified limits to initiate a flow reduction or pause of the lake drawdown or construction until a solution is identified and implemented, for water quality parameters as required to be developed under condition two (2))	Section 3.3 Table 3-1 Table 5-2 Table 6-1	Performance criteria for water quality have been set and if exceeded will trigger a review of releases and management measures. Adjustments to drawdown releases (reduce or cease) will be made if a potential impact associated with the release is detected. The requirement for, and the nature of, the adjustment will be dependent on the identified impact and affected parameter.
	iii. injury and mortality of protected matter(s), including from (but not limited to) lake drawdown equipment and the temporary cofferdam.	Table 5-2	Performance criteria for aquatic flora and fauna have been set, including MNES species, along with aquatic habitat criteria. Where the flora and fauna, and habitat, triggers are exceeded, a review of releases and management measures will be implemented. Adjustments to drawdown releases (reduce or cease) will be made if a potential impact associated with the release is detected. The requirement for, and the nature of, the adjustment will be dependent on the nature of the impact.
	b) details of how proposed management measures take into account relevant approved conservation advice and are consistent with the	Section 5.4 Table 5-3	This plan was developed with regard to relevant advice, key threats and management actions for the MNES species that potentially occur in the

Condition Reference	Condition Requirement	Report Reference	Summary of Key Commitments
	measures contained in relevant recovery plans and threat abatement plans.		project area. Table 5-3 demonstrates how management measures are consistent with the advice.
	c) details of habitat remediation measures, including (but not limited to) the remediation and establishment of habitat for protected matter(s) within Lake Macdonald and downstream in Six Mile Creek.	Section 9	Where impacts to habitat for MNES species are identified, aquatic habitat will be re-established or supplemented (e.g. through replacement of woody debris or snags, bank or bed stabilisation, replacement of bed materials). Seqwater will also investigate opportunities to improve aquatic habitat in Lake Macdonald for a variety of species (e.g. addition of root balls and other fish friendly structures, if needed).
	d) measures to review and update the Adaptive Management Plan if protected matter(s), not previously identified, are found within Lake Macdonald or downstream in Six Mile Creek within 10 km of the project area	Section 1.7	If protected matters not previously identified are found within 10 km of the Project, the plan will be reviewed and updated.
	e) a monitoring program, which must include:		
	i. the timing, frequency, and location of monitoring within Lake Macdonald and downstream in Six Mile Creek, during the lake drawdown and construction, to detect potential impacts on the habitat for protected matter(s) and the exceedance of trigger levels and specified limits for water quality	Section 3.3 Table 3-1 Section 1 Section 6.3	Monitoring to assess potential impacts to MNES species habitat and water quality in relation to the specified performance criteria will occur before and during drawdown, and during construction. The monitoring frequency will range from continuous logging to every six months depending on the parameter and the location. Three downstream sites, two control sites, and one Lake Macdonald sites will be monitored.
	ii. the timing, frequency, and location of monitoring within Lake Macdonald and downstream in Six Mile Creek, post lake drawdown and construction, to detect potential impacts on protected matter(s)	Section 3.3 Table 3-1 Section 5.4 Table 5-2 Section 5.5.11	Monitoring to assess potential impacts to MNES species' habitat and water quality in relation to the specified performance criteria will occur after drawdown and construction. The monitoring frequency will range from continuous logging to quarterly depending on the monitoring outcomes. Three downstream sites, two control sites, and one Lake Macdonald site will be monitored.
	iii. the details and timing of adaptive management measures and corrective action, if negative impacts on habitat for protected matter(s) are detected, including (but not limited to) reducing or ceasing the lake drawdown and construction	Table 5-2 Table 6-1 Appendix F	Where the performance criteria defined for MNES species' habitat are not met, drawdown releases will be reduced or paused (depending on the potential impact detected). Management measures will be reviewed and revised if required. Where adjustments are not effective, alternative mitigation measures will be reviewed (e.g. habitat improvements). The duration of adjustments to releases and management measures will depend on the timing and severity of the potential impact.
	iv. the details and timing of adaptive management measures and corrective actions, if threshold trigger levels for water quality are exceeded, including (but not limited to) reducing or ceasing the lake drawdown and construction	Section 3.3 Table 3-1 Appendix F	Where the performance criteria defined for water quality are exceeded, review and corrective actions will be undertaken. If the low trigger is exceeded, a review of mitigation measures and the potential for environmental harm will be undertaken. If the high trigger value is exceeded, drawdown releases will be reduced or paused (depending on the parameter

Condition Reference	Condition Requirement	Report Reference	Summary of Key Commitments
			and magnitude of potential impact), and a review of management measures and the potential for environmental harm will be undertaken. The adjustments to releases and management measures will depend on the parameter, timing and severity of the potential impact.
6	All monitoring and data analysis required under the Adaptive Management Plan must be undertaken by a suitably qualified and experienced person(s).	Section 3.1.4 Table 3-1 Table 5-2	All monitoring is to be implemented by suitably qualified persons as defined in this plan.
Aquatic Fauna Salvage and Relocation Management Plan			
7	For the protection of protected matter(s) that are subject to salvage and relocation, the approval holder must submit an Aquatic Fauna Salvage and Relocation Management Plan, prepared by a suitably qualified and experienced person, for the Minister's approval. The approval holder must not commence the action until the Aquatic Fauna Salvage and Relocation Management Plan has been approved by the Minister in writing. The approved Aquatic Fauna Salvage and Relocation Management Plan must be implemented for the duration of the action.	Section 5.5	An Aquatic Fauna Salvage and Relocation Management Plan is incorporated in this plan. The project will not commence until this plan has been approved by the Minister in writing.
8	The Aquatic Fauna Salvage and Relocation Management Plan must be reviewed by an independent expert in relation to each of the protected matter(s). The review must be provided to the Department at the time the Aquatic Fauna Salvage and Relocation Management Plan is submitted for the Minister’s approval.	Section 13	This document has been reviewed by independent experts for each of the protected matters (i.e. Mary River cod, Australian lungfish, giant barred frog, Mary River turtle, and white-throated snapping turtle).
9	The Aquatic Fauna Salvage and Relocation Management Plan must be consistent with the Department's Environmental Management Plan Guidelines (2014), and must include:		
	a) details of how proposed management measures take into account relevant approved conservation advices and are consistent with the measures contained in relevant recovery plans and threat abatement plans.	Table 5-5	This plan was developed with regard to relevant approved conservation advice for the MNES species that potentially occur in the project area. Table 5-3 demonstrates how management measures are consistent with the advice.
	b) details of risk assessments and risk management measures to be undertaken and implemented for protected matter(s) at each proposed relocation site prior to the commencement of the lake drawdown (including but not limited to the risk of disease, translocation of aquatic weeds and pests, and risks to the health and safety of aquatic fauna during capture and transport)	Section 10 Table 5-2 Appendix H	A risk workshop and risk assessment were completed for the lake lowering, and incorporated fauna salvage and relocation. A detailed assessment of relocation sites was undertaken to determine their suitability, and visual monitoring of these sites will be undertaken. If new sites are required this will be discussed with DPI prior to relocation of fauna. Fauna capture, handling and transport will be done in accordance with relevant State and Commonwealth guidelines.

Condition Reference	Condition Requirement	Report Reference	Summary of Key Commitments
	c) detailed methodologies for the salvage and relocation operations, including (but not limited to) associated equipment for each species, which demonstrate the application of best practice and species specific methods for the salvage and relocation of the protected matter(s).	Section 5.5	A pre-salvage evaluation survey will be completed in Lake Macdonald to familiarise personnel with the lake and proposed salvage methods. The salvage and relocation operations will be completed by electrofishing, trapping (fyke), and transport teams. Fauna will be held in suitable receptacles before transport to suitable relocation sites (a total time of 3-4 hours). Fauna will be transported using suitable vehicles containing aerated water from Lake Macdonald. Handling of all MNES fauna will be in accordance with relevant Commonwealth and State guidelines.
	d) details of surveys and monitoring, including:	Water Quality: Sections 3.1.4 and 3.3 Erosion and Sediment Control: Sections 4.1.2 and 1 Aquatic flora and fauna: Sections 5.1.2 and 5.4 Aquatic fauna salvage and relocation: Section 5.5.11 Aquatic habitat: Section 6.3 Biosecurity: Section 7.3	Details of baseline monitoring and management and monitoring for water quality, erosion and sediment control, aquatic flora and fauna. Salvage and relocation monitoring of aquatic fauna. Aquatic habitat and biosecurity management and monitoring.
	i. to assess the suitability and carrying capacity of all proposed relocation sites prior to the lake drawdown	Appendix H	Surveys of relocation sites were undertaken in December 2019 and January 2020 assess to assess their suitability. Sites will be re-surveyed prior to the commencement of relocation to ensure continued viability. Survey methods are provided in Appendix H.
	ii. on a monthly basis at all relocation sites for 12 months after week four (4) of the lake drawdown schedule, to assess the long-term success of the salvage and relocation operation	Section 5.5.11	Monitoring of the relocation sites will occur for 12 months post completion of salvage.
	iii. on a monthly basis at Lake Macdonald for 12 months commencing on the final date of the salvage and relocation of the protected		Quarterly monitoring of fish and fish condition in Lake Macdonald during construction and for one year post-construction. There will be no temporary

Condition Reference	Condition Requirement	Report Reference	Summary of Key Commitments
	matter(s) back into Lake Macdonald (Mary River Cod only), to assess the long-term success of the salvage and relocation operation		relocation of Mary River cod, all cod will be relocated to suitable sites (as listed in Table 5-4) and will not be returned back into lake Macdonald at a later date. Efforts will be made to re-stock Mary River cod into Lake Macdonald on project completion as a mitigation action.
10	During salvage and relocation of protected matter(s), the approval holder must ensure that:		
	a) no protected matter(s) other than the Australian Lungfish, Mary River Cod, Mary River Turtle, and White-throated Snapping Turtle are relocated	Table 5-1 Section 5.5.2 Table 5-4	No protected matters (MNES species) other than those identified will be relocated.
	b) the Department is notified within three (3) business days if any Mary River Turtle or White throated Snapping Turtle individuals are identified during salvage and relocation operations	Section 5.5.12	Any MNES species caught and relocated will be reported to Seqwater on the same day. Seqwater will notify DCCEEW of any Mary River turtle and white-throated snapping turtle caught and relocated within three days.
	c) no Mary River Cod or Australian Lungfish are relocated to Tinana Creek or Obi Obi Creek.		No aquatic fauna will be relocated to the Tinana Creek or Obi Obi Creek sub-catchments.
	d) the Mary River Cod is the only protected matter that may be temporarily relocated (until Lake Macdonald is deemed suitable for restocking by a suitably qualified and experienced person). All other protected matter(s) including (but not limited to) the Australian Lungfish, must be permanently relocated		All other MNES species will be permanently relocated.
	e) temporary relocation of the Mary River Cod can only be to the Gerry Cook Fish Hatchery, or other location that is approved by the Queensland Department of Agriculture and Fisheries prior to the commencement of the lake drawdown		All other MNES species will be permanently relocated.
	f) no Australian Lungfish is relocated to farm dams		Australian lungfish will only be relocated to the sites identified in this plan, which exclude farm dams.
Residual Significant Impacts			
11	Within six (6) months after the completion of all monitoring required under both conditions five (5) and nine (9), the approval holder must undertake a Significant Impact Assessment (in accordance with the Significant Impact Guidelines 1.1) to determine if there are any residual significant impacts to each protected matter(s) as a result of the lake drawdown, construction and relocation operations. The assessment must be undertaken by a suitably qualified person(s) and reviewed by an independent expert. The assessment must have regard to approved conservation advices, recovery plans and threat abatement plans, and also include an assessment and evaluation of:		
	a) the effectiveness and success of the Adaptive Management Plan and of the lake drawdown and construction to avoid, mitigate and manage impacts to protected matter(s)	Section 13	A report on the effectiveness and success of this plan, including an assessment of residual significant impacts on MNES species, will be prepared by a suitably qualified and experienced person within six months of the completion of the monitoring.

Condition Reference	Condition Requirement	Report Reference	Summary of Key Commitments
	b) the effectiveness and success of the Aquatic Fauna Salvage and Relocation Management Plan, and salvage and relocation activities to avoid, mitigate and manage impacts to protected matter(s).	Section 13	A report on the effectiveness and success of the fauna salvage and relocation plan, including an assessment of residual significant impacts on MNES species, will be prepared by a suitably qualified and experienced person within six months of the completion of the monitoring.
12	The Significant Impact Assessment and independent review required under condition 11 must be made publicly available on the website within nine (9) months after the completion of monitoring required under both conditions five (5) and nine (9) and be provided to the Minister within five (5) business days of being published.	Section 13	The report will be made publicly available within the specified time frame.

1.6 Content Relevant to Coordinated Project Approval Conditions

Coordinated project approval conditions relevant to the lake lowering in the Coordinator-General's Evaluation Report on the IAR are identified in Table 1-3, along with where these are addressed in this plan and a summary of key commitments.

Table 1-3: Coordinated project approval conditions and location addressed in plan

Condition Reference	Condition Requirement	Report Reference	Summary of Key Commitments
Imposed Conditions			
Schedule 1	**MANAGEMENT OF ENVIRONMENTAL IMPACTS**		
1	Site environmental management plan	Refer to Environmental Management Plan for Project	
5	Flora and fauna management plan: The purpose of this condition is the development and delivery of an adaptive management plan for managing and minimising impacts on terrestrial and aquatic ecology habitat, including fish species, pest species, and MSES species likely to occur in Lake Macdonald, its tributaries. and in Six Mile Creek.		
	a) The purpose of this condition is the development and delivery of an adaptive management plan for managing and minimising impacts on terrestrial and aquatic ecology habitat, including fish species, pest species, and MSES species likely to occur in Lake Macdonald, its tributaries and in Six Mile Creek.	This plan (in part)	This adaptive management plan has been developed to minimise impacts associated with the lowering of Lake Macdonald and will be reviewed periodically.
	b) The plan must include effective management measures (including fauna salvage and relocation program and remediation) to reduce impacts for all other aquatic MSES species.	Table 3-1 Table 5-2 Table 6-1 Table 7-1	Management measures to reduce potential impacts to aquatic flora and fauna associated with the lowering of Lake Macdonald, including a salvage and relocation program (Section 5.5) have been identified, along with performance criteria and monitoring requirements.
	c) The plan must:		

Condition Reference	Condition Requirement	Report Reference	Summary of Key Commitments
	(i) include aquatic habitat management measures for the management of water quantity and quality released downstream from the dam, both during dam drawdown and during construction activities, including:	Section 3 Table 3-1	Management measures for the release of water from Lake Macdonald. Water quality and aquatic habitat are provided.
	(A) monitoring of water level, water quality, velocity and bed and bank stability downstream of the dam	Section 2.5	Monitoring of water level and velocity, water quality, and bed and bank stability will be undertaken before, during and after drawdown.
	(B) performance criteria and trigger levels to detect potential impacts to initiate adaptive management measures, corrective action, or remediation as appropriate	Table 3-1 Table 5-2 Table 6-1 Table 7-1 Table 7-2	Performance criteria are identified for water quality, bed and bank erosion, and aquatic habitat.
	(C) upper threshold limits for water quality that would initiate emergency response measures, including immediate reduction or temporary ceasing of water release	Section 3.3 Table 3-1	Performance criteria (low and high trigger values) are identified and response measures will be undertaken if these trigger values are exceeded.
	(D) detail corrective measures and how they would be implemented if trigger levels are exceeded	Section 3.3 Table 3-1 Table 5-2 Table 6-1 Table 7-1 Table 7-2	Corrective measures / actions have been identified for water quality, bed and bank erosion, and aquatic habitat, including immediate reduction or temporary ceasing of water release
	(E) the requirement for site photographs to record vegetation and stream structure before, during, and immediately after dam lowering to monitor effects of discharge rates on aquatic ecosystems	Appendix F	Photo monitoring will be undertaken before, during and after the drawdown of Lake Macdonald.
	(ii) clearly set out monitoring and reporting requirements on the success of the management measures against performance criteria and trigger levels to meet the environmental flow requirements under the *Water Plan (Mary Basin) 2006*, and if necessary, how the plan has been amended to address exceedances.	Table 3-1 Table 5-2 Table 6-1 Table 7-1 Table 7-2	Monitoring and reporting requirements are identified for environmental flow requirements and water quality.
Stated Conditions			
Schedule 1	***PLANNING ACT 2016***		
Part A	Waterway Barrier Works		

Condition Reference	Condition Requirement	Report Reference	Summary of Key Commitments
1	(a) Drawdown of Lake Macdonald and fish salvage operations must not occur between 1 September and 28 February.	Section 2.2	Drawdown will not occur between 1 September and 28 February.

1.7 Review of Plan

This plan has been prepared based on the best available information at the time of the current revision. It is based on desktop and field data compiled for the IAR and subsequent assessments completed in 2020 and 2023. It is acknowledged that this data is a representation of ecosystem conditions at the time of the assessments and does not account for all ecosystem conditions, or flora and fauna, that may occur in areas relevant to the plan. Consequently, the plan is intended to be adaptive and will evolve over the course of the Project in response to changing conditions and expert advice.

The plan will be implemented for the duration of the Project. Periodic technical review of the plan will be undertaken by the Construction Contractor within three months of completing drawdown and subsequently every six months until the Project is complete. In addition, at any point of the Project, the approved plan may need to be amended in response to changes in potential impacts, increased or decreased risks, and greater or less uncertainty. The plan must be reviewed and updated if:

- Protected matters not identified previously within the project area or a 10 km radius of the project area are found within Lake Macdonald or downstream in Six Mile Creek within 10 km of the Project area
- Project activities change from those described in the current version of the plan
- Performance criteria are not met (as indicated by monitoring)
- Management measures or monitoring requirements are found to be ineffective
- Corrective actions stipulate a review is required
- An environmental incident occurs.

As per conditions 26 to 31 of the EPBC Act approval, if action taken in accordance with the revised plan is unlikely to result in a new or increased impact, the plan can be revised without approval from the Australian Government Minister administering the EPBC Act including any delegate thereof (the Minister). If the plan is revised without approval, Seqwater must notify the Department of Climate Change, Energy, the Environment and Water (DCCEEW) in writing and provide an electronic copy of the plan showing tracked changes, an explanation of the differences between the approved and revised plan, justification as to why the amendments would not be likely to create a new or increase existing impacts, and written notice of the date on which the revised plan will be implemented. The written notice must occur at least 20 business days before the implementation of the revised plan. If the Minister believes the amendments will result in a new or increased impact, the approval holder must implement the action management plan specified by the Minister.

Any proposed changes to the plan can be revoked by Seqwater at any time by notifying DCCEEW and implementing the previous action management plan.

2. Lowering Lake Macdonald

2.1 Water Quantity

Full supply level (FSL) in Lake Macdonald is at an elevation of RL 95.3 m AHD. The corresponding full supply volume (FSV) is 8,018 ML. Water in Lake Macdonald will be lowered to RL 93.0 m AHD to facilitate the construction of a temporary cofferdam with a spillway crest at RL 93 m AHD. Upon completion the temporary cofferdam will control the lake and demolition of the existing dam spillway and embankment will commence. The cofferdam will then maintain the maximum water level at RL 93.0 m AHD for the duration of construction of the new spillway and embankments (36 to 48 months). This equates to retaining approximately 3,368 ML (42% of FSV) of water in Lake Macdonald. The water level during construction will be subject to inflows, evaporation and operational drawdown, and so fluctuation in water level during construction is expected, noting that it is possible for the lake to lower to 91.5 m AHD (15% of FSL) under a worst case (and unlikely) scenario where water extraction for potable use is not replenished by inflows.

Assuming Lake Macdonald is full at the time water lowering begins, a minimum of approximately 4,650 ML of water (plus inflows) will be removed from the lake before the temporary cofferdam can be installed.

2.2 Drawdown Schedule

The initial lowering of Lake Macdonald must not be undertaken between 1 September and 28 February of any year, per conditions of approval for the Project (EPBC 2017/8078). This is to reduce impacts of lowering on breeding seasons of threatened species listed under the EPBC Act[1]. This schedule also avoids breeding seasons of other threatened and common species.

The initial lowering of Lake Macdonald will occur over a period of not less than 4 weeks. The drawdown schedule ensures the lake is lowered in a controlled manner to minimise adverse effects on aquatic fauna and to allow for capture (salvage) and relocation of aquatic fauna. The controlled and gradual drawdown will also minimise adverse effects of released flows in Six Mile Creek downstream and limit the rate of lakebed exposure.

It is to be noted that it is possible that during the drawdown, natural inflow into the storage may increase the lake level. In this circumstance, the lake would be re-lowered at a more rapid rate in an effort to achieve the preferred 4 week program overall.

2.3 Drawdown Rate

The drawdown will target approximately 11% of the lake full supply volume each week. The volume of water discharged downstream will be set by the sum of:

- the lake lowering requirement, plus
- inflow, minus
- operational demand, minus
- evaporation and other losses

The practical limitation on release rate of the siphon system is around 5 m^3/s. Hydraulic modelling indicates that the bankfull rate of Six-Mile Creek is 10 m^3/s. As per Condition 1-d) of the EPBC Approval the lake drawdown must be undertaken in a manner that does not exceed the bankfull height.

2.4 Drawdown Method

Pumps and/or siphons will be used to achieve the drawdown of Lake Macdonald. These will enable variable release rates during the drawdown. Some drawdown equipment may also remain throughout the Project to manage lake levels, if required.

[1] The giant barred frog calling season includes March and potentially April in this area, so the drawdown period may overlap with the breeding season and the presence of tadpoles, but that this is not expected to significantly impact the breeding of the downstream population where water quality and stream flows mimic natural hydrological patterns, as far as it is possible.

Screening requirements for intakes are outlined in Table 5-2. The drawdown release point/s will be installed with suitable energy dissipation to minimise bed and bank erosion (for example, by discharging onto the concrete apron of the existing spillway). This requirement is stipulated in Table 3-1. Discharged water will then flow downstream through Six Mile Creek.

2.5 Post-Drawdown Maintenance of Water Level

Following the drawdown and during the construction of the new spillway and embankments, water levels will be maintained at a temporary FSL of RL 93.0 m AHD (42% of normal FSV) by a cofferdam. The cofferdam will incorporate a 150 m long crest at RL 93.5 m AHD. Noting this, the current cofferdam design only contains a small low-flow slot section which has limited freeboard (relative to the remaining 150 m of the structure). As designed, this is the only section at 93.0 m AHD, therefore the remaining 150 m of cofferdam will have a freeboard greater than 0.5 m, limiting fauna interactions. A section of the existing dam spillway will be cut and lowered to 89.5 m AHD. When this occurs, the main waterbody of the dam will be retained by the coffer dam. Throughout the construction period the temporary FSL will be actively managed by diverting inflows, up to a practical upper limit of 5 m^3/s around the work area through a diversion system comprised of pumps and siphons. The diversion rate will approximately match inflow rate when the storage level gets close to the temporary FSL. Where inflows are larger than 5 m^3/s and the storage level increases above the cofferdam crest, water will discharge downstream through the existing dam spillway. Any active management of water levels will aim to mimic natural flow regimes by reducing the frequency and extending the intervals between release pulses, thereby minimising disruptions to the behavioural patterns of sensitive species.

As preparation for wet weather, the Contractor may drawdown the lake water level through bypass releases no greater than 0.5 m below the coffer dam low-flow crest level.

It must be noted that it is essential that the lake remain operational (i.e. subject to consumptive water extraction) throughout construction to ensure regional and water security. Water levels in the lake will therefore depend on inflows, consumption and other losses.

A small body of water will be retained in between the cofferdam and the existing dam / construction site, referred to herein as the stilling basin, that will need to be lowered or fully dewatered from time to time. Likely conditions of the stilling basin include:

- relatively large surface area (approximately 14,000 m^2 or 1.4 HA)
- depth of 2 – 3 m, depending on thickness of placed rock and accuracy of bathymetry model
- regular pass through of water with water received over cofferdam spillway and discharged through a slot in the existing / partially reconstructed dam
- periodically poor water quality, and therefore moderate risk of fish kill.

Consequently, water quality monitoring and management (e.g. periodic dewatering), and aquatic fauna monitoring and management (e.g. salvage), with respect to the stilling basin will be key aspects of environmental management for the project. To facilitate effective access for environmental management and construction purposes, the design of the cofferdam and adjacent areas will need to accommodate safe access and working conditions.

2.6 Average Monthly Outflows

The operation of the Southeast Queensland Bulk water supply system was simulated under 10,000 stochastics climate replica for two scenarios being the 95.3 m AHD (100% FSV) and 93.0 m AHD (42% FSV) using the Regional Stochastic Model and a Spills Analysis. The simulation was conducted over a period of 10 years starting from the 1st July 2023, and based on a temporary 3-year Lake Macdonald construction lowering that began in March 2024. The statistics obtained from the first three years of the simulation illustrate the average monthly outflow from Lake Macdonald, and provide insight into the impact of lowering the FSL on the average monthly outflow. The average monthly outflows are detailed in Table 2-1: Average Monthly Outflows; and indicate that after the drawdown a limited increase to the average monthly outflows is expected, with variations ranging from 1 to 28%. These increases can be largely attributed to the fact that during normal operating conditions at 100% FSL, the lake will only spill when lake levels are at 100% or above therefore most of the year minor inflows are absorbed into the reservoir without spilling downstream. During construction however most inflows will be diverted directly downstream through the siphon system. Only when the siphon system reaches capacity will flows spill over the UCD and working platform. Other environmental factors such as evaporation and groundwater seepage would also expect to increase water losses during the normal operating conditions of a larger reservoir.

To maintain the lowered lake level, it is anticipated that a monthly increase in water outflow will be necessary. It is assumed that allowing 100 mm of water to flow over the cofferdam spillway will encourage fish to move downstream from the cofferdam area. This 100 mm overflow was used to assess outflow for the current design. The design also aims to prevent fish from passing downstream (with the exception of significant flow events) by maintaining the cofferdam water level at 93 m AHD. A siphoned system is used to maintain this water level and restrict downstream fish passage, except during significant flow events. These outflows are modelled on the use of siphons pipe to facilitate release from Lake Macdonald and reduce the number of days that would have been considered to queue downstream movement of fish (i.e. <100 mm) over the low-flow section of the cofferdam. Currently the siphon design for outflow reduces potential downstream movement of fish via the spillway (at >100 mm) and is modelled at an average of five (5) days per year.

Table 2-1: Average Monthly Outflows

Month	Average Monthly Outflow Volume (ML) FSL 95.32	Average Monthly Outflow Volume (ML) FSL 93.0	Percentage Change (%)
January	3,595	3,771	4.91%
February	6,281	6,368	1.38%
March	5,278	6,774	28.34%
April	3,173	3,373	6.32%
May	2,756	2,911	5.62%
June	2,243	2,294	2.26%
July	1,455	1,519	4.38%
August	312	353	13.19%
September	270	303	11.98%
October	526	590	12.09%
November	1,024	1,084	5.81%
December	1,479	1,637	10.71%

2.7 Management of Environmental Flow Requirements

The impoundment of water by Six Mile Creek is authorised under *Water Act 2000*, by a Water Licence granted to Queensland Bulk Water Supply Authority (Seqwater). The water licence is subject to conditions, which include releases for environmental flow from Lake Macdonald (Six Mile Creek) Dam.

The Water Licence conditions require releases from Lake Macdonald (Six Mile Creek) Dam based on inflow rules. That is, inflows to the dam trigger certain daily releases downstream, whether by manual release or spillway overtopping. These conditions will remain in force during the Project construction, with no change from the existing situation.

During construction, the majority of lake inflows will be diverted downstream through the siphon system, allowing the environmental flows to be achieved with no intervention. If inflows trigger an environmental flow requirement under the Water Licence and temporary cofferdam overtopping does not occur, manual releases from the lake by pump or another means will be required.

It should be noted that the intended outcomes of environmental flows under the Water Licence are not in Seqwater's purview and their intent is not to provide constant downstream flows. Seqwater is not the responsible entity for determining environmental flow requirements to maintain downstream ecosystem health. Nevertheless, in the event of an extended dry or hot period, the feasibility of additional releases may be investigated for the benefit of downstream ecology.

3. Water Quality Management Plan

3.1 Baseline Conditions

3.1.1 Water Quality Objectives

Six Mile Creek, including Lake Macdonald has defined waterway Environmental Values (EVs) and Water Quality Objectives (WQOs) under the *Environmental Protection (Water and Wetland Biodiversity) Policy 2019* (EPP(Water)). The WQOs for parameters listed in the EPP (Water) for the protection of the aquatic ecosystem EV in Lake Macdonald and Six Mile Creek are provided in Appendix B.

3.1.2 Water Quality in Lake Macdonald

Median water quality results from Seqwater long term monitoring data for Lake Macdonald are provided in Appendix B. These are based on data available from a variety of routine and non-routine surface water quality sampling sites located, within and upstream of, Lake Macdonald (refer to Appendix B). A review of the results shows that regional WQOs for nutrient parameters are typically not achieved within Lake Macdonald; with nitrate, total nitrogen and oxidised nitrogen median values exceeding default WQOs. Dissolved oxygen for Lake Macdonald was generally lower than the WQOs. Previous studies also indicated that the regional WQO for chlorophyll-a is not achieved in the lake. All other median values for each parameter were within regional WQO range across Lake Macdonald.

Long-term water quality monitoring data (2011-2017) supplied by Seqwater and previously assessed for the IAR also indicated that:

- Dissolved aluminium in Lake Macdonald was often higher than the Default Guideline Value (DGV) (ANZG, 2018) for the 95% protection level of aquatic ecosystems
- Total aluminium, zinc and cobalt in Lake Macdonald were sometimes higher than the DGV
- Total aluminium, chromium, copper, mercury and zinc, and dissolved aluminium in the Lake Macdonald tailwater were higher than the DGV[2].

The *Water Monitoring Data Collection Standards* (DNR, 2007) defines a reservoir as stratified if the temperature difference between surface and basement layers exceeds 5°C. A review of monthly depth profile measurements in Lake Macdonald (mid-lake) from November 2011 to November 2017 indicated that Lake Macdonald rarely stratifies, and when it does it is only weakly stratified. Further information on stratification is provided in Appendix B.

3.1.3 Water Quality within Six Mile Creek (downstream of Lake Macdonald)

Median water quality results and site-specific water quality trigger values from Seqwater long term monitoring data for Six Mile Creek downstream are provided in Appendix B. These are based on data available from a variety of routine and non-routine surface water quality sampling sites located at the tailwater, and further downstream, of Lake Macdonald (within Six Mile Creek) (refer to Appendix B). A review of the results shows that median values for both pH and turbidity parameters were within regional WQO range across Six Mile Creek. Dissolved oxygen for Six Mile Creek was generally lower than the regional WQOs. Previous assessments also indicated that the tailwater typically fails to achieve WQOs for total suspended solids, and ammonia. This is expected to continue through the construction period as the non-achievement of WQOs is principally related to releases from the dam rather than external factors.

[2] ANZECC & ARMCANZ (2000) guidelines were applicable at the time the IAR was completed. If sampling is required, any future monitoring results for metals will be compared to the Australian & New Zealand Guidelines for Fresh & Marine Water Quality (2018).

3.1.4 Water Quality Monitoring

3.1.4.1 Site-specific water quality triggers

As dam improvement works and associated measures are proposed to deal with a reduced (42% full supply level) impoundment, the following sites have been identified for inclusion (as collated data) for the calculation of triggers:

Lake Macdonald:

- Seqwater active sampling:
  - Lake Macdonald Dam Wall Offtake
  - Lake Macdonald Mid-Lake at Confluence
- Seqwater passive sampling:
  - Lake Macdonald (Inflow passive)
- Virid IFC sample point:
  - Lake Macdonald (I1 and I3)

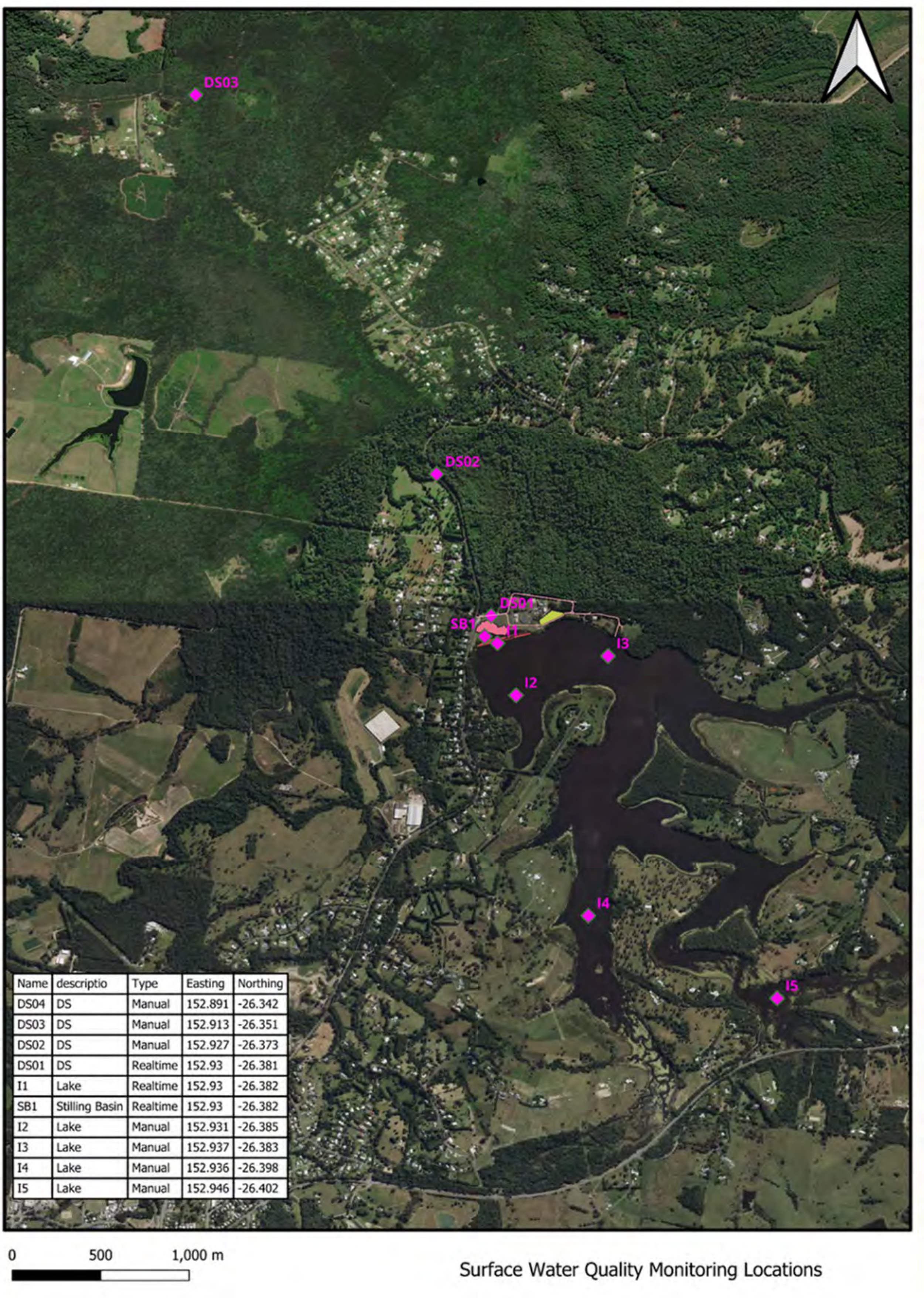
Six Mile Creek:

- Seqwater active sampling:
  - Lake Macdonald Tailwater below Dam Wall
- Seqwater passive sampling:
  - Six Mile Creek (Tailwater passive)
- Virid IFC sample point:
  - Six Mile Creek (DS01 and DS02)

Further description of site locations and coordinates are presented in the *LMDIP site specific water quality objectives 2024* report (*LMDIP-05762-RES-ENV-REP-00001*) (SMEC, 2024). Due to the proximity of the current sites; Lake Macdonald Dam Tailwater and Six Mile Creek (DS01 and DS02), these have been combined to provide data for lake Macdonald Tailwater management triggers.

3.1.4.2 Baseline Monitoring

All baseline water quality monitoring will be undertaken by suitably qualified persons in accordance with the Queensland *Monitoring and Sampling Manual – Environmental Protection (Water and Wetland Biodiversity) Policy 2019* (DES 2018). The monitoring is described in Table 3-1 and the proposed monitoring sites are shown in Figure 3-1. Note that locations are indicative and may be varied for logistical reasons. Additional monitoring will be completed during the month before the lake lowering to record and assess water quality conditions immediately before the Project begins.



Name	descriptio	Type	Easting	Northing
DS04	DS	Manual	152.891	-26.342
DS03	DS	Manual	152.913	-26.351
DS02	DS	Manual	152.927	-26.373
DS01	DS	Realtime	152.93	-26.381
I1	Lake	Realtime	152.93	-26.382
SB1	Stilling Basin	Realtime	152.93	-26.382
I2	Lake	Manual	152.931	-26.385
I3	Lake	Manual	152.937	-26.383
I4	Lake	Manual	152.936	-26.398
I5	Lake	Manual	152.946	-26.402

Figure 3-1 Monitoring and survey sites

3.2 Potential Impacts of Lowering Lake Macdonald

3.2.1 Within Lake Macdonald

The IAR indicated that the risk of adverse impact to water quality in the lake is low, especially considering that the magnitude of drawdown (i.e. from RL 95.3 m AHD to RL 93.0 m AHD) is limited, meaning the maximum and average depth of water in the lake, and area of water coverage, will not be reduced to the extent that water quality and aquatic ecology impacts are likely. While the quality of water in the stilling basin (i.e. body of water in between cofferdam and permanent structure) may periodically deteriorate, this will not affect the lake. Nonetheless, a conservative approach towards environmental management of the drawdown and construction phases of the Project will be implemented. Mitigations and monitoring for the following potential sources of adverse impact will be implemented:

- Increasing turbidity and total suspended solids via disturbance of bed sediments and / or the erosion of bed and banks
- Reducing pH by exposing or disturbing acid sulphate soils[3] and / or decomposing organic material (e.g. aquatic plants)
- Reducing dissolved oxygen, through eutrophication and mobilisation of iron in the lake sediment, which may consume dissolved oxygen when mobilised into oxygenated water
- Eutrophication of Lake Macdonald following the drawdown resulting in an increased occurrence of agal blooms, specifically Blue-green algae
- Reducing dissolved oxygen and pH through decomposition of algae and aquatic plants during and following drawdown (refer to section 5.3.1)
- Contaminating water through spills of fuels, oils or other chemicals from pumping equipment or other machinery / vehicles
- Contaminating water within the stilling basin (e.g. contamination from construction dust and other contaminants).

3.2.2 Within Six Mile Creek (Downstream of Lake Macdonald)

Water quality in Six Mile Creek downstream of the dam is also unlikely to change significantly from current condition given the relatively limited magnitude of drawdown. The main water quality risk relates to an event whereby a significant volume of poor water quality from the stilling basin released downstream. This would only happen in the event of a spill over the cofferdam spillway and hence likely to be a transitory condition that rapidly reverts to water quality consistent with lake water quality. Mitigation and monitoring will be implemented for the following potential sources of adverse impact:

- Poor water quality within the stilling basin
- Increasing turbidity and total suspended solids via disturbance of bed sediments, the erosion of bed and banks, and/or the discharge of turbid water
- Reducing pH if the discharged water has a lower pH than occurs in the creek
- Reducing dissolved oxygen if the discharged water has low dissolved oxygen
- Increasing nutrient concentrations if the discharged water has high nutrient concentrations (or is allowed to eutrophy)
- Contaminating water if there are spills of fuels, oils or other chemicals from pumping equipment or other machinery / vehicles to the creek or the water discharged into the creek.

[3] Testing indicates that although there is some acidity in the soils at lake Macdonald, this is non-sulfuric (i.e. acid sulfate soils are unlikely to be present).

3.3 Management and Monitoring

Potential risks to water quality are overall low, with the exception of poor water quality in the stilling basin, especially if this water was to be released to the downstream Six Mile Creek. However, it is expected that potential sources of adverse impact will be mitigated by implementing the measures outlined in Table 3-1. Where appropriate, the detailed management measures will be adapted over the course of the Project in response to changing conditions and expert advice.

Management objectives for water quality are identified in Table 3-1. These management objectives were derived from water quality monitoring data for Lake Macdonald and Six Mile Creek collected between 2019 and 2024, in accordance with the methods in the Queensland Water Quality Guidelines 2009 (DEHP 2013, see also DES 2022 and ANZG 2018). Therefore, the established management objectives reflect the water quality conditions supporting aquatic fauna (including MNES) in the Project area. For water quality parameters that do not have management objectives, values, historical and baseline data will be used to evaluate monitoring results. The triggers have been updated to incorporate baseline monitoring data prior to the drawdown commencing.

As detailed in Table 3-1, monitoring will be conducted in Lake Macdonald at least 30 days before the drawdown begins to obtain a contemporary water quality data set to be used to inform acute water quality issues from the drawdown. Noting this, this water quality data will also be assessed against developed site-specific water quality trigger values derived from comprehensive background data collected by Seqwater active and passive sampling between 2019 to 2024, and a VIRID IFC between 08/03/2024 and 16/05/2024 (refer to Appendix B). This will be used to identify longer term issues from drawdown (rather than acute issues to physico-chemical water quality parameters associated with the drawdown). Noting the fortnightly monitoring to be conducted within Lake Macdonald before the drawdown, this is proposed for laboratory analytes while physico-chemical parameters are proposed to be undertaken daily. During the drawdown, there are a number of monitoring event timeframes and these are commensurate with the risk of drawdown across various site activities i.e. physico-chemical parameters to be monitored daily (in Lake Macdonald proper and in the cofferdam), laboratory analytes weekly in the stilling basin and monthly in Lake Macdonald proper. The aim of the pre-drawdown monitoring is linked to the performance criteria for minimising the impact of lowering on water quality in Lake Macdonald and Six Mile Creek which indicates water quality will be assessed against the low and high trigger values of recently collected (over the last 5 year period) water quality data (Appendix B). The background water quality data included in Appendix B has been generated from long-term Seqwater data (for all Lake Macdonald dam management) and from sampling undertaken (non-continuous) between 2019 and 2024 by Seqwater and VIRID IFC.

Table 3-1: Management of water quality during the lowering of Lake Macdonald

Environmental objective:

Minimise impact of lowering on water quality in Lake Macdonald and Six Mile Creek.

Performance criteria

Daily monitoring for field parameters and weekly/monthly for laboratory parameters will be undertaken. Investigations will be undertaken if monitoring identifies that levels have exceeded the high and low risk trigger values developed from recent years of water quality data collected by Seqwater and contractors which represents what it typically observed.

Should trigger values be identified during water quality testing associated with this adaptive management plan the following measures will be undertaken (refer to Appendix B for more information):

- Low risk trigger – Implementation of adaptive scenario management measures where increased water quality sampling is undertaken alongside assessing the effectiveness of current mitigation measure controls.
- High risk trigger – Implementation of intervention control management measures (i.e. fish salvage exercises, increased aeration, management of erosion and sediment control devices.

Adaptive management actions will be triggered when multiple samples (at least 2) exceed the performance criteria.

Water Quality Parameter	Unit	Low risk trigger value		High risk trigger value	
		Min low risk value	Max low risk value	Min high risk value	Max high risk value
Lake Macdonald (freshwater lakes/reservoirs)					
pH	log {H+}	6.41	6.64	5.73	7.30
Turbidity	NTU	-	9.75	-	42.60
Dissolved Oxygen	%	>74.10 (6.1 mg/L)	-	31.80 (2.62 mg/L)	-
Total suspended solids	mg/L	-	5	-	9
Total nitrogen	mg/L	-	0.59	-	0.78
Nitrate	mg/L	-	0.0142	-	0.020
Nox	mg/L	-	0.0116	-	0.040
Ammonia	mg/L	-	0.0528	-	0.110
Total phosphorus	mg/L	-	0.034	-	0.048
Six Mile Creek (lowland freshwater)					
pH	log {H+}	6.25	6.65	5.70	7.13
Turbidity	NTU	-	4.13	-	6.69

<table>
<tr><th colspan="9">Environmental objective:
Minimise impact of lowering on water quality in Lake Macdonald and Six Mile Creek.</th></tr>
<tr><td></td><td></td><td>Dissolved Oxygen</td><td>%</td><td>>98.02 (8.07 mg/L)</td><td>-</td><td>56.96 (4.69 mg/L)</td><td>-</td><td></td></tr>
<tr><td>Management measures</td><td colspan="8">
Lake Macdonald
<u>During drawdown</u>:

Arrange dewatering equipment intakes so that suction does not disturb sediments on the bed of Lake Macdonald.
Arrange intakes of dewatering equipment to extract from within top half of water column.
For any mechanical equipment biodegradable oils/lubricants will be used, refuelling will preferentially be undertaken on land and with suitable containment. Where refuelling needs to occur proximate to the lake, appropriate spill kits will be in place to contain any spill.
Ensure that fuels, oils and other chemicals are stored in bunded areas in accordance with Australian Standard 1940 (2004) – The storage and handling of flammable and combustible liquids.
The existing bubble plume destratification unit will be maintained and will run continuously for the life of the project, providing aeration of the water in Lake Macdonald. If the trigger values for relevant parameters are identified and it appears that the destratification unit is not working or there are insufficient inflows, additional measures to restore water quality will be investigated. This will include additional proven aeration devices or methods.
Implement risk-based assessment of any exceedances of water quality trigger values to determine the potential for environmental harm, and if so then implement additional mitigations (e.g. implement additional proven aeration devices or methods in Lake Macdonald if the concentration of dissolved oxygen becomes low and of concern).
Where the current median (50th percentile) exceeds the low risk trigger value but remains below the high risk trigger value, monitoring and management will continue under existing processes. In this case, low risk trigger management measures will not apply to parameters where the median already exceeds the low risk trigger value. This approach acknowledges that if a parameter's median was already above the low risk trigger before the drawdown, the system is naturally operating under those conditions. Trigger values will be reassessed as more data becomes available. If a parameter’s median does not meet the existing regional water quality objectives for aquatic ecosystems, the relevant trigger thresholds will be applied. See Appendix B for details.

<u>During construction</u>:

For any mechanical equipment biodegradable oils/lubricants will be used, refuelling will preferentially be undertaken on land and with suitable containment. Where refuelling needs to occur proximate to the lake, appropriate spill kits will be in place to contain any spill.
Ensure that fuels, oils and other chemicals are stored in bunded areas in accordance with Australian Standard 1940 (2004) – The storage and handling of flammable and combustible liquids.
Comply with the construction erosion and sediment control plan, and stormwater management plan.
Regular dewatering and treatment of poor water quality, when detected, in the stilling basin.
The existing bubble plume destratification unit will be maintained and will run continuously for the life of the project, providing aeration of the water in Lake Macdonald. If the trigger values for relevant parameters are identified and it appears that the destratification unit is not working or there are insufficient inflows, additional measures to restore water quality will be investigated. This will include additional proven aeration devices or methods.
Implement risk-based assessment of any exceedances of water quality trigger values to determine the potential for environmental harm. If potential for environmental harm is identified additional mitigations will be implemented (e.g. implement additional proven aeration devices or methods in Lake Macdonald if the concentration of dissolved oxygen becomes low and of concern).
Where the current median (50th percentile) exceeds the low risk trigger value but remains below the high risk trigger value, monitoring and management will continue under existing processes. In this case, low risk trigger management measures will not apply to parameters where the median already exceeds the low risk

</td></tr>
</table>

Environmental objective: **Minimise impact of lowering on water quality in Lake Macdonald and Six Mile Creek.**	
	trigger value. This approach acknowledges that if a parameter's median was already above the low risk trigger before construction, the system is naturally operating under those conditions. Trigger values will be reassessed as more data becomes available. If a parameter’s median does not meet the existing regional water quality objectives for aquatic ecosystems, the relevant trigger thresholds will be applied. See Appendix B for details. **Six Mile Creek Downstream** <u>During drawdown and construction</u>: • Release rates must comply with mitigations measures outlined in Table 4-1 (under Six Mile Creek Downstream – During drawdown and construction). • Provide aeration of water and mitigate erosion through energy dissipation as water is discharged downstream, such as through armoured discharge points or sprays. • Undertake refuelling or chemical use away from Six Mile Creek, in accordance with the relevant construction environmental management plan. • Ensure that fuels, oils and other chemicals are stored in bunded areas in accordance with Australian Standard 1940 (2004) – *The storage and handling of flammable and combustible liquids.* • Comply with the construction erosion and sediment control plan, and stormwater management plan.
Monitoring	• All monitoring must be implemented by suitably qualified persons in accordance with the Queensland Monitoring and Sampling Manual – Environmental Protection (Water and Wetland Biodiversity) Policy 2019 (DES, 2018). **In Lake Macdonald** <u>Before drawdown:</u> • At least 30 days before lake drawdown begins, conduct monitoring at least daily of temperature, pH, dissolved oxygen, electrical conductivity (EC) and turbidity at one lake site upstream of the cofferdam). • In the month before lake drawdown begins, fortnightly monitoring of chemical oxygen demand (COD), suspended solids, nitrate, ammonia, total phosphorus, and visual observations for oil slicks <u>During drawdown and construction:</u> • Conduct monitoring at least daily of temperature, pH, dissolved oxygen, EC, and turbidity at the lake monitoring location upstream of the cofferdam. • Daily visual observations for oil slicks in the lake immediately upstream of the cofferdam. • Daily monitoring of water quality for pH, dissolved oxygen and turbidity in the stilling basin. • Monthly monitoring of COD, suspended solids, nitrate, ammonia, total phosphorus and total recoverable hydrocarbons (laboratory analysed) at one site in the lake (upstream of the cofferdam). • Weekly monitoring of COD, suspended solids, nitrate, ammonia, total phosphorus and total recoverable hydrocarbons (laboratory analysed) within the stilling basin. <u>Post construction</u> • Quarterly (for 1-year post-construction) in conjunction with habitat monitoring (refer to Appendix F) monitoring of temperature, pH, dissolved oxygen, EC, and turbidity COD, suspended solids, nitrate, ammonia, total phosphorus and total recoverable hydrocarbons (laboratory analysed) at the lake monitoring site (upstream of the cofferdam). Routine Seqwater monitoring of water quality in Lake Macdonald maybe used where requirements overlap. **Six Mile Creek Downstream Sites and Control Sites** <u>Before drawdown:</u>

Environmental objective: **Minimise impact of lowering on water quality in Lake Macdonald and Six Mile Creek.**	
	• In the month before lake drawdown begins, install a logging device for real-time monitoring of temperature, pH, dissolved oxygen, EC, and turbidity at downstream monitoring site SMCDS02. • In the month before lake drawdown begins, fortnightly monitoring of COD, nutrients (nitrate, ammonia and total phosphorus) and suspended solids, and visual observations for oil slicks, at the downstream monitoring sites SMCDS01, SMCDS02 and SMCDS04. • In the month before lake drawdown begins, fortnightly monitoring of temperature, pH, dissolved oxygen, EC, and turbidity at downstream monitoring sites SMCDS01 and SMCDS04. • In the month before lake drawdown begins, fortnightly monitoring of temperature, pH, dissolved oxygen, EC, and turbidity, nutrients (nitrate, ammonia and total phosphorus), suspended solids, temperature, pH, dissolved oxygen, EC and turbidity, and visual observations for oil slicks at upstream control sites SMCUS01 and CU02. During drawdown: • Real-time monitoring of temperature, pH, dissolved oxygen, EC, and turbidity at the downstream monitoring site SMCDS02. • Fortnightly monitoring of nutrients (nitrate, ammonia and total phosphorus), suspended solids, and visual observations for oil slicks, at the downstream monitoring sites SMCDS01, SMCDS02 and SMCDS04. • Fortnightly monitoring of temperature, pH, dissolved oxygen, EC, and turbidity at downstream monitoring sites SMCDS01 and SMCDS04. • Fortnightly monitoring of temperature, pH, dissolved oxygen, EC, and turbidity nutrients (nitrate, ammonia and total phosphorus), suspended solids, temperature, pH, dissolved oxygen, EC and turbidity, and visual observations for oil slicks at upstream control sites SMCUS01 and CU02. During construction: • Real-time monitoring of temperature, pH, dissolved oxygen, EC, and turbidity at downstream monitoring site SMCDS02. • Monthly monitoring of nutrients (nitrate, ammonia and total phosphorus), suspended solids, and visual observations for oil slicks, at the downstream monitoring sites SMCDS01, SMCDS02 and SMCDS04. • Weekly monitoring of temperature, pH, dissolved oxygen, EC, and turbidity at the downstream sites SMCDS01 and SMCDS04. • Weekly monitoring of temperature, pH, dissolved oxygen, EC, and turbidity at the upstream control sites SMCUS01 and CU02. • Monthly monitoring of nutrients (nitrate, ammonia and total phosphorus), suspended solids, temperature, pH, dissolved oxygen, EC and turbidity, and visual observations for oil slicks at the upstream control sites SMCUS01 and CU02. Post construction: • Quarterly (for 1-year post-construction) in conjunction with habitat monitoring (refer to Appendix F), monitoring of temperature, pH, dissolved oxygen, EC, and turbidity COD, suspended solids, nitrate, ammonia, total phosphorus (laboratory analysed) at downstream sites SMCDS01, SMCDS02 and SMCDS04, and upstream control sites SMCUS01 and CU02.
Reporting	• A succinct baseline (before drawdown) water quality memorandum will be provided to the Seqwater Project Manager and regulatory agencies (if requested). • Daily reporting during drawdown and construction will be provided to Seqwater Project Manager where exceedances are recorded by loggers, with reports provided via a brief summary email and MS Excel spreadsheet. • Weekly reporting during drawdown and construction will be provided to Seqwater Project Manager where no exceedances are recorded via a brief summary email and spreadsheet.

Environmental objective: Minimise impact of lowering on water quality in Lake Macdonald and Six Mile Creek.	
	• A summary report will be provided to regulatory agencies where monitoring indicates ongoing exceedances of any high trigger value for more than 3 consecutive monitoring events. • Quarterly reports will be provided during drawdown and construction to regulatory agencies summarising compliance and monitoring results.
Responsibility	Contractor – Site Supervisor or representative Monitoring to be implemented by suitably qualified persons.

Corrective actions	• Low trigger exceeded:
	– Compare water quality results against control site, historical and baseline results and evaluate for non-Project related influences.
	– Determine if additional monitoring of non-compliant parameter(s) in Lake Macdonald and Six Mile Creek is required, as relevant to the situation.
	– Check control measures are operational.
	– Assess the risk of environmental harm as a result of the low trigger being exceeded; assessment to be completed by a suitably qualified person, using an accepted risk framework.
	– If the risk for environmental harm is determined to be anything other than low, review management measures, including rate of release, and revise if appropriate.
	– Increase frequency of monitoring data review to prevent or prepare for high trigger exceedance. Increase monitoring frequency if relevant (i.e. non-real-time parameters).
	• High trigger exceeded:
	– Compare water quality results against control site, historical and baseline results and evaluate for non-Project related influences.
	– Assess the risk of environmental harm as a result of the high trigger being exceeded; assessment to be completed by a suitably qualified person, using an accepted risk framework.
	– If the risk for environmental harm is determined to be anything other than low, take corrective actions as per below:
	    – Reduce the release rate if the relationship with the exceedance is uncertain or pause the release if there is a clear or likely relationship with the exceedance – only reinstate the release to the initial rate if the cause of the exceedance has been identified and is not associated with the release rate.
	    – Check relevant control measures (e.g. sediment controls if turbidity is high) are operational and, if required, reduce or pause releases until measures are reinstated/repaired.
	    – Review management measures relevant to the exceedance, including scheduled rate of release, and revise if appropriate (i.e. if existing measures are insufficient or not functioning as expected).
	    – Attempt to identify cause of non-compliance with trigger value (if not clearly related to existing control and management measures).
	    – Implement incidental fauna salvage as per section 5.5.4.1 if deemed necessary by the Seqwater representative and suitably qualified persons (based on a risk assessment for aquatic fauna).
	– Undertake additional monitoring of non-compliant parameter(s) in Lake Macdonald and Six Mile Creek, as relevant to the situation. Assess if water quality monitoring sites should be extended downstream temporarily to understand the spatial distribution of poor water quality.

Environmental objective: Minimise impact of lowering on water quality in Lake Macdonald and Six Mile Creek.	
	• Implement temporary shutdown of releases where automated monitoring results indicate the high trigger threshold has been exceeded for more than 24 consecutive hours, until cause or likely cause for exceedance has been determined, and appropriate controls have been implemented. • If a particular non-compliance is an ongoing occurrence, review the suitability of monitoring parameters and trigger thresholds with respect to risk of environmental impacts. Changes are not to be implemented without sound evidence and agreement of the Seqwater representative, and with relevant consideration of change management in Project regulatory approvals. • If after all the above mitigation measures and corrective actions have been implemented yet the high trigger threshold has been exceeded for more than 3 consecutive days then construction works must stop. Construction can only restart once the cause of the exceedance has been confirmed and a suitable control measure implemented.

4. Erosion and Sediment Control Management Plan

4.1 Baseline Conditions

4.1.1 In Lake Macdonald and Six Mile Creek

Surface geology mapping indicates that Lake Macdonald and Six Mile Creek are within a drainage channel composed of Quaternary Alluvium overlying Upper Triassic-Jurassic aged Myrtle Creek Sandstone. Triassic Kin Kin Beds outcrop to the east of Lake Macdonald and host a Tertiary aged rhyolite intrusion, and the Jurassic aged Tiaro Coal Measures outcrop further east.

Bore logs show that Lake Macdonald is positioned on top of clay that reaches a depth between 3 m and 21 m below ground level. The alluvium is thought to be largely comprised of fine-grained overbank sediments, rather than coarser channel deposited materials. Field surveys conducted by frc environmental noted that the substrate in Lake Macdonald was dominated by silt with some sand near the banks, while in Six Mile Creek downstream of the dam the substrate was dominated by clay and silt, with gravel and occasional bedrock. Silt and sand are highly mobile sediments.

Sediment quality has not been assessed in detail for the Project, as geology and soils are not expected to be affected. However, the potential for acid sulphate soils to occur in Lake Macdonald was assessed and determined to be unlikely (refer to section 15 of the IAR).

Geomorphic processes have created pool-riffle habitat sequences throughout Six Mile Creek. Pool features in the creek are likely subject to natural bed scour that maintains their channel form (if these events do not occur naturally then over time the pools become shallower, assuming continued sediment supply). Coarse sediment scoured from pool features is typically deposited immediately downstream on riffle features (these are natural deposition processes during floods), while fine sediments are transported further downstream.

4.1.2 Baseline Monitoring

Baseline monitoring of erosion will be completed in Six Mile Creek in the month before lake drawdown begins to establish existing conditions (e.g. areas of scouring and / or deposition) downstream of the dam. The monitoring location will be located at demonstrably representative areas of Six Mile Creek, as a basis for comparison with potential changes during the lake drawdown.

No additional baseline monitoring of sediment in Lake Macdonald is proposed.

4.2 Potential Impacts of Lowering Lake Macdonald

4.2.1 Within Lake Macdonald

The drawdown process for Lake Macdonald could potentially lead to erosion and sedimentation in the lake area, particularly in areas with mobile sediments such as silt and sand. Erosion and sedimentation may also occur after the drawdown, during the 36-48-month period that the lake is lowered. However, the current magnitude of drawdown is limited to approximately the top 2.3 m of the storage. This is within the normal operating range of the storage, and therefore risks associated with erosion and sedimentation are low. Drawdown rates are targeted for approximately 11% of the lake FSL each week (relative to inflows and operational demand). This loss is proposed to occur over a minimum of 4 weeks and as such, roughly allows for a drop of water level of approximately 0.58 m per week (~10 cm/day). Noting this, water quality monitoring will be continually assessed to determine if the lake drawdown it causing erosion issues across the exposed bed & banks within Lake Macdonald.

It is possible that minor erosion of the bed and banks of Lake Macdonald may be caused by wind and / or rainfall events, and associated surface runoff, while the lake is lowered.

Lake Macdonald contains extensive beds of Cabomba (*Cabomba carolina*), along with other aquatic plants. The presence of these aquatic plants will minimise the potential for erosion in the areas where they occur as their roots help bind the sediment and, when the water level is lower, the dying plants will cover sediment that would otherwise be exposed.

Visual inspections of the lake's exposed banks will be undertaken to determine if any unforeseen erosion issues are becoming apparent. Active stabilisation efforts can then be deployed if such occurrences become apparent. Such efforts would include stabilizing exposed sediments with erosion control sprays and non-invasive grasses, and in more significant erosion areas developing a site-specific ESCP and remediation plan.

4.2.2 Downstream of Lake Macdonald (Six Mile Creek) Dam

The drawdown of Lake Macdonald may potentially lead to erosion and sedimentation in Six Mile Creek through the release of water from the lake into the creek. In particular, there is a risk of erosion if the water is not discharged with suitable scour protection in place at the discharge location. Sedimentation may also occur in Six Mile Creek if there is a high sediment load in the water being discharge from the lake.

There is also a risk of erosion and/or movement of woody debris through the flow of water in the drawdown phase; however, this has low likelihood as drawdown rates will be well below naturally occurring flow rates. Based on fluvial geomorphology assessment, there appears to be enough roughness along Six Mile Creek, both on the channel bed and banks, to limit boundary shear stress and provide resistance to fluvial entrainment and mass wasting processes. However, minor fluvial entrainment of the bank and bed or reorganisation of instream wood may still occur. This would also be expected during natural events of similar magnitude. These minor fluvial entrainment processes include entrainment and transport of unconsolidated fine sediments on the bed of Six Mile Creek until natural bed armouring occurs, whereby entrainment of bed sediments will cease until reactivated by a higher boundary stress.

Where erosion occurs, or the discharged water has a high sediment load, the mobilised sediment may be carried downstream and deposited over the substrate and aquatic plants in Six Mile Creek. This has potential implications for water quality and habitat condition and could subsequently affect aquatic fauna, noting risks associated with this are low. Sedimentation associated with releases is likely to be temporary, as subsequent high flow events will entrain and transport the deposited sediments to locations further downstream. Six Mile Creek experiences frequent flow events and so the turnaround is expected to be in the order of weeks under a typical flow regime. Sedimentation may be more prolonged under low flow conditions or if substantial volumes of sediment are deposited, noting this is not expected to occur.

4.3 Management and Monitoring

Table 4-1: Management of erosion and sediment during the lowering of Lake Macdonald

ENVIRONMENTAL OBJECTIVE: **Minimise environmental impact by preventing soil loss and erosion.**	
Performance criteria	**Lake Macdonald** • The risk of erosion within Lake Macdonald after drawdown is managed and mitigated. • No establishment of head-cut erosion. • No detrimental change in structure of lake margin while exposed (from erosion). • Gully erosion locations within exposed bed and banks are identified and managed. **Six Mile Creek Downstream** • Geomorphic impacts on Six Mile Creek as a result of the drawdown and construction phase activities are managed and mitigated. • Achieve monitoring limits identified in Appendix F (Habitat Monitoring Program, Table 16-6) – bank height, substrate composition, and bank and bed erosion.
Management measures	**General** • Engage a suitably qualified person to monitor and advise on planned and responsive mitigations measures through the drawdown and construction phases. **Lake Macdonald** <u>During drawdown and construction:</u>

ENVIRONMENTAL OBJECTIVE: Minimise environmental impact by preventing soil loss and erosion.	

	• Place intake pipes for drawdown equipment in top half of water column, to minimise disturbance of bed sediments and organic matter, for example by using a pontoon-based pump station or floating intake structure.
	• If it does not interfere with works or cause a hazard, allow Cabomba and other exposed aquatic plants to decompose in situ.
	• Where appropriate for the site conditions and drawdown timing, use erosion control sprays to stabilise exposed sediment. The scope for use of erosion control will be limited by constraints, such as safe access, and will be focused on high-risk areas susceptible to erosion (e.g. gullies):
	  – An assessment of high-risk areas susceptible to erosion shall be undertaken by a suitably qualified person and reviewed at intervals suitable to the changing conditions.
	  – Any erosion control sprays must be suitable for use in aquatic ecosystems, as well drinking water sources (noting that Lake Macdonald will not be used to supply water during construction, but any risks relating to return to service must be assessed).
	• Comply with the construction erosion and sediment control plan, and stormwater management plan.
	Six Mile Creek Downstream
	During drawdown and construction:
	Drawdown to occur over not less than 4 weeks.
	Discharge drawdown releases in a manner that dissipates energy and prevents scour at the discharge point. For example, discharge onto the concrete apron on the downstream side of the Lake Macdonald spillway, use diffusers or spray nozzles, and / or energy dissipation methods such as riprap to slow water flow.
	Comply with the construction erosion and sediment control plan and stormwater management plan.
	Ensure releases do not exceed bankfull height of Six Mile Creek.

Monitoring	**Lake Macdonald** • Weekly inspection of sediment and erosion control structures and measures. In wet weather more frequent monitoring will be necessary. • Daily monitoring of turbidity in Lake Macdonald (refer to Table 3-1). • Monthly visual monitoring of any potential erosion & sediment issues occurring throughout the lake edges. These inspections would be incorporated into the monthly fauna inspections described in Table 5-2. **Six Mile Creek Downstream Sites and Control Sites** Before drawdown: • Undertake baseline phase monitoring of erosion at the downstream monitoring locations and the upstream control sites, as outlined in (Habitat Monitoring Program). During drawdown: • Undertake drawdown phase monitoring of erosion at the downstream monitoring sites and upstream control sites, as outlined in Appendix F Habitat Monitoring Program. During construction: • Undertake construction phase monitoring at the downstream monitoring sites and upstream control sites, as outlined in Appendix F Habitat Monitoring Program. Post-construction: • Undertake post-construction phase monitoring at the downstream monitoring sites an upstream control sites, as outlined in Appendix F Habitat Monitoring Program.
Reporting	• Weekly report to Seqwater Project Manager via email that includes details of monitoring, audits, non-compliances, complaints, and incidents. • Report any erosion issues to the Supervisor immediately. • Quarterly report provided to regulatory agencies summarising compliance and monitoring results.
Responsibility	Seqwater – Project Manager or representative (in relation to the lake lowering). Contractor – Site Supervisor or representative (in relation to the lake lowering).
Corrective actions	• If sedimentation or erosion exceeds the triggers defined in Habitat Triggers (Habitat Monitoring Program) and in Table 6-1, review management measures, including rate of drawdown release (slow or pause if needed), and implement additional control measures where required.

ENVIRONMENTAL OBJECTIVE: Minimise environmental impact by preventing soil loss and erosion.	
	• Where turbidity thresholds in Table 3-1 are exceeded, review management measures, including rate of drawdown release (slow or pause if needed), and implement additional control measures where required. • Amend erosion and sediment control management measures to account for changes in site conditions or treatment methods in the case of failure. • Revise erosion and sediment control plan where required.

5. Aquatic Flora and Fauna Management Plan

5.1 Baseline Conditions

The aquatic flora and fauna in Lake Macdonald and Six Mile Creek are described in detail in Section 5.1.1, including detailed descriptions of aquatic MNES and MSES species (Table 5-6). Brief summaries of aquatic flora and fauna in Lake Macdonald and Six Mile Creek downstream of the dam are provided below.

5.1.1 Flora and Fauna in Lake Macdonald and Six Mile Creek Downstream

5.1.1.1 Aquatic Plants

Lake Macdonald contains a dense cover of Cabomba, which is a restricted biosecurity matter, scattered native water snowflake (*Nymphoides indica*), and isolated occurrences of other native aquatic plants. Hygrophila (*Hygrophila costata*), which is also a restricted biosecurity matter, occurs along the margins of the lake. No threatened aquatic plant species is known to occur in Lake Macdonald.

There are few aquatic plants in Six Mile Creek downstream of Lake Macdonald, due to extensive shading by riparian vegetation, though there are isolated occurrences of Cabomba and water snowflake.

5.1.1.2 Fish

Approximately 26 native fish species are known or likely to occur in Lake Macdonald and Six Mile Creek downstream. Of these, several do not occur upstream of the Lake Macdonald (Six Mile Creek) dam wall (e.g. Pacific blue eyes) or were stocked in Lake Macdonald (e.g. saratoga, yellow belly).

Three previous surveys of the lake in 2016, 2023 and 2024 have not recorded any Mary River cod or lungfish from Lake Macdonald. All previous surveys used boat electrofishing, a method that is considered the most effective for catching these species. Records indicate that at least 112,730 Mary River cod fingerlings were released to Lake Macdonald between 1983 and 2015, with 6,430 released to Six Mile Creek (MRCCA 2016). Six Mile Creek is considered to harbour an important relict population of Mary River cod (Simpson & Jackson 2000), and the high stocking rate suggest that this species has the potential to occur in Six Mile Creek and Lake Macdonald. There are no records of Australian lungfish being stocked in Lake Macdonald or Six Mile Creek. Additionally, there have been no confirmed sightings of lungfish by long-term Seqwater ranger staff within the lake. Lungfish routinely gulp air at the surface of the water and are regularly observed in sites where they occur. Large numbers of yellow belly and Australian bass have also been stocked to Lake Macdonald. This suggests that the abundance of large bodied fish in Lake Macdonald could be high.

Five pest fish are known from the area: eastern Gambusia (*Gambusia holbrooki*), platy (*Xiphophorus maculatus*), swordtail (*Xiphophorus hellerii*), guppy (*Poecilia reticulata*) and tilapia (*Oreochromis mossambicus*). Gambusia and tilapia are restricted biosecurity matters. No tilapia has been recorded upstream of the dam wall.

5.1.1.3 Turtles

Four species of turtle have been recorded from Six Mile Creek and Lake Macdonald, with diversity and abundance higher upstream of the dam wall than in Six Mile Creek downstream. These are: Krefft's river turtle (*Emydura macquarii*), saw-shelled turtle (*Wollumbinia latisternum*), eastern long-necked turtle (*Chelodina longicolis*) and broad-shelled river turtle (*Chelodina expansa*). Krefft's river turtle, and possibly saw-shelled turtle, are abundant in Lake Macdonald. White-throated snapping turtle and Mary River turtle, which are MNES, have not been caught in Six Mile Creek or Lake Macdonald. Field surveys and literature review suggest that these species may occur in low abundance in the lower reaches of Six Mile Creek, but it is considered unlikely that these species would be present in Lake Macdonald.

5.1.1.4 Other Fauna

Platypus are known to occur within Lake Macdonald, in the upper reaches of the lake, in Six Mile Creek upstream of the lake, and Six Mile Creek downstream of the dam (SMEC, 2023). This species is listed as Special Least Concern in Queensland's *Nature Conservation (Wildlife) Regulation 2006*, but is not a threatened species.

5.1.1.5 Amphibians

Six amphibian species are known to occur in the vicinity of Lake Macdonald, including two threatened species and four least concern species. Giant barred frogs were heard calling downstream along Six Mile Creek; however, field survey results suggest that only a low density population is present. No giant barred frogs were identified around Lake Macdonald; however, while the habitat around the lake was considered largely unsuitable for this species, it was not possible to survey the entire extent of the lake and there is some potential for the giant barred frog to be present. There is also potential for this species to occur in Six Mile Creek upstream of the Lake Macdonald full supply level.

Field surveys conducted in 2018 and 2023 recorded the tusked frog along Collwood Road, in the upper reaches of Lake Macdonald and within the ponds of the Noosa Botanical Gardens.

Other least concern species observed include sedgefrog (*Litoria fallax*), graceful treefrog (*Litoria gracilenta*) and striped marshfrog (*Limnodynastes peronii*). Cane toads (*Rhinella marina*), which are a restricted biosecurity matter, occur in the Project area.

5.1.2 Baseline Monitoring

Determining baseline populations of fauna typically requires long-term study. Additional baseline monitoring will not be undertaken in Six Mile Creek downstream to supplement existing information. Instead, it has been assumed that threatened fauna (i.e. MNES and MSES) are present in Six Mile Creek downstream of the dam wall and suitable management measures will be implemented accordingly.

Baseline survey of fish biomass in Lake Macdonald was completed by InfoFish (2019, Appendix I) using hydroacoustic monitoring and advanced data processing. Results indicated that the maximum number of large bodied fish (i.e. >200 mm total length) in Lake Macdonald was 17,671 (±1,300), and the maximum number of small bodied fish was 37,698 (± 3,209). The baseline biomass surveys indicated that Australian bass was the most abundant large bodied species in Lake Macdonald.

Additional baseline monitoring in Lake Macdonald to supplement biomass with species composition will not be undertaken. It has been assumed that threatened fauna (i.e. MNES and MSES) are present in Lake Macdonald and suitable management measures will be implemented. An evaluation survey in Lake Macdonald will be completed before the drawdown, as outlined in section 5.5.3 and Table 5-5, to familiarise teams with the site and the proposed salvage methods. The evaluation survey will also allow for targeted survey to estimate potential presence of threatened fauna in the upper reaches of the lake.

5.2 Matters of National and State Environmental Significance

MNES are protected under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC). MSES species are protected under Queensland's *Nature Conservation Act 1992* (NCA). NCA and EPBC species that have the potential to occur within Lake Macdonald and Six Mile Creek are listed in Table 5-1. The identified habitat for these species within the study area is provided in Section 6.

Table 5-1: Species listed under the NCA and EPBC

Species	Key habitat	Known Locations (as of October 2023)	Likelihood of occurrence in Lake Macdonald and Six Mile Creek
Australian lungfish (*Neoceratodus forsteri*)	Wide, slow flowing or still permanent reaches with deep pools (1 m – 3 m). Low flow conditions above 10 cm. Prefer areas with submerged logs, high	The closest record is in Six Mile Creek near the tailwater pool.	Moderate. Minimal suitable habitat is present in Lake Macdonald and Six Mile Creek. One individual has been recorded in Six Mile Creek near the tailwater pool, but an important population of this species does not occur in Six Mile Creek.

Species	Key habitat	Known Locations (as of October 2023)	Likelihood of occurrence in Lake Macdonald and Six Mile Creek
	aquatic plant cover and underwater crevices.		
Mary River cod (*Maccullochella mariensis*)	Shaded pools within complex in-stream structures (i.e. woody debris, crevices). Water depths of 1 m – 3 m. Slow flowing water	The closest record is within 20 m of the Dam wall in Lake Macdonald and also in Six Mile Creek near the tailwater pool.	High. Suitable habitat is present in Lake Macdonald and Six Mile Creek. Three individuals recorded in Six Mile Creek near the tailwater pool, spawning Mary cod recorded in the creek downstream of the dam (Dunlop 2016), and large numbers stocked to Lake Macdonald and Six Mile Creek.
Giant barred frog (*Mixophyes iterates*)	Rainforest and wet sclerophyll forest, occasionally adjacent farmland Moist riparian habitats with deep leaf litter	The closest record is 185 m downstream of Six Mile Creek.	High. Suitable habitat is present in the downstream tributaries of Six Mile Creek and is likely to be present upstream of the dam full supply level. Individuals were recorded downstream during the site survey in 2018.
Tusked frog (*Adelotus brevis*)	Wet eucalypt forest, rainforest, and occasionally dry eucalypt forest. Occur near slow moving sections of streams, stagnant ponds, and dams.	Recorded along Collwood Road, in the upper reaches of Lake Macdonald and within the ponds of the Noosa Botanical Gardens.	High. Wet eucalypt forest has been identified in the vicinity of Six Mile Creek and Lake Macdonald. Two individuals were recorded during the site survey in 2018 and an additional two were recorded during the 2023 survey.
Mary River turtle (*Elusor macrurus*)	Permanent streams and large pool habitats. Sparsely vegetated, north-facing sloping sandy river banks.	Six Mile Creek has not been identified as a Mary River tributary known to contain a significant population of this species. Indeed, the MNES search did not predict the species to occur within 10 km of the Study area and there are no locality records of the species.	Low. Minimal sparsely vegetated sloping sandy river banks present. No individuals were recorded during the site survey and no records within 10 km.
White-throated snapping turtle (*Elseya albagula*)	Permanent, clear, well oxygenated flowing water. Complex habitat structures (i.e. woody debris and undercut banks). Sandy- gravel substrates	Six Mile Creek has not been identified as a Mary River tributary known to contain a significant population. There are no locality records within 10 km of Study area.	Low. Minimal suitable habitat present, with no apparent breeding habitat. No individuals have been recorded in Lake Macdonald or Six Mile Creek downstream of the dam.
Platypus (*Ornithorhynchus anatinus*)	Permanent water surrounding stable earthen banks, held by native overhanging vegetation. Woody debris and cobbled habitats.	Recorded within Lake Macdonald, in the upper reaches of the lake, in Six Mile Creek upstream of the lake, and Six Mile Creek downstream of the dam.	High. Suitable habitat is present in the downstream and upstream tributaries of Six Mile Creek. Observed in the downstream extent of Six Mile Creek around Site 2 and recorded in 2023 surveys upstream of Site 7 entering the water from a burrow. Platypus records obtained from WildNet, the Australian Conservancy Foundation Platy-Project and the Australian Platypus Foundation, show records within the upper reaches of Lake Macdonald, upstream and downstream of Six Mile Creek and within Lake Macdonald adjacent to the water treatment plant.

5.3 Potential Impacts of Lowering Lake Macdonald

5.3.1 Within Lake Macdonald

The drawdown of Lake Macdonald and construction phase of the Project, may impact aquatic flora and fauna in the lake via:

- Impacts to water quality in the lake (see section 3.2.1)
- Lowering the lake level will cause submerged and floating vegetation to die in areas where the water is no longer sufficient to support them, which may result in the following impacts:
  - If algae or aquatic plants die quickly and sink to the bottom of a body of water, decomposition increases, accelerating oxygen consumption resulting in lowered dissolved oxygen levels.
  - Humic acid forms when organic material decomposes which can lead to a decrease in the pH of the water.
  - Decomposing vegetative matter produces methane in an anaerobic setting (where there is an absence of oxygen i.e. under water), which can result in objectionable odours. Conversely, in areas that become completely dry following the drawdown, organic material will be decomposing in the presence of oxygen, i.e. aerobically. Aerobic decomposition uses oxygen, resulting in the production of carbon dioxide instead of methane. Therefore, decomposition of organic matter on areas of dry lake bed will not produce an objectionable odour.
- The spread of aquatic biosecurity matters such as pest species, weeds, and disease (see section 7)
- Stranding of biota in workspace created by the coffer dam waterbody, and exposure to poor water quality.
- Risk of injury or mortality to fauna due to machine strike / crush injuries if fauna move into the construction areas.
- Injury or mortality of fauna from pumping equipment which could result in individuals becoming susceptible to pathogens and disease. Alternatively, aquatic fauna may become fatally injured by pumping equipment or be trapped within pumping equipment and consequently drown. The mitigations described below ensure risk is low.
- Stranding of fauna in shallow isolated pools or burrows as water levels decline as Lake Macdonald is lowered, which may increase predation (e.g. predation of smaller fish by larger fish and / or birds), and / or competition leading to crowding. Inflows may also wash fauna, in particular small fish and tadpoles, into the lake during drawdown and construction. Crowding may result in reduced dissolved oxygen concentrations in water, reduced food supply, and increased stress on fauna. As small, isolated pools evaporate, or in areas that are dewatered rapidly, there is a risk that aquatic fauna could become stranded on dry areas. However, the risk associated with this source of potential impact is low because the rate and magnitude of dewatering is limited.
- After the drawdown phase, catchment inflows may refill the lake above RL 93 m AHD. This may result in re-flooding of areas which were subject to the aquatic fauna salvage operation conducted prior to the drawdown, creating new isolated pools which pose a risk to stranding of fauna. This scenario would only present a risk in the period between completing drawdown and demolition of the spillway.
- Loss of riparian and in-stream vegetation due to potential changes in livestock access.

Injury and mortality of turtles in construction workspaces, and on the spillway of the existing dam which may be utilised by turtles for basking. Similarly, turtles may be injured or killed on the spillway as they move downstream during spilling events. Current observations of turtles within the dam at 100% FSL indicate limited interaction (i.e. basking behaviour) on the dam spillway when access is expected to be facilitated through water level. Turtles are rarely seen on the spillway and few observations (i.e. 2-3) of turtles under the spillway have occurred within the last 15 years. Noting this, the low-flow slot section of the coffer design (with limited freeboard) will have continuous visual monitoring and any turtle interactions (i.e. basking/passage) can be addressed by the site environmental officer to remove or relocate fauna. If significant turtle interactions are noted to be occurring with the low-flow slot section of the cofferdam or the spillway then an investigation of potential solutions may be undertaken as a corrective action (i.e. exclusion engineering solution). Therefore, while turtles may access the spillway section cut to 89.5 m AHD, the majority of the water will be maintained by the cofferdam allowing observation of interactions with the turtle at the low-flow slot section of the cofferdam as a proxy for specific management of turtles at the existing spillway. As such, the current risk is considered low due to the restriction of access to a small section of the cofferdam and limited evidence of current use of the spillway for basking or passage.

The release of water downstream to Six Mile Creek may impact aquatic flora and fauna via:

- Impacts to downstream water quality (see section 3.2.2)
- Changes in the downstream flow conditions during drawdown, which could affect breeding success and habitat conditions
- The spread of aquatic biosecurity matters such as pest species, weeds, and disease (see section 7).

The release of water into Six Mile Creek during the drawdown of Lake Macdonald may impact aquatic fauna through the creation of a high flow event that could transport fauna downstream or trigger behaviour that would usually occur at another time (e.g. breeding migration). However, limiting the drawdown to a minimum 4 week period ensures that this source of potential impact has low risk.

The release of contaminated water from the stilling basin could adversely impact aquatic biota in the downstream Six Mile Creek.

Habitat condition and availability may also be impacted where water released from Lake Macdonald leads to:

- Erosion or sedimentation (refer to section 4), which has ow level of risk
- Disturbance of physical habitat structures (refer to section 6.2.2), which has low level of risk
- High flows or prolonged inundation at times when they would not otherwise occur.

5.4 Management and Monitoring

Potential risks to aquatic flora and fauna will be mitigated by implementing the measures identified in Section 5.3. Where appropriate, the management measures contained in Table 5-2 will be adapted over the course of the Project in response to changing conditions and expert advice.

In addition to the measures described in Table 5-2, monitoring of aquatic habitat, including key habitat features that support MNES and MSES, will be undertaken as a preliminary indicator of potential impacts to aquatic fauna. This monitoring is described in 5.1.2 and Table 6-1.

Management measures for flora and fauna and aquatic habitat have been developed with regard to the relevant recovery and threat abatement plans for MNES species potentially affected by the project. The management measures are designed to:

- Salvage large bodied fish from Lake Macdonald during drawdown, and periodically during construction if required
- Salvage aquatic biota from the stilling basin on an as needed basis (e.g. prior to all waterbody dewatering events, and when poor water quality is detected)
- Protect existing habitat present in and downstream of the project area through the implementation of habitat management measures
- Protect or rehabilitate breeding habitat, where present
- Maintain a variable flow regime downstream of the lake, determined by inflows
- Reduce potential impacts to water quality in Six Mile Creek downstream of the dam
- Avoid breeding periods for MNES species know to occur in the lake and Six Mile Creek downstream
- Not facilitating the spread of pest species
- Support the on-going operation of the Mary River cod hatchery during the project
- Rehabilitate habitat, where appropriate, and restock Mary River cod in Lake Macdonald.

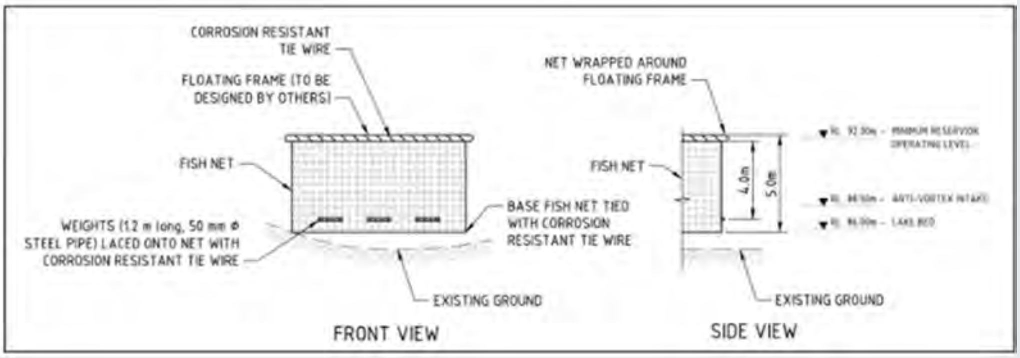
A summary of the advice, key threats, and abatement / management actions, and where this has been incorporated in the plan is provided in Table 5-3.

Table 5-2: Management of aquatic flora and fauna during the lowering of Lake Macdonald

<table>
<tr><th colspan="2">ENVIRONMENTAL OBJECTIVE:
Minimise impact of lake drawdown on aquatic flora and fauna.</th></tr>
<tr><td>Performance criteria</td><td>Lake Macdonald
• Prevent or minimise potential impacts to aquatic fauna in Lake Macdonald, in particular listed threatened species, where minimise means the impact is temporary and reversible.
• Achieve the aquatic habitat performance criteria identified in Table 6-1.
• 95% survival rate* for any MNES fauna captured during salvage and fauna relocation activity (based on advice from the QLD Department of Agriculture and Fisheries Animal Ethics Committee, where a 5% attrition rate is acceptable during fish sampling and research activity). No increased mortality of all MNES fauna remaining in Lake Macdonald.
Six Mile Creek Downstream
• Prevent or minimise potential impacts to aquatic fauna in Six Mile Creek, in particular listed threatened species, where minimise means the impact is temporary and reversible.
• Achieve the aquatic habitat performance criteria identified in Table 6-1.</td></tr>
<tr><td>Managemen t measures</td><td>Lake Macdonald
<u>Before drawdown</u>:
• Undertake an evaluation survey using methods identified in Table 5-5, with a focus on the upper reaches, for:
• Large-bodied fish – specifically MNES species (including salvage of these species).
• Small bodied fish – recording species and their abundance.
• Platypus – Initially undertake eDNA sampling. Use results to inform locations for setting up camera traps in and around active burrows to monitor ongoing presence.
• Turtles – MNES listed and common species, using methods outlined in DSEWPC (2011).
• Tadpoles – identify and record abundance of barred frog tadpoles (genus Mixophyes) caught incidentally using fish and turtle survey methods. If Mixophyes tadpoles are detected, species determination should be undertaken.
• The evaluation survey may be modified to include activities such as evaluation of biomass and pre-drawdown commencement of aquatic fauna salvage and relocation.
• Seqwater will work with individual landholders to ensure stock movements are prevented from moving outside their existing properties.
<u>During drawdown</u>:
• Gradual initial lowering of lake from FSL (RL 95.3 m AHD) to ~42% FSL (RL 93 m AHD) over a period of no less than a four-week period to allow fauna to adapt to reduced water level.
• Begin the drawdown program outside of platypus breeding season (August to October).
• Avoid undertaking initial lake drawdown in hot conditions (e.g. summer months).
• Manage water quality as described in section 3.
• Siphon inlets have been nominated with bell mouth style designs with anti-vortex plates attached to reduce head losses and minimise inlet flow velocities. Diamond mesh nylon netting (9 mm x 9 mm apertures) has been designed to attach to a float around the inlets at a distance where the geometric design of the fish frame ensures flow velocities do not exceed 0.1m/s to prevent fish attraction. These sizing calculations are based on a <u>60% blockage</u> factor. The geometry of the fish net frame is such that it needs to be finally connected in the water with the assistance of divers, specifically to ensure a fully connected net between the pipes and under the anti-vortex plate. All pipe welding of the frame pieces will be assembled in the laydown and moved into the lake. The net will also be assembled in five pieces four vertical sides and the piece around the bottom making a complete seal, complete with lower weights. The divers will complete the connection of the frame to the siphon pipes as well as the final stitching of the nets together, ensuring the correct clearance and that the net is not snagged on</td></tr>
</table>

ENVIRONMENTAL OBJECTIVE:
Minimise impact of lake drawdown on aquatic flora and fauna.

the lakebed.



- To reduce harm to downstream moving fish and turtles the syphon system will be used to reduce the extent of overtopping flow events during construction. This will divert flows around construction site and reduce rates of spilling. Hydraulic modelling shows that the cofferdam spillway will have a flow depth >100 mm only 5 days per year.
- During any drawdown activity in construction phase use intake exclusion screens of suitable design (9 mm x 9 mm aperture) to prevent fish and turtles from being entrained into syphon system.
- To reduce harm to any downstream moving fish and turtles during spilling events, the cofferdam has been designed to reduce risks to both fish and turtles. The design includes maintaining a 30% tailwater depth to spillway height, use of non-abrasive surfaces, eliminating potential impact points and a spillway design with no freefall sections.'
- Implement an aquatic fauna salvage plan to prevent crowding and stranding (see section 5.5) – platypus will not be relocated unless absolutely necessary (as noted in section 8.2.6).
- The existing bubble plume destratification unit will be maintained and will run continuously for the life of the project, providing aeration of the water in Lake Macdonald. If the trigger values for relevant parameters or signs of fish distress are identified and it appears that the destratification unit is not working or there are insufficient inflows, additional measures to restore water quality will be investigated. This will include additional proven aeration devices or methods.
- Do not handle frogs unless relocation is necessary or they appear stranded. If handling is necessary, follow the protocols in section 8.2.5.
- Manage biosecurity matters as described in section 7.
- Manage aquatic habitat as described in section 6.

<u>During construction</u>:

- Implement aquatic biota salvage from the stilling basin as needed.
- The presence of turtles basking in the work space and dam spillway areas will be monitored and if deemed to present an issue specialist advice will be sought on how to best manage their exclusion. Refer to Section 5.3.1.
- Do not handle frogs unless relocation is necessary or they appear stranded. If handling is necessary, follow the protocols in section 8.2.5.
- Monitoring is to be undertaken of areas in the lake which have been re-inundated following a significant inflow (after the initial fish salvage program) to identify if fauna has been stranded in new isolated pools.
- If catchment inflows result in the lake refilling above RL 93 m AHD, the temporary FSL will be actively managed by diverting inflows up to a practical upper limit of 5 m^3/s with drawdown potentially occurring as within 11 days (from FSL to RL93.0) post drawdown. This will allow fauna to adapt to the reduced water level.
- Manage biosecurity matters as described in section 7.
- Manage aquatic habitat as described in section 6.

Six Mile Creek Downstream

<u>During drawdown</u>:

- Release rate tailored to achieve drawdown over a period of not less than four weeks to minimise artificial impacts associated with elevated flow velocity and depth.

ENVIRONMENTAL OBJECTIVE: Minimise impact of lake drawdown on aquatic flora and fauna.	
	• Ensure releases do not exceed bankfull height of Six Mile Creek. • The drawdown is to avoid releases during the breeding seasons for Mary River cod, platypus and giant barred frog, which are known to be in Six Mile Creek downstream of the dam, by conducting drawdown between March and October (refer to section 2.2). • Implement an aquatic fauna salvage plan to prevent stranding (see section 5.5) following high flow pulses – platypus will not be relocated unless absolutely necessary (as noted in section 8.2.6). Do not handle frogs unless relocation is necessary or they appear stranded. If handling is necessary, follow the protocols in section 8.2.5. • Manage water quality as described in section 3. • Manage aquatic habitat as described in section 6. During construction: • Allow inflows to pass downstream. • Manage water quality as described in section 3. • Manage aquatic habitat as described in section 6. **Fauna Relocation Sites** During drawdown: • Weekly visual monitoring of sites where fauna have been relocated during the relocation program (e.g. observations of mortality) and measurement of in situ water quality (focusing on dissolved oxygen). **All Project Areas** All project stages: • All employees working on site to attend induction training sessions. Induction training sessions to include awareness of operating plan for Lake Macdonald during the works, in particular the proposed operating levels. Site inductions should also include protocols in the event of turtles being seen on the cofferdam crest or spillways and in the event of aquatic fauna being seen injured, in distress or dead at the worksite.
Monitoring	**Lake Macdonald** During drawdown: • Daily visual inspection of intake screens – ensure screens are functional, water approach velocity is at or below the limit noted as a mitigation, and no aquatic fauna are trapped against the screens. • Divers will perform an inspection and clean of the intake exclusion device. Initially this will be performed monthly. If weed build up and fauna entanglement is found to be negligible / insignificant then this activity will be scaled back in consultation with the project aquatic ecology expert. During construction: • Camera trap survey of platypus in upper dam reaches (continuous), and eDNA surveys quarterly. • Monthly visual monitoring of fauna in the lake to assess potential for fauna stress and need for adaptive management. • Daily visual monitoring of fauna in the stilling basin to assess potential for fauna stress. • Bi-annual turtle monitoring during September to April for the duration of the project construction period of turtle condition in lake using length weight measurements compared to baseline and evaluation survey data. All captured Mary River turtles and White-throated snapping turtles are to be marked using an approved method by DES prior to release. Measurements to be taken for each turtle are straight carapace length (CL), straight plastron length (PL) and mass (g). • Monthly visual monitoring and water quality measured in situ (dissolved oxygen) of the relocation sites six months after relocations efforts have finished (per schedule provided in Table 5-5) to assess potential for fauna stress and need for adaptive management. • Quarterly monitoring of fish condition in the lake, using length weight measurements compared to baseline and evaluation survey data. • Bi-annual turtle monitoring of turtle condition in lake using length weight measurements compared to baseline and evaluation survey data. Post Construction

ENVIRONMENTAL OBJECTIVE: **Minimise impact of lake drawdown on aquatic flora and fauna.**	
	• Quarterly monitoring (for one year post construction) of fish condition in the lake, using length weight measurements compared to baseline and evaluation survey data, and aquatic habitat monitoring (Appendix F) • Bi-annual turtle monitoring (for one year post construction) of turtle condition in lake using length weight measurements compared to baseline and evaluation survey data. All captured Mary River turtles and White-throated snapping turtles are to be marked using an approved method by DES prior to release. Measurements to be taken for each turtle are straight carapace length (CL), straight plastron length (PL) and mass (g). • Post construction platypus monitoring in the lake and in upstream reaches (12 months post construction). Undertake final eDNA and associated surveys to assess platypus recovery compared to evaluation survey baseline data. • Post construction monitoring to record abundance of barred frog tadpoles (genus Mixophyes) caught incidentally during fish and turtle survey projects outlined above. If Mixophyes tadpoles are detected, species determination should be undertaken. **Six Mile Creek Downstream Sites and Control Sites** To assess the impacts of flow releases during the project, Giant barred frog habitat quality assessments, fish community surveys and water quality monitoring will be undertaken before, during and after the lake drawdown period. Where possible these surveys should be conducted to minimise the impacts and handling of Mary River cod and avoid the breeding season where possible. These surveys should include existing monitoring sites (SMCDS01, SMCDS02, SMCDS04) where practical, or include additional alternative sites. Data to be readily available to mitigate any adverse impacts of flow releases. During drawdown: • Weekly aquatic habitat monitoring as described in Section 6 (and Appendix F), and observations of aquatic fauna for signs of stress, at downstream sites SMCDS01 and SMCDS04, and control sites SMCUS01 and CU02. • Following high flow pulses during drawdown visual monitoring surveys will be conducted at monitoring sites SMCDS01, SMCDS02, and SMCDS04 for potential stranding of fauna. During Construction: • Quarterly aquatic habitat monitoring as described in Section 6 (and Appendix F), and observations of aquatic fauna for signs of stress, at downstream sites SMCDS01 and SMCDS04, and control sites SMCUS01 and CU02. Post construction: • Quarterly (for one year) aquatic habitat monitoring as described in Section 6 (and Appendix F), and observations of aquatic fauna for signs of stress, at downstream sites SMCDS01 and SMCDS04, and control sites SMCUS01 and CU02. **Fauna Relocation Sites** During drawdown: • Weekly visual monitoring of sites where fauna have been relocated during the relocation program (e.g. observations of mortality) and measurement of in situ water quality (focusing on dissolved oxygen). During construction: • Monthly visual monitoring of sites for six months where fauna have been relocated during the construction phase (e.g. observations of mortality) and measurement of in situ water quality (focusing on dissolved oxygen). • From the completion of the drawdown phase until the dam construction is complete, bi-annual surveys will be conducted at relocation sites. These surveys, following the methodology outlined in the Freshwater Ecology (2020) report, will assess the survivorship of relocated MNES species, such as the Mary River cod.
Reporting	• DCCEEW will be notified within three (3) business days if any Mary River turtle or white-throated snapping turtle individuals are identified during salvage and relocation operations. • Weekly email to Seqwater Project Manager if there are no identified issues with fauna, water quality or aquatic habitat. • Daily email to Seqwater Project Manager if there are identified issues with fauna, water quality or aquatic habitat.

ENVIRONMENTAL OBJECTIVE: Minimise impact of lake drawdown on aquatic flora and fauna.	
	• Quarterly report provided to regulatory agencies summarising compliance and monitoring results. • DESI will be notified within three (3) business days if any MSES are identified during salvage and relocation operations. Notification will include species and the number of individuals identified.
Responsibility	Contractor – Site Supervisor or representative, using suitably qualified persons
Corrective actions	• Implement adaptive measures incorporated in the salvage plan (refer to section 5.5). • Review management measures if performance criteria are exceeded and amend if required. • Adjust lowering system intake screens if approach velocity criteria are not met. • If all the above mitigation measures and corrective actions are implemented and the habitat triggers in Appendix F Table 16-6 continue to be exceeded then the project needs to reduce or cease the lake drawdown and stop construction until an investigation confirms the cause of impacts and suitable remediation or mitigation measures are implemented to prevent ongoing impacts.

Table 5-3: Compliance with Conservation Advice, Recovery Plans and Threat Abatement Plans

Species	Key recovery plan/advice	Key threats relevant to the project	Key management actions	Compliance with this advice
Australian lungfish	Approved Conservation Advice for *Neoceratodus forsteri* (Australian lungfish) (11 April 2014)	Dams and impoundments (habitat loss, disturbance, movement barriers)	• Incorporation of fish passage devices (fishways) at dams and weirs. • Manage disruptions to water flows so water levels are not changing erratically. • Manage changes to hydrology.	• Offsite mitigation provided through construction of fauna biopassage at Gympie Weir – refer to IAR. • Drawdown releases will be relatively low tailored to achieve drawdowns in not less than 4 weeks (i.e. – refer to section 2. • Management measures will be implemented to minimise impacts to water quality and sedimentation, with flushing flows released if required – refer to sections 3.3 and 4.3.
		Exotic fish species	• Develop and implement a management plan for exotic fish, including tilapia and Gambusia.	• Management measures will be implemented to manage the potential spread of pest fish species – refer to section 5.5.9 and Table 7-1.
		Recreational fishing	• Ensure that impacts from recreational fishing are minimised. • Raise awareness of the conservation values of the species within the fishing community.	• Some recreation areas and activities at Lake Macdonald will remain open during construction: – The boat ramp at Lake Macdonald Park, next to the Noosa Botanic Gardens – Fishing, stand up paddle boarding, canoeing
		Clearing of riparian vegetation	• Engage with landholders responsible for land adjacent to waterways.	• Seqwater owns the adjacent land and clearing of riparian vegetation will be restricted to the footprint approved under the IAR – refer to Table 6-1 and the IAR.
Giant barred frog	Conservation Advice *Mixophyes iteratus* giant barred frog (Threatened Species Scientific Committee 13/07/2017)	Clearing of riparian and upstream vegetation	• Ensure active maintenance and restoration of riparian vegetation is undertaken to benefit stream flows and water quality. • Monitor and prevent clearing and erosion. • Rehabilitate riparian vegetation. • If present, relocate to another location in Six Mile Creek.	• Clearing of riparian vegetation will be restricted to the footprint approved under the IAR – refer to Table 6-1 and the IAR. • Management measures will be implemented to minimise impacts to water quality and erosion – refer to sections 3.3 and 4.3. • Temporary areas of disturbance will be rehabilitated – refer to IAR and section 9.
	Recovery plan for stream frogs of south-east	Changes to flow regime	• Ensure active maintenance and restoration of riparian vegetation is undertaken to benefit stream flows and water quality.	• Drawdown releases will be relatively low tailored to achieve drawdowns in not less than 4 weeks – refer to section 2. • Ensure releases do not exceed bankfull height of Six Mile Creek.

Species	Key recovery plan/advice	Key threats relevant to the project	Key management actions	Compliance with this advice
	Queensland 2001-2005 (Harry Hines, Queensland Parks and Wildlife Service)		• If found in a work area or stranded, relocate to another location in Six Mile Creek.	
		Degradation of water quality	• Ensure active maintenance and restoration of riparian vegetation is undertaken to benefit stream flows and water quality.	• Management measures will be implemented to minimise impacts to water quality and erosion – refer to sections 3.3 and 4.3.
		Invasive weeds	• Assess and manage the impact of mistflower and crofton weed on habitat.	• Clearing of riparian vegetation will be restricted to the footprint approved under the IAR and remediation undertaken where required, which will minimise the potential spread of invasive weeds – refer to Table 6-1 and the IAR.
		Disease	• Minimise the spread of the chytrid fungus by implementing suitable hygiene protocols.	• Frogs will not be targeted during salvage, with no direct interaction anticipated (refer to Appendix G and section 5.5.1). If handling is necessary, hygiene protocols will be implemented.
Mary River Cod	Conservation Advice *Maccullochella mariensis* Mary River Cod (16/12/2016) The Mary River Cod Research and Recovery Plan (Queensland Department of Primary Industries – Fisheries Group)	Dams and impoundments (habitat loss, disturbance, movement barriers)	• Install fishways at barriers to Mary River Cod movement. • Improve management of stream flows and water quality.	• Offsite mitigation provided through construction of fauna biopassage at Gympie Weir – refer to IAR. • Drawdown releases will be relatively low tailored to achieve drawdowns in not less than 4 weeks – refer to section 2. • Management measures will be implemented to minimise impacts to water quality and sedimentation, with flushing flows released if required – refer to sections 3.3 and 4.3.
		Loss of riparian and in-stream vegetation	• Protect existing riparian vegetation and restore riparian vegetation. • Control livestock in riparian zones.	• Seqwater owns the adjacent land and clearing of riparian vegetation will be restricted to the footprint approved under the IAR – refer to Table 6-1 and the IAR. • Seqwater will work with individual landholders to ensure stock movements are prevented from moving outside their existing properties – refer to Table 5-2. • Cabomba, a restricted weed species that is abundant in the lake, will be left in situ during the Project as a biosecurity management measure – refer to section 7 (Table 7-2); other aquatic plants are sparse (refer to section 6.1.1).
		Exotic and non-indigenous	• Avoid translocating invasive fish species.	• Management measures will be implemented to manage the potential spread of pest fish species – refer to section 5.5.9 (Table 7-1).

Species	Key recovery plan/advice	Key threats relevant to the project	Key management actions	Compliance with this advice
		native fish species		• Pest fish species encountered will be euthanised – refer to section 5.5.9 (Table 7-1). • Non-indigenous native fish species will be left in situ or relocated to a different site than Mary River cod – refer to section 5.5.9.
		Overfishing	• Restock throughout its historic distribution. • Prohibit fishing/taking of this species where not stocked.	• Some recreation areas and activities at Lake Macdonald will remain open during construction: – The boat ramp at Lake Macdonald Park, next to the Noosa Botanic Gardens – Fishing, stand up paddle boarding, canoeing • Lake Macdonald is stocked with Mary River cod and restocking will recommence after the Project – refer to sections 5.4, 8.4 and 9.2.
Mary River Turtle	Approved Conservation Advice for *Elusor macrurus* (Mary River Turtle) (26/03/2008)	Dams and weirs – changes in hydrology and barriers to movement	• Ensure infrastructure activities do not adversely impact populations. • Devices to move aquatic animals upstream of dam walls and weirs (fishways). • Manage disruptions to water flows.	• Offsite mitigation provided through construction of fauna biopassage at Gympie Weir – refer to IAR. • Drawdown releases will be relatively low tailored to achieve drawdowns in not less than 4 weeks – refer to section 2.
		Decline in water quality	• Ensure infrastructure activities do not adversely impact populations.	• Management measures will be implemented to minimise impacts to water quality and sedimentation, with flushing flows released if required – refer to sections 3.3 and 4.3.
		Increased predation and loss of nesting areas	• Predator control. • Protection of eggs and nesting areas. • Identify and protect areas critical to the survival of the species.	• Management measures will be implemented to protect nesting habitat – refer to sections 5.4 and 6.3.
		Decline in food quality and availability	• Ensure infrastructure activities do not adversely impact populations.	• Management measures will be implemented to protect habitat (including habitat of food resources) – refer to sections 5.4.
White-throated snapping turtle	Approved Conservation Advice for *Elseya albagula*	Loss of eggs and nesting areas	• Maintain functional turtle nesting banks throughout the catchments. • Improve recruitment of hatchlings. • Manage water levels so as to avoid inundation of nesting banks.	• Management measures will be implemented to protect nesting habitat – refer to sections 5.4 and 6.3. • There will be no change to the current full supply level of the lake – refer to Section 2.1.

Species	Key recovery plan/advice	Key threats relevant to the project	Key management actions	Compliance with this advice
	(White-throated snapping turtle) (07//11/2014)	Dams and weirs – changes in hydrology, barriers to movement, fragmentation of habitat	• Reduce the incidence of death and physical injury of turtles at existing and future impoundment structures. • Maintain stream flow and high quality in-river habitat between impoundments.	• Offsite mitigation provided through construction of fauna biopassage at Gympie Weir – refer to IAR. • Drawdown releases will be relatively low tailored to achieve drawdowns in not less than 4 weeks – refer to section 2.
		Clearing of riparian vegetation	• Engage with landholders responsible for land adjacent to waterways.	• Seqwater owns the adjacent land and clearing of riparian vegetation will be restricted to the footprint approved under the IAR – refer to Table 6-1 and the IAR.
		Recreational fishing and fish stocking	• Manage recreational fishing and boating activities in impoundments to be compatible with the maintenance of sustainable turtle populations.	• Some recreation areas and activities at Lake Macdonald will remain open during construction: – The boat ramp at Lake Macdonald Park, next to the Noosa Botanic Gardens – Fishing, stand up paddle boarding, canoeing

5.5 Aquatic Fauna Salvage and Relocation Management Plan

5.5.1 Purpose

The purpose of the planned aquatic fauna salvage and relocation is to minimise stranding and crowding of aquatic fauna (in particular large bodied fish) in Lake Macdonald during the Project (i.e. during the lake drawdown and the subsequent construction period). While the modest extent of drawdown has low risk to aquatic fauna, a conservative approach to environmental management will be adopted and fauna salvage will be used to avoid any possibility of crowding in the reduced dam during the construction phase. Aquatic Fauna salvage will also ensure welfare of any fish or turtle species that become stranded in the stilling basin.

5.5.2 Approach

The overall approach to aquatic fauna salvage and relocation is:

- Targeted capture and relocation of large bodied fish (e.g. saratoga, bass, yellow belly), with particular focus on threatened fish species, (i.e. Mary River cod) noting that the occurrence of these threatened species is expected to be low).
- As needed capture and relocation of Australian lungfish as determined by suitably qualified and or experienced personnel under exceptional circumstances (i.e. Lake Macdonald water supply reduces to critical levels as a result of severe drought) and observed fish condition (length weight relationship) has deteriorated (as identified by routine quarterly fish monitoring). If drought is occurring relocation sites must be carefully considered as the conditions at these sites may be worse than the condition of Lake Macdonald. Drought conditions are assumed when the lake level reaches 30% FSL or less. Refer to Table 5-5.
- Opportunistic capture and relocation of small bodied aquatic fauna, if determined to be necessary during the course of the salvage operation.
- As needed salvage of small and large bodied fish, and turtles, from the stilling basin following high flow events during the construction phase, or if stressed fauna are observed, poor water quality is detected or a dewatering event is planned, with salvaged biota to be returned to the lake upstream of the cofferdam.
- Turtle salvage and relocation will only occur should unforeseen circumstances require. Any reference to turtle salvage or relocation in this document is a contingency plan only.

The salvage and relocation plan has been developed with regard to:

- the EPBC Translocation of Listed Species Policy (DSEWPC)
- DPI's Fish Salvage Guidelines (DPI, 2004)
- DPI's Guidelines for Fish Salvage fact sheet (DAF, 2018)
- conservation advice for relevant MNES species
- independent expert advice (through review of plan).

The EPBC *Translocation of Listed Species Policy* identifies information relevant to using translocation (i.e. relocation) as a mitigation for potential impacts to MNES species and their habitat. In particular, potential impacts of translocation and the factors critical to successful translocation identified in the policy have been considered in the development of this plan. No MNES species other than those identified above will be relocated.

The DPI guidelines present principles and guidance for aquatic fauna salvage operations in Queensland and are summarised in Appendix E. Due to scale of the activity and the relatively long period of drawdown modifications to the DPI guidelines will be required; these are described in Section 5.5.4.

As identified in section 14, all salvage will be performed by an adequate number of suitably qualified and or experienced personnel in accordance with required permits.

Note that relocation of turtles, platypus, giant barred frog and tusked frog is not proposed. For platypus, it is proposed to maintain refugial habitat in the upper reaches of Lake Macdonald (Six Mile Creek) for the duration of the Project, where physical conditions in the lowered lake allow (i.e. there are suitable refugial pools or it is possible to deepen the channel). However, contingencies for platypus relocation are provided in section 8. Giant barred frog and tusked frog are expected to relocate in response to changing water levels, both upstream and downstream, and return once the Project is complete, or following drawdown in the case of downstream water fluctuations.

5.5.3 Evaluation Survey

Before the lake drawdown commences, a hydroacoustic evaluation survey of fish abundance in the lake will be implemented, as will a targeted survey of turtles. Additionally, electrofishing will be implemented to provide an indication of the likely catch rates of the species to be salvaged. Preliminary salvage during the evaluation survey will target upstream reaches of the lake as these will be the first areas exposed once drawdown commences and also evaluate the presence of key species in Lake Macdonald. The evaluation survey will initially use eDNA surveys for platypus. The results of these surveys will inform platypus searches (timed transects) searches for active burrows. The results will inform the placement of camera traps for ongoing monitoring. The evaluation survey is identified as a mitigation measure in 5.5.3 and Table 5-2.

The evaluation survey will be used to familiarise personnel with Lake Macdonald and the proposed salvage methods, and focus on:

- Large-bodied fish – specifically MNES species in Lake Macdonald (including preliminary salvage of large-bodied species).
- Small bodied fish – recording species, abundance and health (i.e. length-weigh relationships).
- Platypus – camera trap and eDNA surveys.
- Turtles – MNES listed and common species, using methods including trapping (e.g. fyke nets and baited cathedral traps), as outlined in DSEWPC (2011).
- Tadpoles – identify and record abundance of barred frog tadpoles (genus Mixophyes) where they are caught in other salvage activities. If Mixophyes tadpoles are detected, species determination should be undertaken.

5.5.4 Salvage and Relocation Targets

For the purposes of salvage and relocation of aquatic fauna, the general phases of work can be outlined as:

- **Evaluation Survey Phase** – Lake Macdonald at 100% FSV (or lower natural level at the time)
- **Drawdown Salvage Phase** – Lake Macdonald between 100% and 42% FSV
- **Post-Drawdown Salvage Phase** – Lake Macdonald at 42% FSV.
- **Stilling Basin Salvage Phase** – Monthly salvage of aquatic fauna and transfer of native fish downstream, and following high-flow events, and if stressed fauna are observed, and when poor water quality is detected and if a dewatering event is planned.

The evaluation survey phase has no salvage target. It is for preliminary evaluation and familiarisation and will be completed using the methods identified in Table 5-5.

The drawdown salvage phase has a target for aquatic fauna salvage of at least an equivalent percentage of large bodied fish as the percentage of drawdown that has occurred. This is provisionally assumed to occur over 4 weeks of salvage effort. Salvage will commence within 4 weeks of drawdown commencing and will continue on a week-on week-off basis until the target percentage has been achieved or for 8 weeks of salvage effort – whichever is the sooner. Once the target has been reached, salvage will move to the post-drawdown phase.

The overall fish salvage target during the first stage of salvage will be 55% of large bodied fish compared to evaluation survey result. This percentage may be refined from evaluation survey, depending on catch rates and characteristics of the fish community within the lake. If the fish salvage target set has not been achieved by end of the 4th week of salvage effort, the salvage program will be reviewed and if deemed necessary refined with the objective of maintaining the health of aquatic fauna in the lake.

If water levels decline further than RL 92.0 m AHD during the construction phase or if regular monitoring indicates an unacceptable level of stress on the aquatic fauna, additional salvage will be implemented under the guidance of a suitable qualified and experienced person until the conditions in the storage are sustainable.

The salvage of small and large bodied fish, from the stilling basin following high flow events, or if stressed fauna are observed, poor water quality is detected or a dewatering event is planned, during the construction phase has no specific target. However, the objective will be to salvage as many individuals as is practical. The design of access and the works space will need to provide for effective fish salvage and relocation – specifically, the lowest point of the works space should be positioned where access by salvage crews is easy and have an earthen (i.e. no rock armouring) basement so that seine nets can effectively salvage benthic fish. Typically, fish salvaged from the stilling basin will be returned to the main lake as opposed to one of the off-site relocation areas.

A biomass baseline survey done in November 2024 which estimated 16,850 large bodied fish (>200mm) reside in the lake. This sets a 55% target of 9,268 fish to remove.

The 2025 evaluation survey has found that 81.6% of large-bodied fish captured were bony bream (see section 5.5.4.2). Additionally, 8.5% of large-bodied fish captured were banded grunter which are also unsuitable for relocation as they're not native to SEQLD and would be euthanized. Therefore potentially 90% of large bodied fish captured will be unsuitable for relocation. If salvage efforts result in significantly lower catch rates then more realistic targets may need to be adopted in consultation with DPI and the fish biologist.

This represents a significant change to the overall fish community within the lake which can be rationalised by the fact that no stocking has occurred since 2018. Since 2018 there have been several significant wet seasons where migrating fish species would have had many opportunities to leave the lake to spawn in the downstream estuaries. In 2022 the lake spilled for 8-months straight and there have been many regular spilling events since.

Over 12 days the 2025 evaluation survey caught a total of 5,042 large bodied native fish species representing six species, however of these only 490 were suitable for relocation. If similarly low catch rates occur during the project drawdown targets may need to be revised.

Consideration must also be given to the potential benefits of leaving larger predatory fish such as Australian bass, saratoga, eels and freshwater catfish within the dam as these are likely to assist in regulating populations of bony bream and abundant small bodied fish communities.

5.5.4.1 Comparison of Target with DPI Fish Salvage Guideline

The proposed drawdown and fauna salvage program (i.e. the matched percentage approach) broadly aligns with the DPI guidelines. However, the size and bathymetry of the water body also dictate deviations from a strict approach of salvage at 25% drawdown intervals.

The matched percentage approach to salvage is intended to give confidence to all stakeholders that salvage will be effective in mitigating potential impacts of lowered water levels on aquatic fauna (i.e. demonstrating that collection of fauna has been successful), and have clear points where salvage is no longer needed (i.e. has achieved the target mitigation).

It is anticipated that the water retained in Lake Macdonald during the construction period will be sufficient for the remaining aquatic fauna to survive during the construction period, noting that monitoring measures will be implemented and incidental salvage undertaken if required.

5.5.4.2 Fish Sensitive to Handling

Handling of all fish species will be in accordance with the DPI Fish Salvage Guidelines (DPI, 2004), and Commonwealth Survey Guidelines for Australia's Threatened Fishes (DSEWPaC, 2011).

Bony bream have a biology that makes them well suited to impoundments such as Lake Macdonald. Bony bream are fast growing with males maturing at 1-2 years of age and females at 2 years, they are also have high levels of egg production with between 33,000 and 880,000 eggs being produced per fish depending on size (Lintermans, 2023). The species feeds on detritus, microalgae and microcrustaceans, all food sources that are commonly available in lake environments (Lintermans, 2023). Bony bream are generally a hardy fish species, tolerating high temperatures (up to 38^{o}C), high salinity and low dissolved oxygen (Pusey et al., 2004). Despite this bony bream are highly sensitive to capture and handling.

The 2025 evaluation survey results have indicated that there are large numbers of bony bream (*Nematalosa erebi*) within the lake accounting for approximately 82% of large bodied fish captured. Attempts to salvage and relocate these fish could result in high mortality of this species. Efforts to move these fish are also likely to foul water while in transport and potentially affect other fish being transported at the time.

Release of captured Australian lungfish back into the body of water from which they were captured should be prioritised to minimise stress and discomfort. Immediate release into their original habitat is likely to yield better health and welfare outcomes than relocation if Lake Macdonald is experiencing typical conditions.

With this information in mind, there will be need for flexibility in the salvage approach in the field, notwithstanding the general approach for targeted aquatic fauna salvage (section 5.5.1).

For example, a common native species of large bodied fish may be excluded from salvage and relocation where injury and/or mortality in transport is likely, or where health and welfare outcomes are likely to be better within Lake Macdonald. This flexibility will be managed such that the population remaining within Lake Macdonald following drawdown is sustainable, based on the professional judgement of aquatic ecologists and suitable monitoring. In an unlikely situation of an overabundance (unsustainable population) of common fish sensitive to handling/transport, consultation with DPIF regarding management options will occur. Options may include attempted salvage and relocation of the population or in an extreme fish kill scenario euthanasia be considered if recommended by the fish biologist.

5.5.4.2.1 Management of Mary River cod and lungfish

As per EPBC approvals for the project the following management actions will apply to Australian lungfish and Mary River cod.

- No Mary River cod or Australian Lungfish will be relocated to Tinana Creek and Obi Obi Creek.
- During the fish salvage operation the following actions and steps will be taken to prioritise release sites for Mary River cod:
  - Prior to any fish relocation from Lake Macdonald all of the potential relocation sites for Mary River cod within the Mary River and Yabba Creek will be re-assessed. The results of this assessment will confirm (or modify) the current site priorities from Freshwater Ecology (2020).
  - A strategic release regime based on the numbers of cod expected to be relocated will be refined after the baseline survey, where catch rates of cod will be better understood.
  - Mary River cod caught initially (approximately 8-10 fish) will be equally distributed between the two highest priority sites (currently sites 12 and 37).
  - After the initial catch, fish (3-4 per site) will be released into secondary sites (currently 17, 33, 18 and 31).
  - After this, the above schedule of fish release will be repeated.
- There will be no temporary relocation of Mary River cod, all cod will be relocated to suitable sites (as listed in Table 5-4) and will not return back into lake Macdonald at a later date. Efforts will be made to re-stock Mary River cod into Lake MacDonald on project completion as a mitigation action.
- Captured Australian lungfish to be released back into the body of water from which they were captured, unless relocation is deemed required by a suitably qualified and or experienced personnel as stipulated in Section 5.5.2).
- No Australian lungfish will be relocated to farm dams.

The 2025 evaluation survey did not find any MNES or MSES species living in the lake.

5.5.5 Fauna Relocation Sites

The proposed fauna relocation sites are identified in Table 5-4. The primary relocation sites are described in more detail in Appendix H.

Table 5-4: Proposed fauna relocation sites

Fauna	Primary relocation sites	Contingency relocation sites
Mary River cod	Four Mary River sites – permanent Two Yabba Creek sites – permanent	Mary River downstream of Gympie Weir
Australian lungfish (if required, as stipulated in Section 5.5.2)	Four Mary River sites – permanent Two Yabba Creek sites – permanent	Mary River downstream of Gympie Weir
Large-bodied native fish	Cooloolabin Dam – permanent[4]	Nil

5.5.6 Assessment of relocation sites and carrying capacity

As per EPBC approvals for the project an assessment of the suitability and carrying capacity of potential relocation sites was undertaken in January 2020. The site assessment (Freshwater Ecology, 2020) was very thorough and included an assessment of 38 potential sites. These sites included areas within the main stem of the Mary River, several Mary River tributaries and Cooloolabin Dam in the South Maroochy River. 12 assessment criteria were used to create a short list of 18 sites which were then subject to further detailed assessments (travel times, habitat quality, water quality, macrophyte & macroinvertebrates abundance, fish and turtle surveys). Out of these 18 sites 4 Mary River and 2 Yabba Creek sites were chosen for threatened species and Cooloolabin Dam was selected for other large bodied fish species (Table 5-4). The Freshwater Ecology (2020) report included:

- Desktop review.
- Rapid field assessment and screening of a long list of potential relocation sites.
- Field assessment of a consolidated long list.
- Final screening to produce a short list of relocation sites.
- Logistics – site access, duration of travel to site, safety considerations
- Assessment of fauna communities comprising:
  - diversity and abundance of fish and turtle species, using quantitative or semi-quantitative methods (e.g. electrofishing) that enable calculation of CPUE and estimates of biomass.
  - community composition based on length, weight, life history stage (as appropriate for species).
  - presence of platypus and burrows, using semi-quantitative methods such as timed observations and estimates of size.
- Habitat suitability – assessment of structure, condition and suitability for fauna, with an estimate or calculation of the area of optimal habitat for MNES and MSES species (if present).
- Availability of food resources – quantitative surveys of aquatic macroinvertebrates and aquatic plants (macrophytes).
- The relocation sites recommended by this report are presented in Table 5-4.

It is noted that habitat conditions and carrying capacity status of sites may have changed since this assessment that was completed in 2020. To address this all sites will be revisited prior to any fauna being relocated and if new sites are required this will be discussed with DPI prior to relocation of fauna. If turtles need to be salvaged and relocated and new sites are required, the appropriateness of any proposed turtle relocation sites will also be discussed with DETSI biodiversity experts (via the EIA team) and DCCEEW (where relevant).

Fishology are planning to undertake relocation site surveys as soon as the lake drawdown date has been confirmed. As per the freshwater ecology report (Freshwater Ecology, 2020) it was recommended that visual assessment will be undertaken immediately prior to commencement of any potential relocation activities. This will include an assessment of the streamflow conditions at the time and how this would influence the potential aquatic fauna carrying capacity (e.g. flow, water quality, submerged macrophytes and connectivity).

[4] Cooloolabin Dam is located mostly within a forest reserve making the shoreline mostly inaccessible to vehicles. Where possible, multiple sites will be used for fish release during the project. This will be dependent on lake levels, Seqwater access requirements, and accessibility for vehicles towing a trailer.

It is likely that habitat quality and carrying capacity of these sites would have improved since 2020. The original assessment was undertaken following low rainfall and riverine flow conditions within the catchment. Since the report was written the region has experienced several subsequent wet years that are likely to have increased habitat quality and conditions within the riverine and lake relocation sites. Additionally, several successful riverine stabilisation and habitat improvement projects have been undertaken by MRCCC in partnership with Seqwater during this time.

5.5.7 Salvage Schedule and Resourcing

The drawdown salvage phase has a target for aquatic fauna salvage of at least an equivalent percentage of large bodied fish as the percentage of drawdown that has occurred. This is provisionally assumed to occur over 4 weeks of salvage effort. Salvage will commence within 4 weeks of drawdown commencing and will continue on a week-on week-off basis until the target percentage has been achieved or for 8 weeks of salvage effort – whichever is the sooner.

If the fish salvage target (i.e. 55% of large bodied fish compared to evaluation survey result, to be refined based on biomass estimates undertaken during the baseline survey) has not been achieved by end of the 4th week of salvage effort, the salvage program will be reviewed and if deemed necessary for the health of aquatic fauna, extended for up to 4 additional weeks of salvage effort.

If water volume in the lake reduces beyond the planned construction phase volume of 3,368 ML, then additional salvage will be implemented at the following triggers:

- 2,405 ML, with the fish salvage target becoming 70% of large bodied fish compared to evaluation survey result
- 1,640 ML, with the fish salvage target becoming 80% of large bodied fish compared to evaluation survey result

Hydroacoustic surveys will be used to confirm achievement of salvage target post dewatering phase.

Salvage of aquatic biota from the stilling basin will occur on a frequency required to prevent welfare concerns, determined by the results of visual observations of fauna stress and water quality monitoring. Additionally, aquatic biota will be salvaged before and during all cofferdam dewatering events. Aquatic biota salvaged from the cofferdam space will be released to the upstream lake.

Table 5-5: Indicative pre-construction aquatic fauna salvage schedule

Phase	Week	Lake Volume* (ML)	Indicative Effort
Evaluation Survey	0	8,018 (full)	Hydroacoustic survey of fish Survey of platypus using eDNA and camera traps Salvage using: • 2 boat electrofishing teams • 1 fyke netting team • 1 turtle trapping team • 2 transport teams
Drawdown / Lowering	1-4	8,018 reducing to 4,410 (42%)	Salvage on a 1 week on 1 week off schedule using: • 2 boat electrofishing teams • 1 fyke netting team • 2 transport teams
	4-8	Maintained at 4,410	
Cofferdam Construction	32	Maintained at 4,410	If salvage target has not been achieved, then continue salvage on a fortnightly basis from week 11 onwards until target is achieved, using: • 1 boat electrofishing teams • 1 fyke netting team • 1 transport teams Repeat hydroacoustic survey if further validation of salvage target is required
Construction	–	2,405 (30% FSL,	Contingency salvage if lake volume reduces to 2,405 ML; new salvage target is 70% of large bodied fish compared to evaluation survey result:

Phase	Week	Lake Volume* (ML)	Indicative Effort
		considered drought conditions)	• 1 boat electrofishing teams • 1 fyke netting team • 1 transport teams
	–	1,604 (20% FSL, considered drought conditions)	Contingency salvage if lake volume reduces to 1,604 ML; new salvage target is 80% of large bodied fish compared to evaluation survey result: • 2 boat electrofishing teams • 1 fyke netting team • 2 transport teams

*Assumes no inflow into storage.

5.5.8 Capture Methods

Active salvage will be implemented, with regular monitoring of traps and nets (e.g. twice daily).

The following capture methods will be used (also refer to section 5.5.7 for scheduling and resourcing information):

- Boat electrofishing: large units (7.5 GPP), and potentially small units (3.5 GPP), each operated by a team of suitably qualified persons
- Fyke nets (up to 20, mesh size 10 mm): set in upper reaches of Lake Macdonald for fish by a team of suitably qualified persons from a boat
- Seine net: on an as-needed basis, such as to catch stranded fish from shallow isolated pools.

The species, the number of each species, the apparent health and the total length and weight of all Mary River cod and Australian lungfish individuals that are captured will be recorded. The mark and recapture of these species over the life of the project will assist with determining population size and fish condition over time. It will not be practical, nor in the interests of fish welfare, to record measurements for any other species.

5.5.8.1 Fish Salvage

Fish salvage will be principally undertaken through electrofishing and fyke netting.

Boat electrofishing will be undertaken with purpose-built (industry standard) vessels that contain a generator powered electrofishing unit. These vessels use a pulsed direct current (DC) waveform to immobilise fish, which are then netted and placed in a live well located on the electrofishing vessel. Holding of fish on vessels is outlined below in section 5.5.9. All electrofishing boats will be operated in accordance with the Australian Code of Electrofishing Practice, as per Queensland General Fisheries Permit requirements, and all drivers will be trained in electrofishing and hold senior operator status.

Double winged fyke nets will be set during the day and retrieved the following morning. Setting fyke nets overnight is normal practice and approved by the relevant animal ethics committee and in accordance with Queensland General Fisheries Permit requirements. To avoid harm to air breathing animals (i.e. platypus) the cod end of the net will be kept afloat in case any air breathing animals were caught. Each net will be set out from the bank with wooden stakes used to keep the fyke net wings and cod end in place. The netting team will use standard nets and traps, operated by suitably qualified aquatic ecologists.

It should be noted that no MNES or MSES fish species were recorded in the lake during the 2025 Fishology Biomass Surveys.

5.5.8.2 Turtle Salvage

No turtle salvage activity is planned to occur as part of the project. Lake conditions during the construction phase of the project are likely to be suitable for the turtle population. Furthermore, turtles are likely play an important role in ecosystem functioning within the lowered lake. Turtle communities will be monitored bi-annually during the construction phase, to ensure that the health of this community is not compromised. Note that turtle salvage and relocation will only occur if monitoring suggests it is necessary, or if other unforeseen circumstances occur (i.e. overland turtle migrations).

It should be noted that no MNES or MSES turtle species were recorded in the lake during the 2025 Fishology Biomass Surveys.

5.5.9 Holding Methods

A salvage and relocation holding area will be established, featuring an access jetty from the lake to the shoreline. This area will include two temporary storage tubs, each with a 2,000 L capacity, equipped with shading and aeration. These tubs will be available for emergency use or for isolating fish when necessary. Storage tubs will be positioned to ensure they are under shade for the entirety of the salvage operation.

At the time of capture on each vessel, all fish will be carefully placed in sufficiently large receptacles (either purpose built recirculating live wells and/or sufficiently large tubs to house fish) containing Lake Macdonald water, with dissolved oxygen concentrations of the water maintained using aerator units.

Where possible, threatened species will be housed separately from other fish within a separate aerated tub. This measure will be adapted to suit the occurrence and catch rate of threatened species in the field.

Prior to and during salvage operations, assessments will be undertaken on all fauna housing and aeration systems to ensure they are capable of providing adequate conditions.

The holding capacity of each holding receptacle will be pre-determined in accordance with DPI’s Fish Salvage Guidelines (DPI, 2004). Once the capacity of the holding receptacle is reached or two hours since catching the first individual has passed (whichever comes first), fish in all holding receptacles on the vessel will be moved to the salvage and relocation holding area. Equipment, such as pumps and tanks, will be repurposed for the salvage and relocation activity. The salvage and relocation holding area will be used as the principal transfer location of fauna from salvage vessels to land-based transports, and as a holding facility as required. With the exception of emergencies or if fish need to be isolated, fish will be moved straight from the salvage vessels into the land-based transports.

Any pest fish caught will be euthanised using ethics committee-approved methods and disposed of appropriately (e.g. in plastic bags at an appropriate refuse facility or buried on site a minimum of 20 m from the water’s edge).

It is expected that the average time from capture to release will be less than three hours for Mary River cod, Australian lungfish, and four hours for other species. Detailed planning and work instructions for salvage and relocation will include the maximum timeframes identified for capture, transport and relocation for MNES, non-MNES and pest species.

5.5.10 Transport and Release Methods

Land-based transports (suitable vehicles with purpose-built trailers) will be used to transport native fauna to the pre-determined release locations and released according to the DPI Fish Salvage Guidelines.

Three specialised fish transport trailers with aerated water tanks will be used for transport with one spare all times for keeping fish, this will reduce handling where possible. Two transport trailers will be fitted with 1700 L capacity (single tub), which will be used for general fish salvage capability. One transport trailer fitted with 2 separate holding tanks (500 L each) will be available for general fish transport as well as transport for sensitive species such as Mary River cod (ability to separate fish where required). The trailers will rely on compressed air for aeration with a backup compressed oxygen system. Tanks will be fitted with lids to prevent fish jumping out prior to intentional release.

Assessments of stocking rates, aeration and water volume in tanks will be made prior to any transfer from holding to land-based transports.

Handling of fish will be minimised as far as practical and will be in accordance with the DPI Fish Salvage Guidelines, and Commonwealth Survey Guidelines for Australia’s Threatened Fishes (DSEWPaC, 2011) and Survey Guidelines for Australia’s Threatened Reptiles (DSEWPaC, 2011).

Details of the fauna relocation sites are provided in section 5.5.5. Details of monitoring of relocation sites during the salvage and relocation activity is provided in section 5.5.11.

5.5.11 Monitoring of Relocation Success

Weekly visual monitoring of sites where fauna have been relocated during the relocation program (e.g. observations of mortality) and measurement of in situ water quality (focusing on dissolved oxygen).

On a monthly basis at all relocation sites for 12 months after week four (4) of the lake drawdown schedule, to assess the long-term success of the salvage and relocation operation. This will involve visual monitoring of sites where fauna have been relocated during the relocation program (e.g. observations of mortality) and measurement of in situ water quality (focusing on dissolved oxygen).

Before relocation, all MNES fish species salvaged from Lake Macdonald will be tagged with Passive Integrated Transponder (PIT) tags and surveys will subsequently be undertaken at all sites where MNES species were released. These surveys will occur every six months from the completion of the drawdown salvage phase until the completion of dam construction. The surveys will use the same methods used in the relocation site assessment (Appendix H), and any MNES species caught will be scanned with a hand-held PIT tag reader to estimate the proportion of relocated MNES fauna recaptured as an indication of potential survivorship. Results will be compared to mark-recapture data for both species from the Mary River collected by DR, which will serve as a reference for recapture rates.

5.5.12 Reporting

A count of each species caught for relocation will be made at the time of capture on the boat. In addition, for MNES, size and health/condition shall be measured and recorded per the relevant industry practice. The total catch across all fishing teams will be recorded and reported on a fortnightly basis to track progress and to keep project managers informed. Any MNES species caught and relocated will be reported to Seqwater on the same day. Seqwater will notify DCCEEW of any Mary River turtle and white-throated snapping turtle caught and relocated within three days.

A detailed salvage and relocation report will be prepared at the completion of the Drawdown Salvage Phase (and following verified achievement of the drawdown fish salvage target via the hydroacoustic survey). The report will include but not be limited to:

- Salvage effort
- Trends in catch rates
- Breakdown of relocated fauna by species and relocation site
- Health of MNES species
- Any incidents or mortality
- Observations of fauna and in situ water quality at relocation sites.

Additional compliance reporting and audits are outlined in section 13, specifically relating to residual significant impacts with respect to the project EPBC approval.

5.5.13 Salvage of MNES Species

Table 5-6 provides a summary of the methods for salvage and relocation of MNES species from Lake Macdonald. It also identifies relocation sites, guidance documents, and where further information is provided in this plan.

No MNES species other than those identified in this plan and Table 5-6.

The 2025 evaluation survey did not find any MNES or MSES species living in the lake.

Table 5-6: Salvage details for MNES species

MNES Species	Salvage Methods	Holding Methods	Transport and Release Methods	Estimated Time – Capture to Release	Relocation Sites	Guidance Documents
	Details in section 5.5.8	*Details in section 5.5.9*	*Details in section 5.5.10*	*Details in section 5.5.10*	*Details in section 5.5.5 and Appendix G*	
Australian lungfish (if required, as stipulated in Section 5.5.2)	Boat electrofishing (7.5 GPP and 3.5 GPP) – multiple pass where conditions allow. Fyke netting – up to 20 set overnight, checked every 4-6 hours. Handling of fish will be minimised as far as practical	All fish will be placed in large receptacles with a pre-determined holding capacity, containing aerated water from Lake Macdonald. MNES fish species will be held separately from other fish/ where possible. When the capacity of the holding receptacle is reached or two hours have passed since the first individual was caught, the fish will be moved to the salvage and relocation hub. Handling of will be minimised as far as practical. Tag all individuals with PIT tags and record details.	MNES fish species will be moved in a specialised transport trailer with an aerated water tank (1,500-2,000 L approx.). Tanks will be fitted with lids. Assessments of stocking rates, aeration and water volume in tanks will be made prior to any transfer from holding. Handling of fish will be minimised as far as practical.	< 3 hours	4 Mary River sites 2 Yabba Creek sites	DPI's Fish Salvage Guidelines (DPI, 2004) DPI's Guidelines for Fish Salvage fact sheet (DAF, 2018) Survey Guidelines for Australia's Threatened Fishes (DSEWPaC, 2011)
Mary River cod				< 3 hours	4 Mary River sites 2 Yabba Creek sites	
Giant barred frog	No salvage – expected to move independently from affected areas					

6. Aquatic Habitat

6.1 Baseline Conditions

6.1.1 Aquatic Habitat in Lake Macdonald

Aquatic habitat in Lake Macdonald comprises a large pool, with a high abundance of submerged aquatic flora, predominantly *Cabomba caroliniana* and *Nymphoides indica*, and beds of emergent *Persicaria* spp. near lake margins. The substrate is dominated by silt, with some sand near banks, and there is limited large woody debris. Habitat in the lake does not provide suitable breeding locations for Mary River cod and Australian lungfish, and there is no suitable nesting habitat for Mary River turtle and white-throated snapping turtle on the banks.

6.1.2 Aquatic Habitat in Six Mile Creek

Six Mile Creek downstream of the dam 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 a common habitat element along with medium length pools (i.e. between 6 and 12 channel widths in length) that are less than 2 m deep (DNRM 2004). Riffles and shallow glides over sand also present.

Habitat surveys were undertaken in Six Mile Creek downstream of the dam from 2013 to 2018, using methods that developed to specifically assess suitability of aquatic habitat for Mary River cod, Australian lungfish, Mary River turtle and white-throated snapping turtle. The habitat surveys found:

- A well-defined channel with high steep banks and undercut banks was common
- The substrate was dominated by clay and silt, with gravel riffles and some bedrock present
- High variation in hydraulic habitat types, with riffles, runs and shallow and deep pools all variously occurring
- Low abundance of submerged aquatic flora, except immediately downstream of the dam
- Abundant large woody debris and leaf packs
- The riparian vegetation is in good condition, providing shade and a supply of fine and large woody material
- There are some suitable breeding locations for Mary River cod, but very limited breeding habitat for Australian lungfish
- No suitable turtle nesting habitat was recorded.

In general, the habitat was similar regardless of proximity to the dam, which suggests that the existing flow regime does not have a substantial influence on habitat structure between the dam and the Mary River. There was also little evidence of change in the aquatic habitat condition between surveys despite a number of high flow events occurring during these time periods.

Further assessment of habitat, including habitat mapping for relevant species, was undertaken in July 2020, the details of which are provided in Appendix G.

6.2 Potential Impacts of Lowering Lake Macdonald

6.2.1 Within Lake Macdonald

Aquatic habitat in the lake will be minimally affected by the planned magnitude of water lowering during the drawdown phase, with the amount of aquatic habitat (i.e. volume of water) reduced to approximately 42% of FSL volume, and maximum depth decreasing by 22% compared to FSL. The reduced lake will have a maximum depth of 8.2 m during the construction phase and continue to hold water over most of the impoundment area. Only the upstream extremities of the lake will be temporarily lost during the construction phase, during which time these areas will revert to waterway habitat (rather than impounded / lake habitat). It is likely that pools in these waterways will be retained by inflows and groundwater throughout the duration of the project.

6.2.2 Downstream of Lake Macdonald (Six Mile Creek) Dam

Potential adverse impacts to aquatic habitat in Six Mile Creek downstream of the dam during drawdown may occur due to changes in:

- Water quality – as described in section 3.1.3
- Erosion and sedimentation – as described in 0
- Hydrology – sustained moderate flow for the duration of the dewatering phase that would naturally have a lower median flow and higher variability.

Fine sediments accumulate on the bed of reservoirs (e.g. >90% of sediment is captured in Lake Macdonald Dam - DNRM 2014), which could be mobilised during the drawdown and construction phases and deposited downstream. This has potential to smother benthic habitats, including in-filling pools and interstitial spaces of coarse substrate (e.g. gravels and cobbles), and subsequently affect primary producers (i.e. aquatic plants and benthic algae), macroinvertebrates and fish (Wood and Armitage, 1997). As described in section 4, thus potential impact pathway has low risk, and should some level of sedimentation occur downstream the effect would be temporary in nature, whereby flows following deposition events would further entrain and transport unconsolidated fine sediments to re-establish the creek's natural features and substrates. Six Mile Creek experiences frequent flow events and so the turnaround is expected to be in the order of weeks to months.

Changes in flow conditions have the potential to cause changes in fauna behaviours, including breeding success, that are triggered by flow. Changes in flow conditions may also lead to loss of, or deterioration in, habitat condition through scouring of the substrate, disturbance of physical habitat (e.g. woody debris, leaf packs, aquatic plants, bank erosion) and altered flow habitat (e.g. riffle to pool). Where these potential impacts are not managed or mitigated, further impacts, such as declines in fauna populations and breeding, may also occur.

6.3 Management and Monitoring

Potential impacts to aquatic habitat will be mitigated by implementing the measures identified in Table 6-1. Where appropriate, the management measures contained in table 6-1 will be adapted over the course of the Project in response to changing conditions and expert advice.

Due to the importance of aquatic habitat in supporting aquatic fauna, including MNES and MSES species, monitoring of aquatic habitat will be undertaken not only to assess direct impacts, but also as a preliminary indicator for potential impacts to aquatic fauna.

Table 6-1: Management of aquatic habitat during the lowering of Lake Macdonald

ENVIRONMENTAL OBJECTIVE: **Minimise impact of lake drawdown on aquatic habitat in the lake and Six Mile Creek downstream.**	
Performance criteria	**Lake Macdonald** • Prevent or minimise potential impacts to aquatic habitat in Lake Macdonald, where minimise means the impact is temporary and reversible. • Maintain water quality within the current variability for Lake Macdonald, as identified in Appendix B. • Achieve the erosion and sediment control performance criteria identified in Table 4-1. **Six Mile Creek Downstream** • Achievement of downstream flows where inflows are recorded during the construction phase. • Prevent or minimise potential impacts to aquatic habitat in Six Mile Creek, in particular habitat for listed threatened species, where minimise means the impact is temporary and reversible. • No exceedance of habitat monitoring triggers, as identified in Appendix F (Habitat Monitoring Program, Table 16-6).
Management measures	**Lake Macdonald** • Implement management measures for water quality (Table 3-1), erosion and sediment control (Table 4-1), and aquatic fauna (Table 5-2). • Do not clear vegetation outside of the clearing extent defined in the IAR.

<table>
<tr><th colspan="2">ENVIRONMENTAL OBJECTIVE:
Minimise impact of lake drawdown on aquatic habitat in the lake and Six Mile Creek downstream.</th></tr>
<tr><td></td><td>• Do not disturb bed or banks (e.g. clear vegetation or excavate) until a suitably qualified person has checked the area for threatened fauna and breeding habitat. If any are identified, implement a 3 m x 3 m exclusion zone with flagging tape until approval to impact the area has been granted by the suitably qualified person.
• After construction is completed, and where disturbance or visual assessment indicates this is required, re-establish or supplement aquatic habitat (as per section 9) if it is safe to do so.
Six Mile Creek Downstream
• Implement management measures for water quality (Table 3-1), erosion and sediment control (Table 4-1), and aquatic fauna (Table 5-2).
• Control the drawdown release rate as outlined in Section 2 of this plan.
• Do not clear vegetation outside of the clearing extent defined in the IAR or other relevant approvals.
• Do not complete drawdown of lake in less than 4 weeks.
• Ensure releases do not exceed bankfull height of Six Mile Creek.
• Avoid changes to hydrology during the breeding seasons for MNES and MSES species known to be in Six Mile Creek downstream of the dam, with drawdown not being permitted between 1 September and 28 February of any year (per section 2.2).
• Do not clear vegetation or excavate banks until a suitably qualified person has checked the area for threatened fauna and breeding habitat (e.g. burrows). If any are identified, implement a 3 m x 3 m exclusion zone with flagging tape until approval to impact the area has been granted by the suitably qualified person.
• Re-establish or supplement aquatic habitat (as per section 9.1), where monitoring indicates this is required.</td></tr>
<tr><td>Monitoring</td><td>Lake Macdonald
• Quarterly assessment of aquatic habitat at the lake monitoring site (450 m upstream of the dam) during the construction phase, and quarterly for one year post construction, in accordance with Appendix F.
• Where possible aerial drone surveys will be used to monitoring of the upper reaches of Lake Macdonald before (baseline), during and after the drawdown (i.e. at 42% FSL) to document the rate of exposure and assess the location, variety and abundance of fish habitats across various water levels and seasons. Surveys should encompass a range of fish habitats, including (but not limited to) macrophyte beds, boulders, riffles, woody debris, and identifiable breeding sites, such as eel-tailed catfish (Tandanus tandanus) nests.
Six Mile Creek Downstream Sites and Control Sites
<u>Before drawdown (baseline):</u>
• Undertake baseline monitoring of habitat condition at the three downstream monitoring sites and two control sites, as outlined in Appendix F (Habitat Monitoring Program).
<u>During drawdown:</u>
• Undertake drawdown phase monitoring at the three downstream monitoring sites and two control sites, as outlined in Appendix F (Habitat Monitoring Program).
• Daily flow volume recorded at State Government gauging station at Cooran compared to long-term flow percentiles; flow data accessed and assessed monthly.
<u>During construction:</u>
• Undertake construction phase monitoring of habitat condition at the three downstream monitoring sites and two control sites, as outlined in Appendix F (Habitat Monitoring Program).
• Daily flow volume recorded at State Government gauging station at Cooran compared to long-term flow percentiles; flow data accessed and assessed monthly.
<u>Post-construction:</u>
• Undertake post-construction phase habitat monitoring at the three downstream monitoring sites and two control sites, as outlined in Appendix F (Habitat Monitoring Program).</td></tr>
<tr><td>Reporting</td><td>• Monitoring results provided to Seqwater Project Manager and Contractor’s environmental representative via email, where performance criteria are not met.
• Quarterly report provided to regulatory agencies summarising compliance and monitoring results.
• A brief monitoring data summary report, as outlined in Appendix F (Habitat Monitoring Program), will be provided to the Seqwater Project Manager and regulatory agencies (if requested).</td></tr>
</table>

ENVIRONMENTAL OBJECTIVE: Minimise impact of lake drawdown on aquatic habitat in the lake and Six Mile Creek downstream.	
Responsibility	Contractor – Site Supervisor or representative, using suitably qualified persons
Corrective actions	• Where the performance criteria are not met, reduce or pause releases and investigate as outlined in Appendix F (Habitat Monitoring Program). • Review management measures and adjust to prevent further impact if required. Update the plan and, if required, provide notification as described in section Appendix F. • If impacts are noted and reducing the drawdown releases is not effective, review alternative mitigation options, including habitat improvements, through Seqwater's existing relationship with MRCCC and Noosa and District Landcare. – Note: in-stream actions to manage stream flows are not considered appropriate (e.g. checks or armouring) due to safety considerations and are likely to have greater impact on the ecosystem compared to the release activities. • Where downstream flow requirements are not achieved, release bypass flows or investigate alternative options. • Re-establish or supplement aquatic habitat (as per section 9.1)

7. Biosecurity Management Plan

7.1 Baseline Conditions

7.1.1 Biosecurity Matter in Lake Macdonald and Six Mile Creek Downstream

The *Biosecurity Act 2014* (Bio Act) identifies two types of biosecurity matters: prohibited matters, which are not yet present in Queensland, and restricted matters, which are currently present in Queensland.

Eight restricted biosecurity matters are known to be present in Six Mile Creek:

- Pest fish: eastern gambusia (*Gambusia holbrooki*) and tilapia (*Oreochromis mossambicus*) – all are listed as restricted noxious fish under the Bio Act
- Aquatic plants: salvinia (*Salvinia molesta*), water hyacinth (*Eichhornia crassipes*), Hygrophila (*Hygrophila costata*), and Cabomba (*Cabomba caroliniana*) – all listed as category 3 restricted invasive plants under the Bio Act
- Amphibians: cane toad (*Rhinella marina*) – not listed as a prohibited or restricted invasive animal under the Bio Act

There are extensive beds of Cabomba within Lake Macdonald and the upstream tributaries of Six Mile Creek. Small populations of Cabomba have also been identified downstream in Six Mile Creek. Restricted matters from the lake (e.g. gambusia and Cabomba) are likely transported downstream when the dam overtops, which occurs frequently.

In 2010 it was estimated that Lake Macdonald was home to 86% of Australia's Hygrophila. Since then Seqwater Operations staff estimate that 99% of the plant has been removed from the lake.

Surveys in 2015, 2020 and 2023 identified eastern gambusia populations in Lake Macdonald. To date, tilapia have only been recorded downstream of Lake Macdonald in Six Mile Creek. It is not known if the species is present in Lake Macdonald, though it is considered unlikely.

Cane toads were identified around lake Macdonald during amphibian surveys conducted in 2018 and 2023, including the upstream and downstream tributaries of Six Mile Creek.

It is not known whether frogs present in Lake Macdonald and Six Mile Creek are infected with chytridiomycosis, the infectious disease that affects amphibians across the world. Chytridiomycosis mostly affects species associated with permanent water and appears to be confined to the relatively cool and wet areas of Australia, including along the Great Dividing Range and adjacent coastal areas in Queensland (DSEWPaC, 2013). While it is widespread, with very few suitable host areas remain uninfected in Australia, there are also some disease-free pockets within infected regions. Chytridiomycosis is caused by the Chytrid fungus (*Batrachochytrium dendrobatidis*), a fungus capable of causing occasional deaths in some amphibian populations and complete mortality in others. Chytrid fungi typically live in water or soil and have spores that 'swim' through the water.

7.2 Potential Impacts of Lowering Lake Macdonald

Potential impacts associated with biosecurity matters that could occur by lowering Lake Macdonald are:

- Spread of biosecurity matter (aquatic weeds, aquatic pest species, disease)
- Introduction of new biosecurity matter.

7.2.1 Lake Macdonald

Certain hydrological conditions may potentially allow upstream movement of pest fish such as tilapia into Lake Macdonald dam during the proposed works.

7.2.2 Downstream of Lake Macdonald Dam

There may be a slight increase in the transport of restricted matter downstream, notably Cabomba and Gambusia, from the lake to Six Mile Creek during the lowering process. Water pumped from Lake Macdonald to Six Mile Creek may contain a greater concentration of restricted matter than is present during overtopping events, and this could place pressure on the downstream aquatic communities.

If Chytrid fungus is present in Lake Macdonald or the surrounding area, it is also likely to be in Six Mile Creek downstream of the dam. While not considered likely given the widespread nature of Chytrid fungus, if it is not present, it could also be transferred to the creek on muddy equipment and machinery brought in for the Project, on the boots of workers, or in water trucked in for construction after Lake Macdonald is lowered.

7.2.3 Fauna Relocation Sites

There is potential for the spread of biosecurity matter from Lake Macdonald to relocation sites as a result of the fauna salvage and relocation program. Pest fish species (e.g. Gambusia) and aquatic weeds (e.g. Cabomba) could be inadvertently transported in water from Lake Macdonald used to transport and hold fauna, and on the fauna being transported. If the biosecurity matter being transported is not already present at the relocation sites, there is the potential to introduce a new biosecurity matter to an area.

Relocation of fauna from Lake Macdonald also has the potential to introduce pathogens and diseases (e.g. Chytrid fungus, parasites) to relocation sites. These may be present in the water from Lake Macdonald used for holding and transport of fauna, or on fauna. However, given the widespread nature of Chytrid fungus, it is unlikely that it is not already present at relocation sites.

7.3 Management and Monitoring

Potential impacts of fauna biosecurity matters will be mitigated by implementing the management measures in Table 7-1 and Table 7-2. Where appropriate, the management measures contained in table 7-1 and 7-2 will be adapted over the course of the Project in response to changing conditions and expert advice.

Seqwater plans to implement opportunistic programs to manage pest species in Lake MacDonald. The dam upgrade project team will coordinate with operational staff to make the most of opportunities arising from the temporary lowering of the lake to allow for ongoing pest management activities during the construction period.

Table 7-1: Management of pest animal biosecurity matters during the lowering of Lake Macdonald

ENVIRONMENTAL OBJECTIVE – PEST MANAGEMENT: Distribution of pests does not increase due to the Project and existing populations of pest fauna do not increase.	
Performance criteria	**Lake Macdonald and Six Mile Creek Downstream** Obligations under the Queensland *Biosecurity Act 2014* are met. No new pest infestations, or increase in distribution of pests, as a consequence of the lake lowering activities, including fauna relocation.

ENVIRONMENTAL OBJECTIVE – PEST MANAGEMENT:
Distribution of pests does not increase due to the Project and existing populations of pest fauna do not increase.

Management measures

Lake Macdonald and Six Mile Creek Downstream

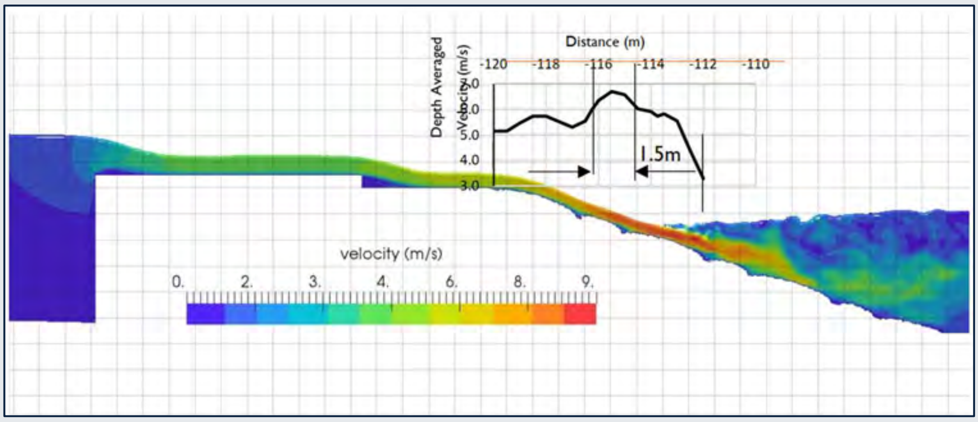
Before drawdown:

- Hydrological modelling conducted prior to the drawdown indicates that the current cofferdam retains 3000 mm during significant inflow events (up to a 1 in 1000 AEP) of freeboard between headwaters and tailwaters, mitigating impact of potential pest fish migration into Lake Macdonald and upstream environments.

Property	Elevation (m AHD)		
	AEP 1 in 1000	AEP 1 in 100	AEP 1 in 10
Headwater	95.2	94.9	94.5
Stilling Pond	92.4	92.1	91.5
Tailwater	92.15	91.45	90.63
Difference Stilling Pond to Tailwater	0.25	0.65	0.87

Extract from the Cofferdam Design Report

Flow velocities over the cofferdam would also be prohibitive to tilapia migrating over the structure. As seen below velocities for a 1 in 100 AEP peak at 6.7m/s across a 1.5m distance. The maximum swimming speed of tilapia is known to be approximately 4.9m/s. For a 1 in 10 AEP event the flow velocities peak at 5.6m/s however as seen in the table above the vertical distance between headwater and tailwater is further increased thereby removing the possibility of upstream fish passage.



Extract from the Cofferdam Design Report for a 1 in 100 AEP event.

- The Lake Macdonald spillway and dam abutment upgrade (including temporary works) has been designed to avoid the spread of pest fish such as tilapia into the lake. No fish passage facilities have been included in the dam upgrade program and the new spillway will exclude fish migration.

During drawdown and construction:

- Manage the water level in the lake to reduce the potential for drown-out / overtopping (i.e. via active releases), where possible (i.e. where weather conditions are favourable).
- If drown-out of the temporary cofferdam occurs, implement a fish salvage event targeting tilapia when conditions are suitable and access is safe. This may include lower the lake level to consolidate biomass density for effective sampling.
- Euthanise pest fish humanely during aquatic salvage or sampling activities.
- Do not use water from Six Mile Creek downstream of the dam for construction purposes, if the purpose presents a credible risk of transferring biosecurity matters (tilapia) into Lake Macdonald.
- All vehicles (including boats) and plant to have weed hygiene certification before entering Lake Macdonald.
- Ensure all relevant personnel complete pest identification training.

Salvage and Relocation

- Ensure all relevant personnel complete pest identification training.

ENVIRONMENTAL OBJECTIVE – PEST MANAGEMENT: Distribution of pests does not increase due to the Project and existing populations of pest fauna do not increase.	
	• During fauna salvage and relocation, euthanise any pest fish or turtles caught using ethics approved methods and dispose of appropriately (e.g. in plastic bags at an appropriate refuse facility or buried on site a minimum of 20 m from the water's edge). • Filter (screen) all water to be used to hold and transport fauna for relocation to reduce potential transport of tadpoles. • Assess fauna condition and do not relocate individuals with impaired condition or visible parasites, lesions or fungi. With the exception of MNES species, fauna with impaired condition should be returned to the lake or euthanised. MNES species should be placed in a suitable receptacle and transported to a suitably qualified wildlife carer. • Wash down fauna relocation vehicles and equipment in accordance with weed washdown protocols before returning to the Project area to remove any attached sediment or mud. • Clean and disinfect footwear, or change footwear, used for fauna relocation in accordance with the Hygiene protocols for the control of diseases in Australian frogs (Murray et al, 2011).
Monitoring	**Lake Macdonald** • During construction, monitor presence of pest species in the lake as part of quarterly fish and turtle monitoring. **Six Mile Creek Downstream** • During construction, monitor presence of pest species as part of quarterly fish and turtle monitoring. **Relocation Sites** • During salvage and relocation, record the number of pest species observed and euthanised (e.g. in a register) during relocation activities.
Reporting	• Immediately report any tilapia in Lake Macdonald to the Seqwater Project Manager. • Fortnightly report submitted to the Seqwater Project Manager via email with details of monitoring results and incidents. • Quarterly report provided to regulatory agencies summarising compliance and monitoring results.
Responsibility	Contractor – Site Supervisor or representative Seqwater – Project Manager or representative
Corrective action	• Where infestations of pest species are identified, implement appropriate treatment / control measures, on a case by case basis. • Regularly review existing control measures to identify potential improvements. • If any biosecurity issues are identified, review and adapt management measures as appropriate.

Table 7-2: Management of pest plant biosecurity matters during the lowering of Lake Macdonald

<table>
<tr><th colspan="2">ENVIRONMENTAL OBJECTIVE – WEED MANAGEMENT:
Restricted invasive plants not present in Lake Macdonald are not introduced.
Restricted invasive plants already present in Lake Macdonald are not spread to new areas.</th></tr>
<tr><td>Performance criteria</td><td>• Obligations under the Queensland Biosecurity Act 2014 are met.
• All vehicles and plant working in the lake have weed hygiene certificates.
• No additional weed infestations or increase in distribution in the lake or at relocation sites due to construction activities.
• All employees working on site attend induction training sessions to identify weeds.</td></tr>
<tr><td>Management measures</td><td>Lake Macdonald, Six Mile Creek Downstream, and Salvage and Relocation
<u>During drawdown:</u>
• Relocate fauna only to the specified relocation sites for each species, which have been selected with consideration to the presence of restricted biosecurity matter that occur in Lake Macdonald.
• Filter (screen) all water to be used to hold and transport fauna for relocation to reduce potential of transport of weeds.
• All vehicles used for fauna relocation to be inspected and washed before leaving site if they have entered Lake Macdonald or margin areas where aquatic plants are exposed.
<u>During construction:</u>
• All vehicles (including boats) and plant to have weed hygiene certification before entering Lake Macdonald.
• Undertake aquatic and terrestrial weed control in the lake area as required, based on monitoring stipulated below. This may include areas where Hygrophila is likely to establish on exposed banks that have previously been controlled or eradicated. Weed control methods and substances shall be selected based on avoidance of impacts on water quality and aquatic fauna.
• The temporary lowering of the lake will allow more direct access to the lake edges by ARGO (mud buggy) from which the remaining plants can be more readily targeted and either manually removed or spot-sprayed with approved herbicides.</td></tr>
<tr><td>Monitoring</td><td>Lake Macdonald
<u>Before drawdown</u>
Baseline monitoring of the lake (and lake margins) to establish a baseline understanding of the species and distribution of restricted aquatic or semi-aquatic plants.
<u>During drawdown and construction:</u>
• Spot checks of weed hygiene certifications and inspection and wash down records.
• Weekly monitoring of the lake (and lake margins) for outbreaks of not previously established restricted aquatic or semi-aquatic plants (noting that new growth of Cabomba will not be prevented in the lake to provide food for aquatic species).
Six Mile Creek Downstream
<u>During drawdown and construction:</u>
• Record visual observations of aquatic and semi-aquatic weed species as part of aquatic habitat monitoring.
<u>Post-construction:</u>
• Record visual observations of aquatic and semi-aquatic weed species as part of aquatic habitat monitoring.
Relocation Sites
• Record visual observations of aquatic and semi-aquatic weed species as part of relocation site monitoring.</td></tr>
<tr><td>Reporting</td><td>• Personnel to notify the Seqwater Project Manager of weed outbreaks or potential contamination immediately.
• Monthly report via email to Seqwater that includes details of monitoring and audits.
• Quarterly report provided to regulatory agencies summarising compliance and monitoring results.</td></tr>
<tr><td>Responsibility</td><td>Contractors – Site Supervisor or representative
Seqwater – Project Manager or representative</td></tr>
</table>

ENVIRONMENTAL OBJECTIVE – WEED MANAGEMENT: Restricted invasive plants not present in Lake Macdonald are not introduced. Restricted invasive plants already present in Lake Macdonald are not spread to new areas.	
Corrective action	• If an outbreak of a restricted weed is observed in Lake Macdonald, Six Mile Creek or a relocation site: – where practical and safe, treat weed(s) to control outbreak using appropriate methods (e.g. herbicide approved for use in waterways, physical removal) – increase monitoring of weed hygiene measures, if relevant – review mitigation and adapt the management measures, as appropriate.

8. Incident and Contingency Planning

This section describes proposed measures to manage unforeseen events and incidents that may occur during the drawdown process and construction period. The described management measures are indicative only, and will be adapted in response to an event, and in response to changing conditions and expert advice.

8.1 Drawdown of Lake Macdonald

During the drawdown phase, gradual releases will aim to lower the water level for aquatic fauna salvage and for minimising potential for downstream habitat changes. Nevertheless, there are likely to be rainfall events in the drawdown phase that disrupt the drawdown schedule. Where the drawdown release rate is exceeded by catchment inflows, the drawdown release will be temporarily increased to reinstate the drawdown schedule.

Monitoring for downstream geomorphic and habitat impacts shall be undertaken as per the drawdown phase frequency outlined in Appendix F. Where increased release rate is required, the frequency of downstream aquatic habitat monitoring will increase for that period.

If issues are detected during monitoring, the release rate will be slowed or stopped to enable appropriate management measures, to be implemented. The management measures will be similar to those described in this plan but adapted as needed in response to the conditions at the time.

8.2 Aquatic Fauna Salvage and Relocation

8.2.1 High Fauna Abundance

During the baseline evaluation survey and during the fish salvage operation, multiple biomass assessments will be undertaken so the biomass of fauna in the lake can be validated. This will allow informed choices regarding fish management during the project.

Should the abundance of fauna in Lake Macdonald be higher than expected, to the extent that the active salvage teams are unable to safely capture and relocate adequate numbers of aquatic fauna, then additional salvage teams will be mobilised to assist in the salvage and relocation effort. The contingency relocation sites discussed in sections 5.5.5 and 8.2.3 may also need to be used to accommodate any additional fauna.

Additionally, salvage will prioritise fauna species as follows:

- 1st Priority – MNES and MSES species (i.e. Mary River cod, Australian lungfish (if required, as stipulated in Section 5.5.2), Mary River turtle, white-throated snapping turtle)
- 2nd Priority – other large-bodied native fish species.

Where fauna abundance is higher than anticipated, holding facilities will be prioritised for MNES and MSES species. Additional common fauna will be returned to the lake for later management, either in the lake or during later salvage phases.

8.2.2 Unable to Achieve Salvage Targets

The 2025 evaluation survey found that 81.6% of large-bodied fish captured were bony bream which are unsuitable for relocation (see section 5.5.4.2). Additionally, 8.5% of large-bodied fish captured were banded grunter which are also unsuitable for relocation as they’re not native to SEQLD. Therefore potentially 90% of large bodied fish captured will be unsuitable for relocation. If salvage efforts result in significantly lower catch rates then more realistic targets may need to be adopted in consultation with DPI and the fish biologist.

If after 2 weeks of salvage effort catch rates are <25% of the targets specified in Section 5.5.4 then the salvage program will be modified to substitute salvage and relocation for additional monitoring of WQ and aquatic fauna health. The monitoring program will be expanded from what’s described in Table 3-1 to include WQ sampling profiling the various depth ranges at each sampling location. This will give the fish biologist a clearer picture of lake health.

8.2.3 Relocation Sites

As described in section 5.5.5, a suite of suitable relocation sites has been identified, which includes contingency sites that will be utilised if the conditions at primary relocation sites change or more fauna than anticipated are caught during salvage activities.

8.2.4 Fauna Injury or Death

All salvage will be implemented in accordance with DPI’s Fish Salvage Guidelines to protect the welfare of fish during capture, transport and release. Seqwater will liaise with wildlife parks, carers and veterinarians in the region before the lake drawdown begins in order to develop:

- Awareness of the Project and the potential need for care and treatment of injured fauna
- A network that can provide support if required.

In the event that an aquatic animal is injured during the salvage operation:

- If the species is a Mary River cod or Australian lungfish, it will be transported as quickly as possible in an appropriately sized receptacle with aerated water for assessment by a qualified wildlife carer as nominated in the Construction Contractor's Flora and Fauna Management Plan
- If it is any other native fish species (e.g. yellow belly or Australian bass), then it will be:
  - placed in holding tank of suitable size with aerated water to allow for recovery and subsequent relocation
- If at the end of the day recovery has not been achieved, the fish will be humanely euthanised using methods approved under an ethics permit. If the species is a turtle, it will be transported as quickly as possible to a qualified wildlife carer
- If the species is a platypus, it will be transported as quickly as possible to a qualified wildlife carer, as nominated in the Construction Contractor's Flora and Fauna Management Plan.

8.2.5 Giant Barred Frog

While giant barred frogs are expected to adapt to the lower lake level or relocate of their own accord in response to changing water levels. They may be encountered during fauna salvage activities, and construction. Where the frogs are unable to voluntarily relocate, they will be relocated to Six Mile Creek downstream of the dam at locations with suitable habitat that are not affected by construction or drawdown releases.

All handling and relocation of frogs will be done in accordance with the following protocols, as per the *Survey Guidelines for Australia’s Threatened Frogs* (DCCEEW, 2010), *Hygiene protocols for the control of diseases in Australian frogs* (Murray et al 2011), and Queensland *Technical Manual, Wildlife Management, Interim Hygiene Protocol for Handling Amphibians* (DEHP, 2016):

- Minimise handling as much as possible – have a transport bag/container ready to put the frog in before catching it
- Wear non-powdered vinyl or nitrile gloves whenever handling frogs

- Use soft cloth bags or a suitable container to hold frogs for transport, with only one frog per bag / container, and only use the bag / container once
- Release the frog as soon as possible and hold for no more than one hour.

The release of frogs to sites downstream of the lake is not expected to facilitate the spread of Chytrid fungus, as the fungus will be present downstream if it is present in the lake.

8.2.6 Platypus

It is not planned to relocate platypus during the Project. However, if maintaining suitable habitat conditions becomes difficult/impractical or a platypus is in distress, relocation will be necessary. If circumstances require the care and/or relocation of platypus, the following steps are proposed:

- A qualified wildlife carer will be contacted to assess the platypus condition and take it into care
- If the platypus is considered to be in healthy condition, and suitable habitat is present in the vicinity of where it was found, it will be returned to the habitat in this location by a suitably qualified person (i.e. carer or aquatic ecologist) and monitored using camera traps for two weeks.
- If the platypus is considered to be in healthy condition, and no suitable habitat is present in the vicinity of where it was caught, the platypus will be relocated to an appropriate location further upstream or downstream on Six Mile Creek. It will be relocated by a suitably qualified person and monitored using camera traps for two weeks.

If a platypus is relocated to a holding facility (as opposed to a waterway site) due to unavailability of suitable release locations, it will be returned to Lake Macdonald once conditions in the lake are suitable and monitored using camera traps.

8.2.7 Traffic Assessment

A traffic assessment should be undertaken prior to each day (or individual transfer) of fish capture and relocation activity. This will assist in determining the best routes to the relocation sites to avoid delays to fish relocation. Ongoing team communication during each day will allow the capture and transport of fish to be streamlined and avoid any transport delays.

8.2.8 Unforeseen Situations During Salvage and Relocation

In the event that unforeseen situations arise during salvage and relocation operations, the following contingencies will be implemented:

- In an emergency, the temporary storage tubs set up at the salvage and relocation holding area can be used to store fish.
- The relocation operation will be undertaken by two transport teams using two transport trailers, with a third spare trailer available if delays occur for any reason.
- Two oxygen bottles will be available in each trailer in the event one runs out. A back up air blower will be also available.
- A communication plan will be in place, along with a fish relocation coordinator at the lake to manage risks of traffic delays etc.
- Welfare checks on fish will be made at set points along the route in the event aeration system fails. Oxygen testing and recording will be included in routine transfers.

8.3 Aquatic Habitat and Fauna in Lake Macdonald

While Lake Macdonald is lowered it is possible, but unlikely given the modest drawdown magnitude proposed, for the remaining aquatic habitat to become unsuitable for fauna. If monitoring indicates aquatic fauna are in distress or dying, the following actions will be taken:

- Review of water quality monitoring results. If monitoring indicates that water quality in the lake is not meeting the objectives identified in section 3.1.1, the following actions will be taken:

- Low dissolved oxygen – assess and implement additional aeration measures, including effective and proven aeration devices or methods.
- Low pH – dose with appropriate agent, with consideration of potential impacts to fauna
- High turbidity – investigate and manage potential erosion sources, institute additional or alternative erosion controls.

- Construction phase salvage if reduced water volume targets are exceeded, to reduce potential crowding and pressure on resources.

8.4 Aquatic Habitat and Fauna in Six Mile Creek

Where monitoring indicates a potential impact to aquatic habitat in Six Mile Creek downstream of the dam (i.e. performance criteria are not met), the following actions will be taken:

- Drawdown releases will be reduced or paused
- Targeted monitoring of habitat and/or fauna will be undertaken to identify the cause and extent of the impact, with the monitoring design to be determined on a case by case basis, but consistent with the routine monitoring described in this plan
- Review of management measures and additional or alternative measures implemented to prevent further impact.

If a reduction in flow release rates, or pauses in releases, are not effective the following alternative mitigation options will be investigated and implemented where appropriate:

- Appropriate habitat improvements after lowering (based on impacts identified during monitoring and the affected fauna), through Seqwater's existing relationship with MRCCC and Noosa and District Landcare
- Restocking of Mary River cod after lowering
- Physical protection of aquatic habitat (e.g. increase in energy dissipation measures).

8.5 Protected Matters (Flora and Fauna) not Previously Identified

Where flora and fauna species classified as protected matters (MNES and MSES) that were not previously identified in the IAR are encountered in the project area or downstream, the following actions will be taken:

- Drawdown releases will be reduced or paused.
- Works in the area where the species was found will cease.
- Seqwater and the relevant regulatory agencies will be notified.
- A targeted survey of the species and its habitat will be undertaken in the project area and Six Mile Creek downstream. The survey design will be determined on a case by case basis but be consistent with relevant threatened species survey guidelines and the routine monitoring described in this plan (where applicable).
- Management measures will be reviewed and, if required, additional or alternative measures implemented within the AMP to prevent impact. These will have regard to the recovery and threat abatement plan for the species identified, where available. The revised AMP will then be reviewed by an independent expert and submitted for approval by DCCEEW as per Condition 27 of the EPBC approval, prior to the reissue and re-commencement of works.

9. Remediation of Lake Macdonald

Based on Seqwater water balance modelling for Lake Macdonald Dam (GoldSim simulation over a period of 1890-2011), mean annual inflow and direct rainfall for Lake Macdonald is 33,732 ML/y. The full supply volume of Lake Macdonald on completion of the Project will remain unchanged compared with the existing dam, at 8,018 ML. Under typical rainfall conditions Lake Macdonald is expected to return to its full supply level within approximately one year of the completion of the Project.

9.1 Aquatic Habitat

Where the monitoring described in section 6.3 and Appendix F indicates that aquatic habitat in Lake Macdonald has been negatively impacted, or project activities have disturbed the bed or banks of Lake Macdonald, habitat remediation measures will be implemented. The remediation measures will be contingent on the identified impact, but may include revegetation and stabilisation of banks, replacement of substrate materials, and the reestablishment of any habitat removed for works (e.g. woody debris and snags).

The lowering of Lake Macdonald may also provide an opportunity to improve aquatic habitat in the lake for some fauna (e.g. native fish in general, MNES species, turtles). Seqwater will investigate these opportunities in the lead up to and during construction. Seqwater plans to implement opportunistic programs to manage pest species in Lake MacDonald. The dam upgrade project team will coordinate with operational staff to make the most of opportunities arising from the temporary lowering of the lake to allow for ongoing pest management activities during the construction period. Depending on the target species (to be identified during the investigation), fish habitat structures could be created through the strategic placement of:

- Broken concrete slabs from existing dam spillway structure
- Leftover concrete from pours during construction, which may be redirected into moulds designed to produce fish habitat structures
- Root balls and hollow logs from vegetation cleared for the Project
- Objects resembling hollow logs such as concrete culverts.

The project will set aside Coarse Woody Debris (large rootballs / hollow logs etc) in a separate stockpile to be inspected by the project fish ecologist who will identify and mark-up pieces suitable for aquatic ecology enhancement projects. The project will endeavour to install as many of these as possible throughout the lake during rehabilitation or offer them to local environmental groups like MRCCC for beneficial reuse.

A targeted instream woody habitat (IWH) survey will be conducted prior to any introduction of structures to ensure that the most effective use of resources is achieved in Lake Macdonald and in any other locations. The following information will be recorded to describe the implemented structures for any future monitoring or research purposes:

- Location (latitude and longitude)
- date of installation
- area of timber in square meters
- complexity and description of IWH.

In addition, the opportunity to facilitate the growth of native aquatic plant species and increase competitive pressure on Cabomba through the seeding and planting of native plants will also be investigated and considered.

Where the monitoring described in section 6.3 and Appendix F indicates that aquatic habitat in Six Mile Creek downstream has been affected or removed by flows associated with the lake lowering, the habitat will be rehabilitated at the completion of the lake lowering. Remediation will include the reestablishment of snags, large woody debris and aquatic vegetation, and replacement of banks and substrate materials, as required.

Habitat Remediation will be the responsibility of the Contractor, reporting to Seqwater. The Contractor is to produce a Rehabilitation Management Plan that covers remediation works required in Lake Macdonald as well as any impacted areas of downstream Six Mile Creek. The plan needs to be submitted to DCCEEW for approval prior to implementation.

9.2 Aquatic Fauna

Quarterly fish and turtle monitoring data collected during the construction phase will be compared to baseline data, including species, abundance and condition (length weight relationships). Where review of this data at the completion of the construction phase indicates habitat augmentation or stocking should be considered as management options, then further investigation will be undertaken at that time.

Seqwater will collaborate with local stakeholders, including MRCCC and the Freshwater Fishing and Stocking Association of Queensland (FFSAQ), to identify the most effective approach for restoring the lake to its pre-construction condition.

9.3 Water Quality

The water quality data logging meters will be kept in place after completion of construction until the lake has refilled to at least 80% FSL. Where turbidity is found to be higher than baseline condition, then visual surveys for erosion hotspots and sources of turbid runoff will be implemented in the inflow areas and upper margins of the dam and stabilised using appropriate sediment and erosion control.

9.4 Removal of Project Infrastructure

At the completion of the Project, equipment and facilities associated with construction, including erosion and sediment controls, will be demobilised and removed from the Project site. Areas of ground disturbance will be seeded with suitable grasses or re-vegetated with locally sourced plants.

10. Risk Assessment

A risk based approach to the management of Lake Macdonald and Six Mile Creek downstream of the dam during the project has been undertaken. A risk workshop for the lake lowering was held on 29 August 2018 and attended by a range of stakeholders including Seqwater, MRCCC, Aquatic Biopassage (Andrew Berghuis) and frc environmental. Following the workshop, a preliminary version of this lowering plan was developed and reviewed as part of the IAR process. A subsequent risk workshop for the lake lowering to RL93m AHD was held on 14 December 2023 and attended by a range of stakeholders including Seqwater, Fishology (Kris Pitman), Virid IFC (Craig Thamm), John Holland.

Issues considered in the workshop held on 14 December 2023 included:

- The cofferdam and construction process
- Timing of and approach to lake drawdown
- Impacts to water quality
- Erosion and sediment control
- Impacts to flora and fauna
- Potential management measures
- Fauna salvage and relocation
- Maintenance and remediation.

A qualitative risk assessment was subsequently completed for the plan in accordance with the risk framework described in the DCCEEW Environmental Management Plan Guidelines (2014). This risk assessment is provided in Table 10-3. The risk framework is provided in

Table 10-1, with the likelihood and consequence categories defined in

Table 10-2.

Table 10-1: Risk framework

		CONSEQUENCE				
		Minor	Moderate	High	Major	Critical
LIKELIHOOD	Highly Likely	Medium	High	High	Severe	Severe
	Likely	Low	Medium	High	High	Severe
	Possible	Low	Medium	Medium	High	Severe
	Unlikely	Low	Low	Medium	High	High
	Rare	Low	Low	Low	Medium	High

Table 10-2: Likelihood and consequence

QUALITATIVE MEASURE OF LIKELIHOOD (how likely is it that this event/circumstances will occur after management actions have been put in place/are being implemented)	
Rare	May occur in exceptional circumstances
Unlikely	Could occur period of EPBC approval but considered unlikely or doubtful
Possible	Might occur during the period of EPBC approval
Likely	Will probably occur during the period of EPBC approval
Highly likely	Is expected to occur
QUALITATIVE MEASURE OF CONSEQUENCES (what will be the consequence/result if the issue does occur)	
Minor	Minor risk of failure to achieve the plan's objectives. Results in short term delays to achieving plan objectives, implementing low cost, well characterised corrective actions.
Moderate	Moderate risk of failure to achieve the plan's objectives. Results in short term delays to achieving plan objectives, implementing well characterised, high cost/effort corrective actions.
High	High risk of failure to achieve the plan's objectives. Results in medium-long term delays to achieving plan objectives, implementing uncertain, high cost/effort corrective actions.
Major	The plan's objectives are unlikely to be achieved, with significant legislative, technical, ecological and/or administrative barriers to attainment that have no evidenced mitigation strategies.
Critical	The plan's objectives are unable to be achieved, with no evidenced mitigation strategies.

Table 10-3: Risk assessment and management

Environmental Attribute	Management Objective	Main Potential Impact Pathways	Management Measures	Residual risk			Monitoring and Corrective Actions
				Likelihood	Consequence	Risk	
Water Quality	Minimise impact of lake lowering on water quality in Lake Macdonald and Six Mile Creek	Poor water quality results from low inflows and evaporation of the lake.	As per Table 3-1, which includes the existing bubble plume destratification unit being maintained and run continuously for the life of the project, providing aeration of the water in Lake Macdonald. If the trigger values for relevant parameters are identified and it appears that the destratification unit is not working or there are insufficient inflows, additional measures to restore water quality will be investigated. This will include additional proven aeration devices or methods.	**Unlikely**	**Moderate**	**Low**	Table 3-1
		Increasing turbidity and total suspended solids via disturbance of bed sediments and / or the erosion of bed and banks.	As per Table 3-1, which includes standard controls such as arranging dewatering intakes to extract from within the top half of water column and so that suction does not disturb sediments on the bed of Lake Macdonald, and implementing sediment and erosion control.	**Possible**	**Moderate**	**Medium**	Table 3-1
		Reducing pH by exposing or disturbing acid sulphate soils	As per Table 3-1, which includes standard controls such as arranging dewatering intakes to extract from within the top half of water column and so that suction does not disturb sediments on the bed of Lake Macdonald. As stated in Section 8.3, if low pH is identified dosing will be undertaken with an appropriate agent, with consideration of potential impacts to fauna.	**Unlikely**	**Moderate**	**Low**	Table 3-1
		Eutrophication of Lake Macdonald following the drawdown resulting in an increased occurrence of agal blooms, specifically Blue-green algae.	As per Table 3-1 the existing bubble plume destratification unit will be maintained and run continuously for the life of the project, providing aeration of the water in Lake Macdonald. Implement risk-based assessment of any exceedances of water quality trigger values to determine the potential for environmental harm, and if so, then implement additional mitigations (e.g. implement additional proven aeration devices or methods in Lake Macdonald if the concentration of dissolved oxygen becomes of concern).	**Possible**	**Moderate**	**Medium**	Table 3-1
		Reduced water quality and/or drought conditions leading to reduced inflows resulting in stratification of the lake.	As per Table 3-1, the existing bubble plume destratification unit will be maintained and will run continuously for the life of the project, providing aeration of the water in Lake Macdonald. If the trigger values for relevant parameters are identified and it appears that the destratification unit is not working or there are insufficient inflows, additional measures to restore water quality will be investigated immediately. This will include additional proven aeration devices or methods. If before additional measures can be implemented it is identified that fish are showing signs of serious distress indicating they cannot remain within the lake then incidental fauna salvage as per section 5.5.4.1 is to be undertaken.	**Unlikely**	**Moderate**	**Low**	Table 3-1
		Reducing dissolved oxygen and pH through decomposition of organic matter (e.g. algae and aquatic plants) during and following drawdown.	As per Table 3-1, which includes standard controls such as arranging dewatering intakes to extract from within the top half of water column and so that suction does not disturb sediments on the bed of Lake Macdonald. Additionally, the existing bubble plume destratification unit will be maintained and will run continuously for the life of the project, providing aeration of the water in Lake Macdonald. If the trigger values for relevant parameters are identified and it appears that the destratification unit is not working or there are insufficient inflows, additional measures to restore water quality will be investigated. This will include additional proven aeration devices or methods. As stated in Section 8.3, if low pH is identified dosing will be undertaken with an appropriate agent, with consideration of potential impacts to fauna.	**Possible**	**Moderate**	**Medium**	Table 3-1
		Contaminating water through spills of fuels, oils or other chemicals from pumping equipment or other machinery / vehicles.	As per Table 3-1, which includes standard controls such as the use of biodegradable oils/lubricants, refuelling to be preferentially undertaken on land, appropriate spill kits to be in place, storage of hydrocarbons and chemicals in bunded areas, and compliance with the construction erosion and sediment control plan.	**Unlikely**	**Moderate**	**Low**	Table 3-1
		Contaminating water within the stilling basin (e.g. contamination from construction dust and other contaminants).	As per Table 3-1, which includes standard controls such as the use of biodegradable oils/lubricants, refuelling to be preferentially undertaken on land, appropriate spill kits to be in place, storage of hydrocarbons and chemicals in bunded areas, and compliance with the construction erosion and sediment control plan.	**Unlikely**	**Minor**	**Low**	Table 3-1
		Release of poor-quality water from the stilling basin to the downstream Six Mile Creek.	As per Table 3-1, regular monitoring of water quality in the stilling basin, and regular dewatering and treatment of poor-quality water from the stilling basin, will effectively mitigate this risk. Additionally, aeration of water and mitigation of erosion through energy dissipation as water is discharged downstream is to be provided, such as through armoured discharge points or sprays.	**Possible**	**Minor**	**Low**	Table 3-1

Environmental Attribute	Management Objective	Main Potential Impact Pathways	Management Measures	Residual risk			Monitoring and Corrective Actions
				Likelihood	Consequence	Risk	
Geomorphology	Minimise impact of lake lowering by preventing soil loss and erosion	Erosion of exposed bed sediments in upper lake areas.	As per Table 4-1, primarily engaging a suitably qualified person to undertake ongoing monitoring and implementation of the Erosion and Sediment Control Plan approved by a Certified Profession in Erosion & Sediment Control (CPESC). Additionally, if it does not interfere with works or cause a hazard, allow Cabomba and other exposed aquatic plants to decompose in situ as the dying plants will cover sediment that would otherwise be exposed.	**Unlikely**	**Minor**	**Low**	Table 4-1
		Bed and bank erosion of Six Mile Creek downstream.	As per Table 4-1, engaging a suitably qualified person to undertake ongoing monitoring and implementation of the Erosion and Sediment Control Plan approved by a CPESC, release rates complying with mitigations measures outlined in Table 4-1 (under Six Mile Creek Downstream – During drawdown and construction), as well as discharge drawdown releases in a manner that dissipates energy and prevents scour at the discharge point. For example, discharge onto the concrete apron on the downstream side of the Lake Macdonald spillway, use diffusers or spray nozzles, and / or energy dissipation methods such as riprap to slow water flow.	**Unlikely**	**Minor**	**Low**	Table 4-1
		Increase in chance of construction rubble and gravel being washed downstream during demolition of spillway and embankment structures.	As per Table 4-1, primarily engaging a suitably qualified person to undertake ongoing monitoring and implementation of the Erosion and Sediment Control Plan approved by a CPESC.	**Rare**	**Moderate**	**Low**	Table 4-1
Flora and Fauna	Minimise the impact of lake drawdown on aquatic flora and fauna in Lake Macdonald	Stranding of fauna in isolated pools in upper dam areas and overcrowding of fauna in the reduced lake.	Undertake an evaluation survey, with a focus on the upper reaches, to assess species presence and abundance (refer to Table 5-2 and section 5.5.3). Control the drawdown release rate as outlined in section 2 of this plan to allow fauna to move away from potential isolated pools to minimise the need for intervention. Do not complete drawdown of lake in less than 4 weeks. Implement contingency planning for incidental fauna salvage, where required (see section 8).	**Rare**	**Minor**	**Low**	Table 5-2
		During the period between completing the drawdown and demolition of the spillway, catchment inflows may refill the lake above RL 93 m AHD. This may result in re-flooding of areas which were subject to the aquatic fauna salvage operation conducted prior to the drawdown, creating new isolated pools which pose a risk to stranding of fauna.	Following the drawdown and during the construction of the new spillway and embankments, water levels will be maintained at a temporary FSL of RL 93.0 m AHD (42% of normal FSV) by a cofferdam. Undertake an evaluation survey, with a focus on the upper reaches, to assess species presence and abundance (refer to Table 5-2 and section 5.5.3). Implement contingency planning for incidental fauna salvage, where required (see section 8).	**Rare**	**Minor**	**Low**	Table 5-2
		Stranding of fauna in stilling basin, and exposure to potentially poor-quality water.	As per Table 5-2, diligence in monitoring fauna in the stilling basin and implementing a fauna salvage program to prevent overcrowding in the stilling basin on an as needed basis. As per Table 3-1, regular monitoring of water quality in the stilling basin, and regular dewatering and treatment of poor-quality water from the stilling basin. Additionally, aeration of water and mitigation of erosion through energy dissipation as water is discharged downstream is to be provided, such as through armoured discharge points or sprays.	**Likely**	**Minor**	**Low**	Table 5-2
		The stilling basin will need to be lowered or fully dewatered from time to time meaning aquatic fauna within the stilling basin will be impacted.	As per Table 5-2, daily visual monitoring of fauna in the stilling basin to assess potential for fauna stress and salvage aquatic biota from the stilling basin on an as needed basis (e.g. prior to all waterbody dewatering events, and when poor water quality is detected).	**Likely**	**Minor**	**Low**	Table 5-2
		Risk of injury or mortality to fauna due to machine strike / crush injuries if fauna move into the construction areas.	As per Table 5-2, primarily having a fauna salvage program to remove fauna from the construction area, and diligence in monitoring and salvaging fauna on an as needed basis from the construction area. The presence of turtles basking in the construction areas will be monitored and if deemed to present an issue specialist advice will be sought on how to best manage their exclusion.	**Unlikely**	**Moderate**	**Low**	Table 5-2
		Injury and mortality of turtles in construction workspaces, and on the spillway of the existing dam which may be utilised by turtles for basking.	As per Section 5.3.1, the low-flow slot section of the coffer design (with limited freeboard) will have continuous visual monitoring and any turtle interactions (i.e. basking/passage) can be addressed by the site environmental officer to remove or relocate fauna. If significant turtle interactions are noted to be occurring with the low-flow slot section of the cofferdam or the spillway then an investigation of potential solutions may be undertaken as a corrective action (i.e. exclusion engineering solution). Therefore, while turtles may access the spillway section cut to 89.5 m AHD, the majority of the water will be maintained by the cofferdam allowing observation of interactions with the turtle at the low-flow slot section of the cofferdam as a proxy for specific management of turtles at the existing spillway. As such, the current risk is considered low due to the restriction of access to a small section of the cofferdam and limited evidence of current use of the spillway for basking or passage.	**Unlikely**	**Moderate**	**Low**	Table 5-2

Environmental Attribute	Management Objective	Main Potential Impact Pathways	Management Measures	Residual risk			Monitoring and Corrective Actions
				Likelihood	Consequence	Risk	
		Risk of lake lowering impacting fauna breeding activities in downstream environments.	Control the drawdown release rate as outlined in Section 2 of this plan. Do not complete drawdown of lake in less than 4 weeks. Avoid changes to hydrology during the breeding seasons for MNES and MSES species known to be in Six Mile Creek downstream of the dam by conducting drawdown between March and October of any year (refer to Section 2.2).	Unlikely	Moderate	Low	Table 5-2
		Possible injury to downstream moving fish and turtles during a spill event due to barotrauma or strike with hard surfaces.	• In accordance with State code 18: Constructing or raising waterway barrier works in fish habitats, the temporary coffer dam will be designed, constructed and maintained to avoid and minimise impacts on matters of national and state environmental significance. The drownout characteristics of the waterway barrier works will be designed in consultation with a suitably qualified person (fish biologist) and constructed to not result in adverse impacts to fish passage. • To reduce harm to downstream moving fish and turtles the syphon system will be used to reduce the extent of overtopping flow events during construction. This will divert flows around construction site and reduce rates of spilling. • During any drawdown activity in construction phase use intake exclusion screens of suitable design (9mm x 9mm aperture) to prevent fish and turtles from being entrained into syphon system. • To reduce harm to any downstream moving fish and turtles during spilling events, the cofferdam has been designed to reduce risks to both fish and turtles. The design includes maintaining a 30% tailwater depth to spillway height, use of non-abrasive surfaces, eliminating potential impact points and a spillway design with no freefall sections.	Likely	Moderate	Medium	State code 18: Constructing or raising waterway barrier works in fish habitats and Table 5-2
		Entrainment, entrapment, injury and mortality of aquatic fauna in the screens and siphons during the dam lowering and bypassing of any inflows.	• During any drawdown activity in construction phase use intake exclusion screens of suitable design (9mm x 9mm aperture) to prevent fish and turtles from being entrained into syphon system. The mesh aperture and type that will be used is the same as the aperture and type previously proposed, assessed by DPI, accepted, and implemented for a siphon arrangement on another Seqwater project (Ewen Maddock). Performance for this project indicated there were no issues with fish/fauna entanglement or weed blockages. The mesh specified is diamond mesh aquaculture netting that is soft and has no knots (knotless nylon netting) which minimises harm to aquatic fauna. • Daily visual inspection of intake screens – ensure screens are functional, water approach velocity is at or below the limit noted as a mitigation, and no aquatic fauna are trapped against the screens. • Divers will perform an inspection and clean of the intake exclusion device. Initially this will be performed monthly. If weed build up and fauna entanglement is found to be negligible / insignificant then this activity will be scaled back in consultation with the project aquatic ecology expert.	Likely	Moderate	Medium	Table 5-2
Fauna Salvage and Relocation	Minimise the stranding and crowding of aquatic fauna in Lake Macdonald due to lake drawdown	Salvage and handling of fauna from lake results in injury or mortality to MNES species.	Undertake fauna salvage in accordance with the methodology in section 5.5.	Unlikely	Moderate	Low	Section 5.5
		Transport and handling of fauna results in injury or mortality.	Undertake fauna salvage in accordance with the methodology in section 5.5.	Unlikely	Moderate	Low	Section 5.5

Environmental Attribute	Management Objective	Main Potential Impact Pathways	Management Measures	Residual risk			Monitoring and Corrective Actions
				Likelihood	Consequence	Risk	
		Relocation sites are not suitable, leading to illness or mortality of relocated fauna or fauna already present at relocation sites.	As discussed in section 5.5.6, all sites will be revisited prior to any fauna being relocated and if new sites are required this will be discussed with DPI prior to relocation of fauna. Fishology are planning to undertake relocation site surveys as soon as the lake drawdown date has been confirmed. As per the freshwater ecology report (Freshwater Ecology, 2020) it was recommended that visual assessment will be undertaken immediately prior to commencement of any potential relocation activities. This will include an assessment of the streamflow conditions at the time and how this would influence the potential aquatic fauna carrying capacity (e.g. flow, water quality, submerged macrophytes and connectivity). As discussed in section 5.5, weekly visual monitoring of sites where fauna have been relocated during the relocation program (e.g. observations of mortality) and measurement of in situ water quality (focusing on dissolved oxygen) will be undertaken. Monitoring will also be undertaken on a monthly basis at all relocation sites for 12 months after week four (4) of the lake drawdown schedule, to assess the long-term success of the salvage and relocation operation. This will involve visual monitoring of sites where fauna have been relocated during the relocation program (e.g. observations of mortality) and measurement of in situ water quality (focusing on dissolved oxygen). Before relocation, all MNES fish species salvaged from Lake Macdonald will be tagged with Passive Integrated Transponder (PIT) tags and surveys will subsequently be undertaken at all sites where MNES species were released. These surveys will occur every six months from the completion of the drawdown salvage phase until the completion of dam construction. The surveys will use the same methods used in the relocation site assessment (Appendix H), and any MNES species caught will be scanned with a hand-held PIT tag reader to estimate the proportion of relocated MNES fauna recaptured as an indication of potential survivorship. Results will be compared to mark-recapture data for both species from the Mary River collected by DR, which will serve as a reference for recapture rates.	**Unlikely**	**Moderate**	**Low**	Section 5.5
		Fauna salvage efforts are unable to achieve the specified targets	Undertake additional WQ and aquatic fauna health monitoring. WQ monitoring described in Table 3-1 will be expanded to include sampling various profile depths at each monitoring site.	**Likely**	**Moderate**	**Medium**	Section 8.2.2
Aquatic Habitat	Minimise impact of drawdown on aquatic habitat in Lake Macdonald and Six Mile Creek downstream of the dam	Physical disturbance to downstream aquatic habitat.	As per Table 6-1, including: • Implement management measures for water quality (Table 3-1), erosion and sediment control (Table 4-1), and aquatic fauna (Table 5-2). • Control the drawdown release rate as outlined in section 2 of this plan. • Do not clear vegetation outside of the clearing extent defined in the IAR or other relevant approvals. • Do not complete drawdown of lake in less than 4 weeks. • Ensure releases do not exceed bankfull height of Six Mile Creek. • Avoid changes to hydrology during the breeding seasons for MNES and MSES species known to be in Six Mile Creek downstream of the dam, with drawdown not being permitted between 1 September and 28 February of any year (per section 2.2). • Do not clear vegetation or excavate banks until a suitably qualified person has checked the area for threatened fauna and breeding habitat (e.g. burrows). If any are identified, implement a 3 m x 3 m exclusion zone with flagging tape until approval to impact the area has been granted by the suitably qualified person. • Re-establish or supplement aquatic habitat (as per section 9.1), where monitoring indicates this is required.	**Unlikely**	**Moderate**	**Low**	Table 6-1
		Changes in flow conditions that lead to decline in habitat condition through scouring, disturbance of physical habitat (e.g. woody debris, leaf packs, aquatic plants) and altered flow habitat (e.g. riffle to pool).	As per Table 6-1, including: • Control the drawdown release rate as outlined in section 2 of this plan. • Avoid changes to hydrology during the breeding seasons for MNES and MSES species known to be in Six Mile Creek downstream of the dam, with drawdown not being permitted between 1 September and 28 February of any year (per section 2.2).	**Unlikely**	**Moderate**	**Low**	Table 6-1

Environmental Attribute	Management Objective	Main Potential Impact Pathways	Management Measures	Residual risk			Monitoring and Corrective Actions
				Likelihood	Consequence	Risk	
		Disturbance of banks and riparian vegetation during construction.	As per Table 6-1, including: • Implement management measures for erosion and sediment control (Table 4-1). • Do not clear vegetation outside of the clearing extent defined in the IAR. • Do not disturb bed or banks (e.g. clear vegetation or excavate) until a suitably qualified person has checked the area for threatened fauna and breeding habitat. If any are identified, implement a 3 m x 3 m exclusion zone with flagging tape until approval to impact the area has been granted by the suitably qualified person. • After construction is completed, and where disturbance or visual assessment indicates this is required, re-establish or supplement aquatic habitat (as per section 9) if it is safe to do so.	Unlikely	Moderate	Low	Table 6-1
		Temporary decrease in available habitat for aquatic flora and fauna during construction.	As per Table 6-1, including: • Implement management measures for water quality (Table 3-1), erosion and sediment control (Table 4-1), and aquatic fauna (Table 5-2). • Do not clear vegetation outside of the clearing extent defined in the IAR. • Do not disturb bed or banks (e.g. clear vegetation or excavate) until a suitably qualified person has checked the area for threatened fauna and breeding habitat. If any are identified, implement a 3 m x 3 m exclusion zone with flagging tape until approval to impact the area has been granted by the suitably qualified person. • After construction is completed, and where disturbance or visual assessment indicates this is required, re-establish or supplement aquatic habitat (as per section 9) if it is safe to do so.	Unlikely	Moderate	Low	Table 6-1
		Loss of riparian and in-stream vegetation due to potential changes in livestock access.	As per Table 5-2, Seqwater will work with individual landholders to ensure stock movements are prevented from moving outside their existing properties.	Unlikely	Minor	Low	Table 5-2
Biosecurity	Restricted invasive plants already present in Lake Macdonald are not spread to new areas Restricted invasive plants not present in Lake Macdonald are not introduced	The spread or introduction of aquatic weeds on vehicles, machinery and personnel.	As per Table 7-1 and Table 7-2, primarily having weed hyenine protocols, and designing the cofferdam with fish biologist input to ensure tilapia cannot pass upstream under drownout conditions.	Possible	Moderate	Medium	Table 7-1 and Table 7-2
	Distribution of pests does not increase due to the Project and existing populations of pest fauna do not increase	The upstream spread of tilapia at the edges of the coffer dam during spilling events.	Risk of tilapia migrating upstream has been reduced due to physical barrier of cofferdam.	Unlikely	Moderate	Low	Table 7-1
	Distribution of aquatic diseases and pathogens does not increase due to the project	Spread of aquatic diseases and pathogens to Lake Macdonald, Six Mile Creek, and/or fauna relocation sites.	As per Table 7-1: • Do not use water from Six Mile Creek downstream of the dam for construction purposes, if the purpose presents a credible risk of transferring biosecurity matters (tilapia) into Lake Macdonald. • Assess fauna condition and do not relocate individuals with impaired condition or visible parasites, lesions or fungi. With the exception of MNES species, fauna with impaired condition should be returned to the lake or euthanised. MNES species should be placed in a suitable receptacle and transported to a suitably qualified wildlife carer. • Wash down fauna relocation vehicles and equipment in accordance with weed washdown protocols before returning to the Project area to remove any attached sediment or mud. • Clean and disinfect footwear, or change footwear, used for fauna relocation in accordance with the Hygiene protocols for the control of diseases in Australian frogs (Murray et al, 2011).	Unlikely	Moderate	Low	Table 7-1

11. Key Roles and Responsibilities

The persons responsible for implementing and reviewing this plan are identified in Table 11-1.

Table 11-1: Key roles and responsibilities

Role	Responsibilities
Contractor – Senior Project Manager	• Management of lake lowering • Implementation of plan • Internal compliance audits • Compliance reporting • Site and habitat remediation • Ensuring design and operational elements are sourced (e.g. from experts in the field) and incorporated into the works to minimise the likelihood of injury and mortality of aquatic fauna
Contractor – Environmental Representative	Implementation of management measures and monitoring
Contractor – Suitably Qualified Persons	• Water quality monitoring • Flora and fauna salvage and relocation program • Flora and fauna surveys • Aquatic habitat monitoring • Technical review of plan
Seqwater – Project Manager	• Direction of erosion and sediment control measures • Direction of biosecurity management • Internal compliance audits
Seqwater – Planning and Approvals Advisor	Periodic review of plan
Seqwater – Rangers	Visual monitoring of lake for stranded fauna during routine duties
Independent Auditor	External compliance audits
Independent Expert Reviewer	Review of Plan

12. Data Handling and Storage

All monitoring data, quality control documents (e.g. laboratory reports) and site photographs are to be stored electronically, and with appropriate documentation to outline the data captured, storage location, type and any other relevant information.

All monitoring data are to be stored in a suitable database, spreadsheet(s), or software, which is to be kept up to date, secure and backed up. Integrity of monitoring data is to be ensured through suitable quality control processes, and access control as required.

13. Compliance Reporting and Audits

A report on residual significant impacts will be prepared within six months of the completion of the monitoring described in section 5.4. The report will include a Significant Impact Assessment (in accordance with the Significant Impact Guidelines 1.1) to determine if there are any residual significant impacts to MNES as a result of the lake drawdown, construction, and salvage and relocation operations.

The report will be prepared by suitably qualified and experienced persons, reviewed by an independent expert (refer to definitions provided in EPBC approval – EPBC 2017/8078), and made publicly available within nine months of the completion of monitoring. It will have regard to approved conservation advices, recovery plans and threat abatement plans and include an assessment of the effectiveness and success of the:

- Adaptive Management Plan and of the lake drawdown and construction to avoid, mitigate and manage impacts to protected matter(s)
- Aquatic Fauna Salvage and Relocation Management Plan, and salvage and relocation activities to avoid, mitigate and manage impacts to protected matter(s).

Compliance and non-compliance reporting and independent audits for the lake lowering will be undertaken in accordance with the Construction Environmental Management Plan. Reporting requirements for the EPBC Approval are identified in Table 13-1 and an audit schedule is provided in Table 13-2.

Reporting requirements for the different aspects managed under this plan are provided in the relevant management sections (1, 3.3, 5.4, 6.3, and 7.3 Table 6-1, Table 7-1, and Table 7-2).

Seqwater will notify DCCEEW of any Mary River turtle and white-throated snapping turtle caught and relocated within three days.

Table 13-1: EPBC reporting requirements

Report type	Content	Schedule	Person responsible	Recipient
Notification of commencement	Notification of commencement of action in accordance with Condition 14 of Part B.	Within 10 business days after the date of commencement of the action.	Seqwater Project Manager	DCCEEW
Compliance records	Electronic copies of compliance records in accordance with Conditions 16 and 17 of Part B.	As requested	Seqwater Project Manager	DCCEEW
Compliance reporting	Evidence of compliance with plan and monitoring data in accordance with Condition 20 of Part B.	Annually	Seqwater Project Manager and Contractor	DCCEEW
Non-compliance / incident reporting	Information on any incident, non-compliance with the conditions, or non-compliance with the commitments in this plan in accordance with Conditions 21 and 22 of Part B.	Notification – within 2 business days Detailed – within 10 business days	Seqwater Project Manager and Contractor	DCCEEW

Report type	Content	Schedule	Person responsible	Recipient
Audit report	Outcomes of independent compliance audits in accordance with Conditions 23, 24 and 25 of Part B.	Annually	Seqwater Project Manager and Contractor	DCCEEW
Plan revision	Details of any changes to this plan in accordance with Conditions 26 to 31 of Part B.	20 days before the implementation of the revised plan	Seqwater Project Manager and Contractor	DCCEEW
Completion notification	Notification of completion of the action in accordance with Condition 32 of Part B.	Within 30 business days of completion of the action.	Seqwater Project Manager	DCCEEW
Significant residual impact report	Significant Impact Assessment in accordance with Conditions 11 to 13 of Part A	Within nine months of the monitoring required under Conditions 5 and 9 of Part A.	Seqwater Project Manager, or representatives	DCCEEW

Table 13-2: Audit Schedule

Audit	Trigger / Subject	Frequency	Person responsible	REPORTING
Independent audit	Routine – compliance with plan in accordance with Conditions 23 to 25 of Part B.	Annually	Independent auditor	Compliance report to Seqwater and Contractor
Internal audit	Routine or in response to non-compliance – compliance with mitigation and monitoring measures.	Monthly or when triggered by a non-compliance	Contractor Site Supervisor, or representative	Compliance report to Seqwater

14. Permits and Qualifications

14.1 Permits and Approvals

The necessary permits and approvals required for the lake lowering and fauna relocation include:

- Remediation Permit (Spotter Catcher) in conjunction with a Species Management Program (SMP)
- SMP – required to tamper with the breeding place of a protected animal under the *Nature Conservation Act 1992*
- General Fisheries Permit
- Animal Ethics Permit is needed only for monitoring but not salvage.

14.2 Qualifications

The qualifications required of individuals managing and undertaking monitoring and the fauna salvage and relocation may include:

- Training, skills, and/or experience surveying and/or handling aquatic fauna
- A remediation permit issued under the *Nature Conservation Act 1992*.

15. References

ANZECC & ARMCANZ, 2000, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, National Water Quality Management Strategy, Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

ANZG 2018. Australian and New Zealand guidelines for fresh and marine water quality. Governments of Australia and New Zealand.

DAF 2018. Guidelines for fish salvage. Department of Agriculture and Fisheries. https://www.daf.qld.gov.au/business-priorities/fisheries/habitats/policies-guidelines/factsheets/guidelines-for-fish-salvage Accessed February 2020.

DEHP 2016. Technical Manual, Wildlife Management, Interim Hygiene Protocol for Handling Amphibians. Queensland Department of Environment and Heritage Protection.

DERM 2010. Environmental Protection (Water) Policy 2009, Mary River Environmental Values and Water Quality Objectives Basin No. 138, including all tributaries of the Mary River. Queensland Department of Environment and Resource Management, Brisbane.

DES 2018. Monitoring and Sampling Manual, Environmental Protection (Water) Policy 2009. Queensland Department of Environment and Science, Brisbane.

DES 2022. Deciding aquatic ecosystem indicators and local water quality guideline values, Environmental Protection Policy (Water and Wetland Biodiversity) 2019. Queensland Department of Environment and Science, Brisbane.

DNR 2007. Water Monitoring Data Collection Standards, Version 2.1. Queensland Department of Natural Resources, Brisbane.

DPI 2004. Fish Salvage Guidelines. Queensland Department of Primary Industries and Fisheries, Brisbane.

DCCEEW 2010. Survey guidelines for Australia's threatened frogs Guidelines for detecting frogs listed as threatened under the *Environment Protection and Biodiversity Conservation Act 1999*. Department of the Environment, Water, Heritage, and the Arts.

DSEWPC 2011. Survey Guidelines for Australia's Threatened Reptiles: guidelines for detecting reptiles listed as threatened under the EPBC Act 1999. Department of Sustainability, Environment, Water, Populations and Communities, Canberra.

DSEWPaC, 2013. Chytridiomycosis (Amphibian chytrid fungus disease) – Fact Sheet. Department of Sustainability, Environment, Water, Populations and Communities, Canberra.

Dunlop, J., McGregor, G. and Horrigan, N. 2005. Potential Impacts of Salinity and Turbidity in Riverine Ecosystems: characterisation of impacts and a discussion of regional target setting for riverine ecosystems in Queensland. Queensland Department of Natural Resources and Mines, Brisbane.

Dunlop, A. 2016. Ecology of Larval Freshwater Fish in the Mary River System, South-eastern Queensland, with a focus on the nationally threatened Mary River cod (*Maccullochella mariensis*). Honours Thesis, Griffith University.

Eyre TJ, Ferguson DJ, Hourigan CL, Smith GC, Mathieson MT, Kelly, AL, Venz MF, Hogan, LD & Rowland, J. 2018. Terrestrial Vertebrate Fauna Survey Assessment Guidelines for Queensland. Department of Environment and Science, Queensland Government, Brisbane.

Freshwater Ecology (2020). Lake Macdonald Aquatic Fauna Relocation Sites Preliminary Assessment.

Murray KA, Skerratt LF, Marantelli G, Berger L, Hunter D, Mahony M and Hines H (2011b). Hygiene protocols for the control of diseases in Australian frogs. A report for the Australian Government Department of Sustainability, Environment, Water, Population and Communities. Available from: http://www.environment.gov.au/biodiversity/invasive-species/publications/hygiene-protocols-control-diseases-australian-frogs.

Simpson R. & Jackson P. (2000) The Mary River Cod Research and Recovery Plan. Environment Australia: Canberra.

SMEC (2023). Terrestrial Field Survey Report.

SMEC (2024. LMDIP site specific water quality objectives 2024 (LMDIP-05762-RES-ENV-REP-00001).

16. Glossary, Acronyms and Abbreviations

Abbreviations

Term	Definition
AHD	Australian Height Datum
AMP	Lake Macdonald Water Lowering – Adaptive Management Plan (this document)
ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
COD	Chemical oxygen demand
CPUE	Catch per Unit Effort
DAF	Department of Agriculture and Fisheries
DCCEEW	Department of Climate Change, Energy, the Environment and Water (formally Department of Sustainability, Environment, Water, Populations and Communities)
DC	Direct Current
DES	Department of Environment and Science
DETSI	Department of Environment, Tourism, Science and Innovation (formally Department of Environment and Science)
DNRM	Department of Natural Resources and Mines
DR	Department of Resources (formally Department of Natural Resources and Mines)
DPI DSEWPC	Department of Primary Industries (formerly DAF) Department of Sustainability, Environment, Water, Populations and Communities
EC	Electrical Conductivity
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
EPP (Water)	*Environmental Protection (Water and Wetland Biodiversity) Policy 20109*
EVs	Environmental values
FSL	Full supply level
FSV	Full supply volume
GPP	Generator Powered Pulsator
HMP	Habitat Monitoring Program
IAR	Impact Assessment Report
MNES	Matters of National Environmental Significance
MRCCA	Mary River Catchment Coordination Association
MRCCC	Mary River Catchment Coordinating Committee
MSES	Matters of State Environmental Significance
NCA	*Nature Conservation Act 1992*

Term	Definition
SMP	Species Management Program
WQO	Water Quality Objectives
WTP	Water Treatment Plant

Glossary of Terms

Term	Definition
Abundance	Number of individuals per species.
Action	Any specified activity associated with the action including clearing, lake drawdown, construction and salvage and relocation.
Acid sulfate soils	Naturally occurring soils that contain iron sulphides.
Bankfull height	The water level at which a stream, river or lake is at the top of its banks, and any further increase in water level would result in water flowing into the flood plain.
Bathymetry	The study and mapping of a waterbody floor.
Baseline surveys	Surveys undertaken before the drawdown.
Benthic	An ecological region at the lowest level of a body of water, including the sediment surface and some sub-surface layers.
Destratification unit	Mechanism to prevent the lake from stratifying.
Baffle	A device (plate, wall or screen) to deflect, check, or regulate flow or passage.
Biomass	Amount of living matter in a given habitat.
Bypass arrangement	A pumping, siphoning or drainage arrangement that allows for bypassing of the low flow channel through the construction site.
Carapace	A bony or chitinous shield or shell covering some or all of the dorsal part of an animal.
Catchment	The area of land, which collects and transfers rainwater into a waterway.
Catch Per Unit Effort	The total catch divided by the total amount of effort used to harvest the catch.
Clearing	The cutting down, felling, thinning, logging, removing, killing, destroying, poisoning, ringbarking, uprooting or burning of vegetation (but not including weeds – see the Australian weeds strategy 2017 to 2027 for further guidance).
Cofferdam	A watertight structure, usually made of sheet piling, which encloses an area usually under water, so that it can be pumped dry to facilitate construction.
Common species	Species that are listed under the EPBC Act and/or the NCA as 'least concern.'
Compliance reports	Means written reports: providing accurate and complete details of compliance, incidents, and non-compliance with these approval conditions and commitments in the plans details of contingency measures or corrective actions that have been or will be implemented; consistent with the Department's Annual Compliance Report Guidelines (2014). include a shapefile of any clearance of any protected matter(s), or their habitat, undertaken within the relevant 12-month period; and annexing a schedule of all plans prepared and in existence in relation to the conditions during the relevant 12 month period.
Conservation advice	Conservation advice means a conservation advice approved by the Minister under the EPBC Act.
Controlled action	An action (including a project, development, undertaking, activity, or series of activities) that is likely to have a significant impact on a Matter of National Environmental Significance.

Term	Definition
Construction	The erection of a building or structure that is or is to be fixed to the ground and wholly or partially fabricated on-site; the alteration, maintenance, repair or demolition of any building or structure; preliminary site preparation work which involves breaking of the ground (including pile driving); the laying of pipes and other prefabricated materials in the ground, and any associated excavation work; but excluding the installation of temporary fences and signage.
Defined waterway	A defined waterway has one or more of the following attributes (Fisheries Act 1994): Defined bed and banks An extended, if non-permanent, period of flow Flow adequacy Fish habitat at, or upstream of the site
Department	The Australian Government agency responsible for administering the EPBC Act.
Discharged water	Water that is transported through a cross-sectional area. This includes any suspended solids, dissolved chemicals or biologic material in addition to the water itself.
Dissolved oxygen (DO)	The amount of oxygen dissolved in water.
Diversity	The variety of a particular factor.
Downstream	Means within Six Mile Creek and within 10 km down gradient of the project area.
Environment	The total of all the external conditions that act upon an organism.
Environmental flow	Freshwater flow that is maintained solely for environmental reasons, e.g. flows to act as an environmental cue, to deliver nutrients and sediment downstream etc.
Environmental Management Plan	Environmental Management Plans describe how an action might impact on the natural environment in which it occurs and sets out clear commitments from the person taking the action on how those impacts will be avoided, minimised and managed.
Erosion	The process by which rocks are loosened, worn away and removed from parts of the Earth’s surface. Seven processes of erosion discussed separately; in practice they overlap and it is often difficult to isolate the net effects of any one process. Rain splash erosion: the detachment and removal of soil and debris by raindrop impact. Overland flow OR surface runoff: water flowing over the surface before being concentrated into definite streams. Sheet erosion, sheet wash, or slope wash: the combined effect of overland flow and rain splash. Gully erosion: the rapid development of gullies, usually in first- or second-order tributaries of streams, BUT also in situations unrelated to an integrated drainage system (e.g. highly dispersive soils) Mass Movement: downhill movement of debris en masse rather than as individual particles. It can occur slowly (creep), or rapidly (rock falls, slumps, landslides). Surface rock creep: the movement of stones down sloping surfaces. Fluvial erosion: the detachment and removal by streams of material in solution, suspension, or as bed load. Includes removal of debris supplied to the streams by slope wash, mass movement, and gullies.
Euthanise	The act or practise of causing or permitting the death of hopelessly sick or injured individuals in a relatively painless way and in accordance with animal ethics permits and guidelines.
Eutrophication	The process in which a body of water becomes enriched in dissolved nutrients that stimulate the growth of aquatic plant life, usually resulting in the depletion of dissolved oxygen.
Evaporation	The process that changes a liquid or a solid into a gas. In the tropical hydrological cycle, this involves the conversion to water vapor and the return to the atmosphere of the precipitation (rainfall) that has reached the earth’s surface.

Term	Definition
Fauna	The collective animals of a given region.
Flora	The collective plants growing in a geographic area.
Flow regime	The variation in flow characteristics, such as volume, for a particular stream over time.
Fluvial	The river system.
Full supply level (FSL)	The maximum normal operating water surface level of a reservoir (Lake Macdonald is 95.3 AHD).
Full supply volume (FSV)	The volume of the lake at full supply.
Geomorphic processes	The formation and deformation of landforms on the surface of the earth,
Habitat	The biophysical medium or media occupied (continuously, periodically or occasionally) by an organism or group of organisms.
Hydrology	The study of the movement, distribution and management of water.
Incident	Any event which has the potential to, or does, impact on one or more protected matter(s).
Incidental catch	A catch that was not originally targeted but was caught and retained regardless.
Incidental salvage	Fauna salvage undertaken in response to flow and/or stranding event.
Independent audit	Audit conducted by an independent and suitably qualified person as detailed in the Environment Protection and Biodiversity Conservation Act 1999 Independent Audit and Audit Report Guidelines (2019).
Independent expert	A person that: does not have, an individual or by employment or family affiliation, any conflicting or competing interests with the approval holder; the approval holder's staff, representatives or associated persons; or the project, including any personal, financial, business or employment relationship, other than receiving payment for undertaking the role for which the condition requires an independent expert. has professional qualifications relevant to the protected matter(s) is a recognised expert, supported by relevant peer reviewed publications, regarding the protected matter(s) has at least 7 years of experience designing and undertaking surveys relevant to the protected matter(s).
Inflows	Water moving into Lake Macdonald due to inclement weather.
Inundation area	The area that will be flooded with water above the existing water level, from raising of the dam.
Lake drawdown	Intentional draining of water from within Lake Macdonald to facilitate construction.
Lake drawdown equipment	Lake drawdown equipment means equipment required to undertake the lake drawdown, including (but not limited to) pumping equipment.
Lake Macdonald	Means the area designated as 'Lake Macdonald' coloured in dark blue on the map at Figure 1–1.
Listed species	A plant or animal included in a schedule of endangered, vulnerable, or near threatened biota, such as the schedules in the Environment Protection and Biodiversity Conservation Act 1999 (Cth) or the Nature Conservation (Wildlife) Regulation 2006 (Qld).
Low flow channel	The low flow channel is the section of channel within the waterway that holds water during periods of low flow.
Macroinvertebrate	Organisms without a backbone which are large enough to be seen with the naked eye.
Macrophyte	An aquatic plant that is large enough to be seen with the naked eye.

Term	Definition
Matter of national environmental significance (MNES)	The matters of national environmental significance include: listed threatened species and communities listed migratory species Ramsar wetlands of international importance the Commonwealth marine environment World heritage properties National heritage places Nuclear actions
Mesohabitat	Medium sized habitat
NATA accredited laboratory	A laboratory in which independent authorities have assured the technical competence through a network of best practise industry experts.
Native species	A species that is indigenous to Australia or an external Territory, or periodically or occasionally visits.
Overtop	Where inflows will flow over the temporary cofferdam.
Performance criteria	The measurable standard set to which an activity is to perform.
pH	Measure of the acidity or alkalinity of a substance, with 1 being the most acidic, 7 being neutral and 14 being the most alkaline.
Population	Occurrence of a species or ecological community in a particular area.
Project area	The proposed construction and ancillary works area necessary to safely undertake the demolition and construction of the dam and embankments.
Protected matters	A matter protected under a controlling provision in Part 3 of the EPBC Act for which this approval has effect, including: Mary River Cod Australian Lungfish Mary River Turtle White-throated Snapping Turtle Giant Barred Frog.
Published	Means made publicly available on the approval holders website.
Recovery plans	Recovery Plans set out the research and management actions necessary to stop the decline of, and support the recovery of, listed threatened species or threatened ecological communities.
Regulatory agencies	Independent governmental body established by legislative act in order to set standards in a particular field of activity or operations.
Remediation	Making the land useful again after a disturbance. It may involve the recovery of ecosystem functions and processes in a degraded habitat.
Release rates	The rate at which the water in Lake Macdonald is released.
Relocation sites	A site used to relocate any protected matter(s) during salvage and relocation activities.
Reservoir	A natural or artificial place where water is collected and stored for use.
Riffle	A shallow landform in a flowing channel.
Riparian	Pertaining to, or situated on the bank of, a body of water, especially a watercourse such as a river.
Risk	Future uncertainty about deviation from an expected outcome.
Risk controls	Measures to minimise the risk.
Risk treatments	Measures taken if risk is realised.

Term	Definition
Risk workshop	A workshop designed to identify risks and give stakeholders a better understanding of what the risks are and how they can affect the Project.
Run	An area in a stream that is characterised by moderately straight channels and medium water flow.
Salvage and relocation	Means capturing any protected matter(s) from one area of habitat and transferring it to another area of habitat.
Sediment	A naturally occurring material that is broken down by processes of weathering and erosion and is subsequently transported by the action of wind, water or gravity.
Six Mile Creek	Means the watercourse designated as 'Six Mile Creek' as shown in Figure 1–1.
Six Mile Creek Dam	Dam on Six Mile Creek that forms Lake Macdonald.
Species	A group of biological entities that (a) interbreed to produce fertile offspring; or (b) possess common characteristics derived from a common gene pool.
Spotter/catcher	An ecologist who is accredited by the Queensland Parks and Wildlife Service (QPWS) to capture and relocate fauna (mainly mammals) from trees prior to vegetation clearance.
Stratification	When water masses with different properties – salinity, oxygenation, density and temperature – to form layers that act as barriers to water mixing.
Suitably qualified person(s)/Suitably qualified and experienced person(s)	Means a person who has professional qualifications, training, skills and experience related to the nominated subject matter and can give authoritative independent assessment, advice and analysis on performance relative to the subject matter using the relevant protocols, standards, methods and/or literature.
Suspended solids	Small solid particles which remain in suspension in water as a colloid.
Tailwater	Waters located immediately downstream from a hydraulic structure.
Telemetry	The in-situ collection of measurements or other data at remote points and their automatic transmission to receiving equipment for monitoring.
The Department	The Department of Climate Change, Energy, the Environment and Water
the Minister	Australian Government Minister administering the EPBC Act including any delegate thereof
The Project	The Lake Macdonald (Six Mile Creek) Dam upgrade, including all phases of the project (pre-construction, construction and operational) and temporary and permanent works
Threat abatements plans	Threat abatement plans provide for the research, management, and any other actions necessary to reduce the impact of a listed key threatening process on native species and ecological communities.
Threatened species	Species listed under the EPBC Act and/or the NCA.
Translocation	The act, process or instance of changing location or position
Tributary	A stream that flows into a larger stream or other body of water.
Turbidity	The clarity of a waterbody; depends on the concentration of particles that are suspended in the water column.
Velocity	The speed at which water is moving.
Zooplankton	The aggregate of animal or animal like organisms in plankton.

Appendix A

Declaration of Accuracy

Appendix A Declaration of Accuracy

DECLARATION OF ACCURACY

I declare that:

To the best of my knowledge, all the information contained in, or accompanying the Lake Macdonald Water Lowering – Adaptive Management Plan, Rev 12, 18 February 2025 is complete, current and correct.

I am duly authorised to sign this declaration on behalf of the approval holder.

I am aware that:

Section 490 of the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act) makes it an offence for an approval holder to provide information in response to an approval condition where the person is reckless as to whether the information is false or misleading.

Section 491 of the EPBC Act makes it an offence for a person to provide information or documents to specified persons who are known by the person to be performing a duty or carrying out a function under the EPBC Act or the Environment Protection and Biodiversity Conservation Regulations 2000 (Cth) where the person knows the information or document is false or misleading.

The above offences are punishable on conviction by imprisonment, a fine or both.

Signed

Full name (please print)

Nathan Carruthers

Organisation (please print)

SEQWATER

Date: 2/05/2025

Appendix B

Background Information – Water Quality

Appendix B Background Information – Water Quality

Environmental Values and Water Quality Objectives

The Queensland Department of Environment, Tourism, Science and Innovation (DETSI) has published a report relevant to the Project alignment listing relevant environmental values (EVs) and WQOs, as:

- *Environmental Protection (Water and Wetland Biodiversity) Policy 2019* Mary River environmental values and water quality objectives Basin No. 138, including all tributaries of the Mary River (Department of Environment and Resource Management, 2010).

The EPP (Water) supports the achievement of the objectives of the *Environmental Protection Act 1994* (EPA 1994) in relation to Queensland waters. This document relevant to the catchment areas of the Mary River form part of the EPP (Water) subordinate to the EPA 1994. The WQOs most relevant to the Project are those within the EPP (Water and Wetland) relating to moderately disturbed and high-ecological value waters (as identified by the current condition within Schedule 1 of EPP (Water) surface water ecosystems).

Default *Australian and New Zealand Guidelines for Fresh and Marine Water Quality Guidelines 2018* (ANZG) for pesticides, heavy metals and other toxic contaminants are used where the regional EPP (Water) guidelines are less applicable. Within the WQOs relevant to the Project, thresholds for the protection of aquatic ecosystems were selected for assessment of current environmental conditions.

Water bodies within the project area are in the following:

- Mary River catchment – Lake Macdonald (freshwater lakes/reservoirs)
- Mary River catchment - Six Mile Creek (moderately disturbed - lowland streams)

All waterbodies associated with this Flora and Fauna (Dewatering) Management Plan are considered moderately disturbed. All sample points, depending on the waterbody in which they are located, have been assigned to one of the above categories to derive WQOs.

Water Quality

Table 16-1 provides the initial median values of the collected datasets prior to normalisation, compared against the relevant default regional EPP (Water) or ANZG WQOs for each parameter. Data was used from a variety of routine and non-routine surface water quality sampling sites located upstream, within and downstream of Lake Macdonald. Data was collected across a five (5) year timeframe from 2019-2024. The water quality data was collected from the following sites:

Lake Macdonald:

- Seqwater active sampling:
  - Lake Macdonald Dam Wall Offtake
  - Lake Macdonald Mid-Lake at Confluence
- Seqwater passive sampling:
  - Lake Macdonald (Inflow passive)
- Virid IFC sample point:
  - Lake Macdonald (I1 and I3).

Six Mile Creek:

- Seqwater active sampling:
  - Lake Macdonald Tailwater below Dam Wall
- Seqwater passive sampling:
  - Six Mile Creek (Tailwater passive)

- Virid IFC sample point:
    - Six Mile Creek (DS01 and DS02).

Site locations and further details are discussed in the *LMDIP site specific water quality objectives 2024* report (*LMDIP-05762-RES-ENV-REP-00001*) (SMEC, 2024).

Critical analysis of median values for each parameter indicates regional WQOs for nutrient parameters are typically not achieved within Lake Macdonald; with nitrate and total and oxidised nitrogen values exceeding default WQOs. Both Lake Macdonald and Six Mile Creek did not achieve regional WQOs for dissolved oxygen. All other median values for each parameter were within Regional WQO range across Lake Macdonald and Six Mile Creek.

Previous long-term monitoring and assessment of Seqwater water quality data (from 2011-2017) also indicated that:

- dissolved aluminium was commonly higher than the National Water Quality Guideline (ANZECC & ARMCANZ 2000) for the 95% protection level of aquatic ecosystems in Lake Macdonald
- total aluminium, zinc and cobalt were sometimes higher than the National Water Quality Guideline in Lake Macdonald, and
- total aluminium, chromium, copper, mercury, zinc, and dissolved aluminium were higher than the National Water Quality Guideline in the Lake Macdonald tailwater.

The *Water Monitoring Data Collection Standards* (DNR 2007) defines a reservoir as stratified if the temperature difference between surface and basement layers exceeds 5ºC. Depth profile measurements of water temperature through the depth profile in Lake Macdonald (mid-lake) were summarised on a monthly basis between November 2011 and November 2017 (i.e. 70 months), with measurements for 69 of these months indicating no stratification. Stratification was detected in only one month (January 2015). Overall, these results indicate that Lake Macdonald rarely stratifies, and when it does it is only weakly stratified. Seqwater operates a 24hr aeration system located close to the WTP intake which ensures more stable conditions within the lake and is likely playing a role in minimising stratification events.

Table 16-1: Summary statistics for Lake Macdonald and Six Mile Creek

Water quality parameter	Unit	Water quality objective for Aquatic Ecosystems	Median (50th percentile) value
Lake Macdonald (2019 – 2024)			
pH	log {H+}	6.5 – 8.0	6.51
Turbidity	NTU	1 – 20	8
Dissolved Oxygen	%	90 - 110	49 (4.32mg/L)
Total suspended solids	mg/L	-	3
Total nitrogen	mg/L	<0.35	0.52
Nitrate	mg/L	2.4[a]	0.01
N_{ox}	mg/L	<0.01	0.04
Ammonia	mg/L	<0.010	0.016
Total phosphorus	mg/L	<0.03	0.03
Six Mile Creek (2019 - 2024)			
pH	log {H+}	6.50 – 8	6.61
Turbidity	NTU	<50 NTU	2.57
Dissolved Oxygen	%	90 -110	75.49 (6.4 mg/L)

[a] Trigger values for freshwater (based on 95% level of protection for surveillance nitrate concentrations

Site Specific water quality objective values

Data normalisation was adopted to further reduce skew between values collected from each site. Interquartile ranges identified non-normal distributions and exceedances within each data set. A 1.5 sensitivity scale was used to detect extreme outliers to follow Gaussian distribution. The method dictates that any data point that's 1.5 basis points below the lower bound quartile or above the upper bound quartile is an outlier. Outliers were removed from the dataset after identification if a deviation existed from 1.5 interquartile range limits, grouped by site.

Trigger values in water quality management refer to specific thresholds that indicate whether the water quality is acceptable or requires further investigation and potential action. These values help in assessing the health of aquatic ecosystems and the safety of water for human consumption, recreational use, and ecological health.

<u>Low Trigger Values</u>

- Definition: Low trigger values represent acceptable minimum thresholds below which water quality may be compromised. These values help ensure that the ecosystem remains healthy and that water quality meets regulatory standards.

<u>High Trigger Values</u>

- Definition: High trigger values are thresholds that, when exceeded, indicate a potential problem with water quality. They signal that the water may be unsafe or unsatisfactory for its intended use, necessitating immediate action or further monitoring.

<u>Importance of Trigger Values</u>

Trigger values are crucial for:

- Water Quality Monitoring: They guide regular assessments and help identify trends in water quality over time.
- Regulatory Compliance: They ensure that water bodies meet legal standards set by environmental agencies.
- Conservation Efforts: They inform management decisions aimed at protecting aquatic ecosystems and public health.

Overall, effectively using high and low trigger values in water quality assessments helps in the proactive management of water resources, safeguarding both human health and ecological integrity. Seqwater aims to avoid both low and high trigger values as these would indicate a potential issue with water quality management measures.

Triggers were then calculated the normalised data for each trigger (excluding dissolved oxygen) as below:

• Low trigger – based on either > 20th or < 80th percentile (depending on the parameter)

• High trigger - based on either the maximum or minimum recorded values (depending on the parameter).

Due to specific management of dissolved oxygen concentrations within waters (i.e. prevention of hypoxic conditions and adherence to key ranges of dissolved oxygen concentrations), the 20th and 80th percentile were used to calculate the high and low triggers, respectively.

All reference sample point sites within the Mary River basin are classified as moderately disturbed waters. For moderately disturbed waters the 20th and 80th percentiles of reference site values are used to derive site-specific objectives. Whilst ANZG 2018 Guidelines recommends 24 data points, in accordance with the QWQG 2009, for the 20th and 80th percentile values, error values diminish at an estimated 15-20 data values. As a result, the majority of data values within this range were considered sufficient to merit inclusion and acceptable to provide a statistically sound estimate of the true percentile values. Refer to the *LMDIP site specific water quality objectives 2024* report (*LMDIP-05762-RES-ENV-REP-00001*) (SMEC, 2024) for more information regarding requirements for deriving site-specific objectives and methodologies of data normalisation.

Implementation of low risk and high risk triggers were calculated from data obtained from routine and passive monitoring conducted by Seqwater and a monitoring campaign conducted by Virid IFC. Data was collated for sites from various periods across 2019 to 2024. This data was normalised prior to broad data summaries and calculation of triggers.

- The low risk triggers are presented in Table 16-2
- The high risk triggers are presented in Table 16-3.

These triggers will be used as a performance criterion for the management of the impact of lowering on water quality within Lake Macdonald and within Six Mile Creek. These results are to be read in conjunction with the *LMDIP site specific water quality objectives 2024* report (*LMDIP-05762-RES-ENV-REP-00001*) (SMEC, 2024).

The implementation of the below water quality objectives is to be considered as an assessment of management measures rather than a compliance tool. Management is based around mitigating significant impact to ecological receptors within Lake Macdonald and within Six Mile Creek and will inform ongoing management rather than as a compliance reporting tool. As such, the trigger values identified here are not intended as assessment triggers (for compliance) but rather indicators of adequacy of implemented management measures at time of sampling. Should trigger values be identified during water quality testing associated with this adaptive management plan the following measures will be undertaken:

- Low risk trigger – Implementation of an active watch scenario where increased water quality sampling is undertaken alongside identification of effectiveness of current mitigation measure controls (as per the Lake Macdonald (Six Mile Creek) Dam Improvement Project adaptive management plan)
- High risk trigger – Implementation of intervention control (i.e. fish salvage exercises, increased aeration, management of erosion and sediment control devices (Lake Macdonald (Six Mile Creek) Dam Improvement Project adaptive management plan).

Where the current median (50th percentile) exceeds the low risk trigger value but remains below the high risk trigger value, monitoring and management will continue under existing processes. In this case, low risk trigger management measures will not apply to parameters where the median already exceeds the low risk trigger value. This approach acknowledges that if a parameter's median was already above the low risk trigger before the drawdown, the system is naturally operating under those conditions. Trigger values will be reassessed as more data becomes available. If a parameter’s median does not meet the existing regional water quality objectives for aquatic ecosystems, the relevant trigger thresholds will be applied.

Low-risk trigger values

The low-risk trigger values are presented in Table 16-2.

Table 16-2 Low-risk trigger values

Water Quality Parameter	Unit	WQO for Aquatic ecosystem EV	Low risk trigger value[a]	
			Min trigger value	Max trigger value
Lake Macdonald (freshwater lakes/reservoirs)				
pH	log {H+}	6.50 – 8.00	6.41	6.64
Turbidity	NTU	1 – 20	-	9.75
Dissolved Oxygen[b]	%	90 – 110%	>74.1 (6.1 mg/L)	-
Total suspended solids	mg/L	-	-	5
Total nitrogen	mg/L	<0.35	-	0.59
Nitrate[c]	mg/L	2.4000	-	0.0142
Nox	mg/L	<0.0100	-	0.0116
Ammonia	mg/L	<0.0100	-	0.0528
Total phosphorus	mg/L	<0.030	-	0.034
Six Mile Creek (lowland freshwater)				
pH	log {H+}	6.50 – 8.00	6.25	6.65
Turbidity	NTU	<50 NTU	-	4.13
Dissolved Oxygen[b]	%	90-110	>98.02 (8.07 mg/L)	-

a Where a range is presented for a specific parameter, low risk trigger is outside of range identified.

b Dissolved Oxygen concentrations triggers require concentration to remain above identified percentile.

c Nitrate's calculated trigger value acts as an interim, low-risk, site specific WQO.

High-risk trigger values

The high-risk trigger values are provided in Table 16-3.

Table 16-3 High-risk trigger values

Water Quality Parameter	Unit	WQO for Aquatic ecosystem EV	High risk trigger value[a]	
			Normalised minimum recorded values	Normalised maximum recorded values
Lake Macdonald (freshwater lakes/reservoirs)				
pH	log {H+}	6.50 – 8.00	5.73	7.30
Turbidity	NTU	1 – 20	-	42.6
Dissolved Oxygen[b]	%	90 - 110	31.80 (2.62 mg/L)	-
Total suspended solids	mg/L	-	-	9
Total nitrogen	mg/L	<0.35	-	0.78
Nitrate	mg/L	2.40	-	0.02[c]
N_{ox}	mg/L	<0.01	-	0.04
Ammonia	mg/L	<0.01	-	0.11
Total phosphorus	mg/L	<0.030	-	0.048
Six Mile Creek (lowland freshwater)				
pH	log {H+}	6.50 – 8.00	5.70	7.13
Turbidity	NTU	<50 NTU	-	6.69
Dissolved Oxygen[1]	%	90-110	56.96 (4.69 mg/L)	-

a Where a range is presented for a specific parameter, high risk trigger is outside of range identified.

b Dissolved Oxygen concentrations triggers require concentration to remain above identified percentile.

c Nitrate’s calculated trigger value acts as an interim, low-risk, site specific WQO.

Appendix C

Background Information – Aquatic Flora and Fauna

Appendix C Background Information – Aquatic Flora and Fauna

Aquatic Plants

The aquatic plant community of Lake Macdonald is characterised by a dense cover of the 'restricted biosecurity matter' Cabomba (*Cabomba carolina*), scattered occurrence of the native water snowflake (*Nymphoides indica*), and isolated occurrences of other native aquatic plants, such as Javan pondweed (*Potamogeton javanicus*), water primrose (*Ludwigia peploides*), spike rush (*Eleocharis* sp.), and bull rush (*Typha* sp.). There are few aquatic plants in Six Mile Creek downstream of Lake Macdonald, although there are isolated occurrences of Cabomba and water snowflake. A range of native aquatic plants grow on the banks of Lake Macdonald and Six Mile Creek, including sedges (*Carex* spp. and *Cyperus* spp.), knot weeds (*Persicaria* spp.) and mat rushes (*Lomandra* sp.). The 'restricted biosecurity matter' *Hygrophila* (*Hygrophila cosata*) occurs in high cover along the margins of the lake.

Relatively high concentrations of chlorophyll a, and blue-green algae cell counts, for water samples taken from Lake Macdonald indicate an abundant phytoplankton community.

No threatened species of aquatic plant is known from the Project area. Several aquatic plants known from the Project area are biosecurity matters, including notable infestations of *Cabomba* and *Hygrophila.*

Aquatic Macroinvertebrates

A range of aquatic macroinvertebrates are known from Lake Macdonald and Six Mile Creek, including crustaceans (e.g. river prawns, glass shrimp and crayfish), insects (e.g. aquatic beetles, various aquatic bugs, mayflies, caddisflies and true flies), molluscs (e.g. snails and mussels) and worms.

While the *abundance* of macroinvertebrates is variable but relatively high overall, the overall *diversity* of macroinvertebrates is lower than the biological WQO for macroinvertebrates presented in the EPP(Water) (DERM 2010). The diversity of sensitive taxa, and the abundance of sensitive taxa, also tended to be lower than the biological WQO presented in the EPP(Water) (DERM 2010).

No threatened species of aquatic macroinvertebrate is known from the Project area, and none of the macroinvertebrate species known from the Project area are biosecurity matters.

Fish

The native fish community of the Project area comprises approximately 26 species that are known or likely to occur in Six Mile Creek. The community was numerically dominated by small bodied species, such as Agassiz's glassfish (*Ambassis agassizii*), unspecked hardyhead (*Craterocephalus fulvus*), common gudgeons (*Hypseleotris* spp.), purple spotted gudgeon (*Mogurnda adspersa*), flat head gudgeones (*Philypnodon* spp.), crimson-spotted rainbowfish (*Melanotaenia duboulayi*), Pacific blue-eye (*Pseudomugil signifer*), and Australian smelt (*Retropinna semoni*). Medium-sized native fish included bony bream (*Nematolosa erebi*), spangled perch (*Leiopotherapon unicolor*), eel-tailed catfish and mouth almighty (*Glossamia gillii*); and large bodied species included eels (*Anguilla* spp.), saratoga (*Scleropages leichardti*), Australian lungfish (*Neoceratodus forsteri*), Australian bass (*Percalates novemaculeata*), yellow belly (*Macquaria ambigua*) and Mary River cod (*Maccullochella mariensis*). Mary River cod is endemic to the Mary River Basin.

A number of diadromous species expected to occur in Six Mile Creek have not been recorded (e.g. striped gudgeon (*Gobiomorphius australi*) and Empire gudgeon (*Hypseleotris compressa*), potentially reflecting cumulative impacts from barriers to fish passage in the lower Mary River between the estuary and Six Mile Creek.

Of the native species occurring in the Project area, several of them:

- occur in Six Mile Creek downstream of Lake Macdonald but do not occur upstream of the Lake Macdonald (Six Mile Creek) dam wall (e.g. Pacific blue eyes)
- have been stocked and although native to Australia, do not occur naturally in Six Mile Creek (e.g. saratoga, yellow belly), and

- are threatened species under the *Environmental Protection and Biodiversity Conservation Act 1999* (i.e. are Matters of National Environmental Significance):
  - Mary River cod, listed as endangered, and
  - Australian lungfish, listed as vulnerable.

Surveys have recorded Mary River cod and Australian lungfish only from Six Mile Creek downstream of Lake Macdonald, although records indicate that at least 112,730 Mary River cod fingerlings were released to Lake Macdonald between 1983 and 2015, with 6430 released to Six Mile Creek (MRCCA, 2016). There are no records that Australian lungfish have been stocked in Lake Macdonald or Six Mile Creek, and while this species is known from the Project area, Six Mile Creek is not likely preferred habitat for the Australian lungfish and it is consequently considered that this species would be in relatively low abundance in the Project area. In contrast, Six Mile Creek is considered to harbour an important relict population of Mary River cod (Simpson & Jackson 2000), and the high stocking rate suggest that this species has the potential to occur in relatively high numbers, especially in Lake Macdonald. Large numbers of yellow belly and Australian bass have also been stocked to Lake Macdonald, suggesting that the abundance of large bodied fish in Lake Macdonald could be relatively high.

Five pest fish are known from the Project area: eastern Gambusia (*Gambusia holbrooki*), platy (*Xiphophorus maculatus*), swordtail (*Xiphophorus hellerii*), guppy (*Poecilia reticulata*) and tilapia (*Oreochromis mossambicus*), with this latter species only recently recorded for the first time in Six Mile Creek downstream of the Lake Macdonald (Six Mile Creek) dam wall. It is currently unknown if tilapia occur in Lake Macdonald, or if the dam wall has prevented this species extending further upstream. Eastern gambusia and tilapia are restricted biosecurity matters.

Two threatened species of fish (Mary River cod and Australian lungfish) occur in the Project area. Two species of fish (Eastern gambusia and tilapia) that are biosecurity matters occur in the Project area.

The 2025 evaluation survey did not identify any MNES or MSES species living in the lake.

Turtles

Recent surveys found that four species of turtle (i.e. Krefft's river turtle (*Emydura macquarii*); saw-shelled turtle (*Wollumbinia latisternum*); eastern long-necked turtle (*Chelodina longicolis*); and broad-shelled river turtle (*Chelodina expansa*) occur in the Project area, with the diversity and abundance of turtles higher upstream of the Lake Macdonald (Six Mile Creek) dam wall than in Six Mile Creek downstream of Lake Macdonald. It is possible that white-throated snapping turtle (*Elseya albagula*) and Mary River turtle (*Elusor macrurus*), both of which are endemic to the Mary River Basin, also occur in the lower reaches of Six Mile Creek, with white-throated snapping turtle likely occurring further upstream than Mary River turtle. These two species of turtle are threatened species under the EPBC Act 1999, with:

- White-throated snapping turtle listed as critically endangered, and
- Mary River turtle listed as endangered.

Platypus

Platypus (*Ornithorhynchus anatinus*) is known from Six Mile Creek, Lake Macdonald, and the tributaries upstream of Lake Macdonald. This species is listed as Special Least Concern in Queensland's *Nature Conservation (Wildlife) Regulation 2006* but is not a threatened species.

Aquatic Matters of National Environmental Significance

Matters of National Environmental Significance (MNES) are matters that are protected under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC). This section considers in greater detail, aquatic species that are MNES: Mary River cod, Australian lungfish Mary River turtle and white-throated snapping turtle.

Mary River cod

Status

The Mary River cod (*Maccullochella mariensis*) is listed as endangered under the EPBC Act and is a 'no take' species under the Queensland *Fisheries Act 1994* except from specific impoundments nominated by DPI to which the species has been stocked.

Distribution

The Mary River cod is endemic to the Mary River system. Through the 1950's to the 1970s, the Mary River cod became very rare in the main channel of the Mary River, Yabba Creek, Munna Creek and Booloumba Creek. Currently, only three tributaries of the Mary River (i.e. Tinana-Coondoo creek, Six Mile creek and Obi Obi Creek) contain relatively abundant numbers of Mary River cod. The approximate area of occupancy across these three creeks is between 5 – 7.5 km^2, with the population size estimated to be fewer than 600 individuals (Simpson & Jackson 1996). In Six Mile Creek, Mary River cod have been caught at the confluence with the Mary River (SKM 2007) and occur in the creek for approximately 40 km upstream to Lake Macdonald. Historically, the Six Mile Creek population has been considered to be in a stable condition (Simpson & Jackson 1996). In Tinana-Coondoo Creek, Mary River cod occur up to seventy kilometres upstream of the confluence with the Mary River, of which only 25-30% is considered suitable habitat. In Obi Obi creek, the species range extends approximately 10 km upstream from the confluence with the Mary River (Simpson & Jackson 1996). A number of impoundments have been stocked with Mary River cod for recreational fishing (DoE SPRAT Profile).Preferred Habitats

The pool habitats within Obi Obi, Six Mile and Tinana-Coondoo creeks are known strong-holds for Mary River cod. These pools are not particularly deep (up to 3 m) and usually occur along pool and shallow riffle or run sequences (Simpson & Jackson 1996). The in–stream habitat features preferred by Mary River cod include submerged large woody debris, undercut banks, rock ledges and boulders (SKM 2007; DoE SPRAT profile). Reaches of creek with intact riparian vegetation are also favoured by the species as it provides shade and a supply of woody debris (GHD 2012). Woody debris and other complex submerged habitat features (e.g. boulders, undercut banks) are utilised by the species for foraging, shelter and nesting (SKM 2007; DoE SPRAT profile). Of the three creeks inhabited by Mary River cod, preferred habitat for the species is most common in Tinana–Coondoo Creek. This creek flows through areas of low human population density (Simpson & Jackson 1996). Larval and juvenile fish habitat preferences are relatively unknown.

Water Quality

The reported water quality tolerances of Mary River cod are:

- pH = 6.0 – 7.3
- conductivity (µS/cm) = 100 – 800
- temperature (ºC) = 15.7 – 29.0, and
- dissolved Oxygen (mg/L) = 3.9 – 9.7 (Hydrobiology 2008a).

Of the listed water quality parameters, temperature and dissolved oxygen are the most important, as high temperatures and low dissolved oxygen levels can be lethal to the species (DNRM, pers. Com.)

Flow Requirements

Adults of the species typically prefer low flowing water of suitable depth (i.e. 1 – 3 m) and generally avoid shallow (<1 m) areas. During periods of high flow, they shelter amongst woody debris and undercut banks which act to baffle and reduce flow velocities (GHD 2012). Mary River cod have been observed dispersing from 10 km to 70 km over several months following high flows (Simpson & Jackson 1996). Juvenile Mary River cod utilise shallow water habitats, including runs and pools margins, where sufficient cover in the form of trailing root masses or rocky substrates occurs. Spawning is triggered by light episodic rainfall (up to 20 mm) and associated flows, when it coincides with a water temperature of at least 19 ºC and the full moon phase (R Manning 2014, pers. comm.).

Foraging and Movement

Mary River cod typically have relatively narrow home ranges, and have been reported to occupy a particular pool for extended periods (Simpson & Jackson 1996). Within their ranges, movement tends to be upstream during the summer months when rainfall and flows are higher, connecting pools, and downstream or into larger tributaries during the winter months (DoE SPRAT profile). Murray River cod disperse widely as larvae drifting at night for approximately one to two weeks (DoE SPRAT profile), suggesting larval drift could be important for dispersal of Mary River cod.

Mary River cod are predatory and generally feed on smaller fish and crustaceans, most commonly during dawn and dusk; but the species is also known to consume waterbirds and other fauna (DoE SPRAT Profile ; MRCCC ; Aurecon 2013). The species often forages on prey immediately downstream of riffles, presumably due to a constriction of the watercourse and the concentration of prey items (SKM, 2007). This suggests that shallow riffle habitat is important for Mary River cod, although this habitat may not be commonly occupied by the species.

Breeding

Mary River cod mature at approximately 38 cm and are considered to be a large, slow growing, long-lived fish with relatively low fecundity (DoE SPRAT Profile; Aurecon, 2013). The cod is presumed to spawn more than once a year, initiated by a rise in water temperature to 20 °C during spring and into early summer (Simpson & Jackson, 1996). Eggs are typically deposited inside a nest formed by a hollow log or similar habitat features (e.g. submerged open pipe) (Simpson & Jackson 1996). The male will subsequently guard the eggs until they begin to hatch towards the end of the fourth day at 20°C (Aurecon 2013). The male will continue to guard the brood until they are ready to search for food between seven and nine days after hatching (Aurecon 2013; Simpson & Jackson 1996). In the event that conditions do not coincide i.e. water temperature of at least 19ºC, moon phase at full and light episodic rainfall up to 20 mm, female Mary River cod will reabsorb their eggs and will not spawn (DoE SPRAT Profile).

Threats

There are a number of threats facing the Mary River cod, including:

- Overfishing - overfishing during the late 1800’s and early 1900’s saw the removal of large numbers of fish (Simpson & Jackson 1996). Currently, fishing for Mary River cod is prohibited in the Mary River, however there is evidence that illegal capture of the Mary River cod still occurs (Simpson & Jackson 1996).
- habitat degradation – specifically clearing of riparian zones, which exposes bank soil to erosion and leaded to sedimentation of pool habitats (Simpson and Jackson 1996). Loss of riparian vegetation also reduced input of branches and other habitat elements that are preferred by Mary River cod.
- dams and weirs – impose barriers to movement; while long-range dispersal by cod is not frequent as they generally have relatively small home ranges, periodic movement over longer distances is likely important for the long-term survival of the species (Simpson & Jackson 1996). Cold-water releases from dams and altered flows downstream of dams may also impact breeding and / or survival of larvae (DoE SPRAT Profile)
- pollution – various sources of pollution may impact the suitability of water quality for Mary River cod, with increased nutrients and reduced dissolved oxygen known water quality issued for Mary River cod (Simpson & Jackson 1996), and
- introduced species – may increase competition for food or habitat resources or may prey on larval and juvenile cod (Simpson & Jackson 1996).

Australian lungfish

Status

Australian lungfish (*Neoceratodus forsteri*) is listed as vulnerable under the EPBC Act, and as a ‘no take’ species under the Queensland *Fisheries Act 1994*.

Distribution

Australian lungfish is known to occur in the Mary River and several of its tributaries between Conondale (220 km from the mouth of the river) and the Mary River Tidal Barrage (59.3 km from the mouth of the river) (DoE SPRAT profile). It has previously been caught at Coles Crossing and near the confluence of the Mary River and Six Mile Creek (LinkWater Projects 2008). The natural distribution of Australian lungfish also includes the Burnett River system. It has been stocked into several other rivers (e.g. Brisbane River). It is estimated that the Australian lungfish population consists of less than 10,000 individuals (DoE SPRAT Profile).

Preferred Habitats

Generally, Australian lungfish require riparian vegetation comprising eucalypt woodland, native grasslands or minimally modified pastures in moderate to good condition, although the species has been reported from reaches with moderately cleared riparian zones (Smith et al., 2012).

Australian lungfish are generally found in wide, slow-flowing or still permanent reaches with deep pools (i.e. 1 – 3 m) and shallower sections (i.e. 1 – 2 m deep) with abundant aquatic plant cover. Riffles or runs may also be present along a reach (DCCEEW, 2009). Open water with an absence of complex in-stream structures is not preferred habitat of the species (DoE SPRAT profile).

Australian lungfish tend to inhabit reaches with structurally complex submerged habitat, including submerged logs, high aquatic plant cover and underwater crevices formed by rock scouring and / or undercut banks (SKM 2007; Hydrobiology 2008a; Arthington 2009). Aquatic plant species associated with Australian lungfish habitat include *Vallisneria* sp., *Hydrilla vertillata, Egeria densa, Ludwigia peploides* and *Nymphoides* sp. (DoE SRPAT profile).

Water Quality

The water quality tolerances of Australian lungfish are:

- pH = 7.0 – 9.1
- conductivity (µS/cm) = 421 – 1165
- temperature (°C) = 10 – 30, and
- dissolved Oxygen (mg/L) = 6.9 – 15.6 (Hydrobiology 2008a).

Flow Requirements

The specific flow requirements for lungfish are only partly understood. Adults of the species are found mostly in permanent still or slow flowing deep pools, or in shallow pools with high cover of submerged aquatic plants. Breeding and recruitment occurs under low flow conditions (i.e. water levels between 10 and 30 cm above cease to flow levels) (Hydrobiology 2008b).

Foraging and Movement

Lungfish are largely sedentary, having home ranges of less than 2 km, although long-term recoding of movement patterns shows that some individuals may move up to 5 km over a number of years (Kind 2002). Most movement is reported to occur during the summer months (Kind 2002).

Lungfish feed on benthic invertebrates, amphibian larvae and aquatic plants (e.g. *Vallisneria* spp. and *Hydrilla* spp.) (Aurecon 2013; DoE SPRAT profile). Lungfish tend to forage at night with adults utilising shallow macrophyte beds and juveniles employing ambush tactics (Aurecon 2013; DoE SPRAT Profile).

Breeding

Male Australian lungfish begin breeding at approximately 15 years of age while females first breed at approximately 20 years of age (Aurecon 2013, DoE SPRAT profile). Australian lungfish spawn over a variety of habitats (e.g. woody debris, rocks, boulders and aquatic plants), however, under slow-flow conditions they tend to spawn more commonly among aquatic plants e.g. ribbon weed (*Vallisneria* sp.) (Department of the Environment 2013). Spawning tends to occur at night from August to December and is triggered by increasing day length (Bunn 2008; Espinoza et al. 2012; DoE SPRAT profile). If spawning habitat is disturbed, Australian lungfish will either delay breeding or skip breeding entirely (DoE SPRAT profile). After spawning the Australian lungfish thrash their tail to disperse eggs that then adhere to submerged surfaces (DoE 2014). A single clutch consists of 50 to 100 eggs (DoE SPRAT profile). Hatching of eggs occurs approximately one month after fertilisation (McGrouther 2013). Juvenile lungfish are almost exclusively found in dense submerged aquatic plant beds (DoE SPRAT profile). Recently hatched lungfish are poor swimmers, and tend to rest on their sides on the stream bed while they digest their yolk and avoid daylight (DoE SPRAT profile).

Threats

The main threats to Australian lungfish are:

- Dams - impoundments act as a physical barrier to breeding sites; lungfish will migrate to find suitable areas for breeding. However, if they are unable to reach appropriate breeding habitat due to obstructions, spawning will not occur that year (Arthington 2009; DoE SPRAT profile). Repeated failure to breed may cause lungfish populations to decline substantially in a small number of generations (Aurecon 2013; DoE SPRAT profile). Furthermore, fluctuations of water levels in impoundments can result in stranding of lungfish and mortality of lungfish eggs (Arthington 2009; DoE SPRAT profile); and some reservoirs are known to undergo periods where lungfish density is very high (i.e. crowding of lungfish), which reduces the health and condition of lungfish at these times (DoE SPRAT profile).
- Fishing - recreational fishers are known to unintentionally catch the Australian lungfish. While some are returned to the water and survive others are unaccounted for (DoE SPRAT profile).
- Exotic fish species - predation on lungfish eggs and juveniles by exotic and native translocated fish species has also put pressure on the lungfish population, and alien fish also compete with adults for breeding habitat (Arthington 2009; DoE SPRAT profile), and
- Habitat degradation – specifically clearing of riparian zones, which exposes bank soil to erosion and leads to sedimentation of pool habitats.

Mary River turtle

Status

The Mary River turtle (*Elusor macrurus*) is listed as endangered under the EPBC Act and endangered under the NC Act.

Distribution

The Mary River turtle has been recorded in the Mary River and several of its tributaries (e.g. Yabba Creek and Tiana Creek) between Kenilworth (260 km from the river mouth) and the Mary River tidal barrage at Tiaro (Limpus 2007; SKM 2007 and references cited therein; Red Leaf Projects 2013; DoE 2014a). Individuals of the species have well defined home ranges and show strong site fidelity (Cann & Legler 1994; DCCEEW 2008; Kuchling 2008; Limpus 2008; Micheli-Campbell et al. 2013).

Preferred Habitats

Much of the Mary River turtle habitat is surrounded by cleared grazing and agricultural land, although in such reaches, the species has been caught in areas where the river is wide and there is trailing vegetation and in-stream habitat (Cann & Legler 1994). Some areas of Mary River turtle habitat retain some riparian and catchment vegetation, especially in upper catchment areas and along several tributaries.

The species is regularly associated with areas of submerged habitat, including sparse to dense aquatic plant coverage, woody debris and rock crevices (SKM 2007 and references cited therein). Similar to other reptiles, the Mary River turtle often basks on emerging rocks and logs within the waterbody or along its banks (Cann & Legler 1994).

Water Quality

There are no specific water quality tolerances that have been published for Mary River turtle, however, they are known to prefer flowing water with high concentrations of dissolved oxygen (Thomson et al. 2006). It would be reasonable to assume that their preferences for other water quality parameters (e.g. temperature, electrical conductivity, turbidity and pH) would be similar to that of the Mary River cod, given that both species are endemic to the Mary River. Declines in water quality may reduce the efficiency of cloacal respiration by Mary River turtle, which can reduce foraging efficiency and more frequently expose juveniles to predators at the water surface.

Flow Requirements

The Mary River turtle prefers habitats characterised by shallow, fast-flowing streams with riffle zones and well-oxygenated water, and reaches with deep connected pools (depth ranging from approximately 1 m – 5 m) (DCCEEW 2008; Flakus & Connell 2008). During flooding, the Mary River turtle takes refuge in backwaters until flow decreases to pre-flood levels (Sadlier et al. 2004). They are also known to swim upstream during moderate to high flow events, returning to the same pool once water levels recede (Flakus & Connell 2008).

Foraging and Movement

The Mary River turtle is omnivorous and feeds on aquatic plants (including algae) and invertebrates (including bivalves) (Cann & Legler 1994). Juvenile Mary River turtles eat aquatic insect larvae, supplemented by freshwater sponges, aquatic plants including green algae, and fruits of some terrestrial trees (Flakus 2002; Micheli-Campbell et al. 2013). During the winter months movement is generally limited to within a particular reach; however, movement up to 2 km in search of breeding sand banks have been recorded during the early summer months (Sadlier et al. 2004).

Breeding

Mary River turtles live for between 30 and 80 years of age and do not breed until between 15 and 25 years of age (Limpus 2008). Sparsely vegetated sandy river banks in close proximity to riffles and pools are preferred nesting habitats, with these sites revisited across decades by the same individual (Flakus 2002; Limpus 2008). Breeding occurs only once every year with a clutch size of approximately 13 eggs (Flakus et al 2008). Successful hatching is dependent on 50 consecutive days of non-inundation after nesting. For this reason, nests are typically located 5 m above the water level and up to 30 m inland from the watercourse. Nesting occurs in late October to December after the first significant summer rain (Cann & Legler 1994; Flakus & Connell 2008; Limpus 2008). Depending on sand temperature, eggs have an incubation period of 50 – 56 days (Cann & Legler 1994).

Threats

Major threats to the Mary River turtle include:

- Nest predation and reduced success of recruitment - for twelve years during the 1960's and 1970's large numbers of Mary River turtle eggs were collected for commercial purposes (DoE SPRAT Profile; Bunn 2008; Limpus 2008). As a result, little to no recruitment occurred during this time and this has resulted in poor breeding success of Mary River turtle for four decades (DoE SPRAT profile). Furthermore, pressure from predation in nesting areas by foxes, goannas and wild dogs has meant the hatching success of the Mary River turtle continues to be very low (DoE SPRAT Profile; Flakus et al 2008; Limpus 2008).
- Dams - impoundments do not provide suitable habitat for the Mary River turtle, having typically still water with low levels of dissolved oxygen that reduces the efficiency of cloacal respiration (DoE SPRAT profile). There is also a decline in types and quality of food available for Mary River turtles in impoundments due to fluctuating water levels; aquatic plants and terrestrial fruiting trees do not tolerate inundation and will consequently die back. Dams also lack the insect larvae of flowing water habitats comprise part of the diet of the Mary River turtle (DoE SPRAT profile). Lastly, dams reduce the availability of suitable nesting habitat, as they do not support suitable sandy banks, and dams act as a physical barrier preventing females from reaching nesting sites (DoE SPRAT profile).
- Habitat degradation - including clearing of the riparian zone, which exposes bank soil to erosion and leaded to sedimentation of pool habitats, and sand and gravel mining which results in the destruction of sand banks that are used as nesting sites. The Mary River turtle may increase territorial behaviour with reduced habitat and breeding area, leading to a decrease in population size (DoE SPRAT profile).

White-throated snapping turtle

Status

White-throated snapping turtle (*Elseya albagula*) is listed as critically endangered under the EPBC and endangered under the NC Act.

Distribution

The white-throated snapping turtle is restricted to the Fitzroy, Mary and Burnett river catchments in Queensland (Threatened Species Scientific Committee 2014). The species has also been recorded in:

- adjacent small coastal river basins, including the Kolan and Gregory-Burrum systems (Hamann et al. 2007)
- impoundments upstream of weirs such as Eden Bann Weir and Glebe Weir (Limpus et al. 2007), and
- the spring-fed pools of the Dawson River (Hamann et al. 2007; frc environmental 2008).

White-throated snapping turtle is widely distributed in the Mary River and its major tributaries, including Tinana, Wide Bay, Obi Obi and Yabba creeks (Limpus et al. 2008).

Preferred Habitats

White-throated snapping turtles are habitat specialists that prefer permanent, clear, well oxygenated water that is flowing and contains shelter (e.g. large woody debris and undercut banks) (Limpus et al. 2008; Todd et al. 2013). The species has also been recorded in non-flowing waters, such as impoundments (e.g. Borumba Dam, Imbil Weir, Mary River Barrage) but only in low numbers (Limpus et al. 2008; Threatened Species Scientific Committee 2014). Within the greater Fitzroy, Burnett and Mary river catchments, this species has been recorded almost exclusively in close association with permanent flowing stream reaches that are typically characterised by a sand-gravel substrate with submerged rock crevices, undercut banks and / or submerged logs and fallen trees, and are rarely found in reaches without such refuge (Hamann et al. 2007; Limpus et al. 2007). Across its distribution, individuals have been recorded from both shallow and deep, slow flowing pools (Hamann et al. 2007).

White-throated snapping turtles are rarely present in water bodies that are isolated from flowing streams, such as farm dams or sewage treatment ponds, suggesting that the species does not move extended distances over dry land (Hamann et al. 2007; Limpus et al. 2008). However, white-throated snapping turtles have been observed walking short distances from drying waterholes to nearby water bodies (Limpus et al. 2007).

Water Quality

There are no published water quality tolerances for white-throated snapping turtle, although they are known from flowing streams with generally clear, well-oxygenated water.

Flow Requirements

Flowing streams with clear water, in both shallow or deep pools. Uncommon in non-flowing waters and isolated waterbodies that are not connected to flowing water habitats. As the species is a cloacal ventilating species, it is thought that it would not function well in deeper habitats of larger pools where dissolved oxygen concentrations are low, such as dry season conditions in standing water bodies (Limpus et al. 2008), although could be in shallow upper reaches of impoundments where there are inflows.

Foraging and Movement

White-throated snapping turtles feed primarily on aquatic plants along with fruits and leaves from overhanging riparian vegetation (Limpus et al. 2007). They may also eat periphyton, freshwater bivalves and insects, particularly when plant food resources are limited (Limpus et al. 2007). The diet of juveniles is dominated by invertebrates, whereas the diet or larger individuals (i.e. standard carapace length < 6 cm) is dominated by plant material (Limpus et al. 2008).

Little is known of the movement patterns of these turtles in the greater Fitzroy River catchment. However, in the Burnett River they generally have small home ranges of less than 500 m and have limited spatial and temporal movements (Hamann et al. 2007).

Breeding

The life history of white-throated snapping turtles is characterised by a long life span and slow growth to maturity (Threatened Species Scientific Committee 2014). The age at first breeding is approximately 15 to 20 years (Limpus et al. 2011). Breeding occurs once per year, mostly during autumn and winter, with adult females breeding in each successive year unless the turtle has been injured or debilitated, or riverine habitat has been altered (e.g. water extraction, drought or weeds) (Threatened Species Scientific Committee 2014). Females generally nest on sandy banks, although nests have been observed on loose gravels and soils. Females lay a single clutch of eggs during the breeding season, with an average of 14 eggs per clutch (Hamann et al. 2007; Limpus et al. 2011). Nests are generally laid in areas of low canopy cover and in areas of dense grass cover; however, dense weeds at the water's edge may limit suitability of potential nesting banks (Hamann et al. 2007; Limpus et al. 2011). Nests are an average of 16.6 m from the water's edge, with eggs laid in deep chambers (greater than 20 cm in depth) and on banks with a slope of up to 26.5º (Hamann et al. 2007; Limpus et al. 2011). However, nests have been recorded up to 60 m from the water (Hamann et al. 2007). White-throated snapping turtles will repeatedly use specific areas of banks over multiple years (Limpus et al. 2007).

There is no parental care, and egg and small juvenile survival is typically low (Heppell et al. 1996; Hamann et al. 2007). There is abundant evidence of nesting in all three river basins (i.e. Fitzroy, Burnett and Mary River Basins), but most eggs are lost to predation or trampling by stock (Hamann et al. 2007; Limpus et al. 2011). The population growth or decline rate is highly responsive to changes in adult survivorship, rather than changes in egg or juvenile survivorship (Heppell et al. 1996). Nonetheless, where egg predation rates are high, population growth rate will be constrained.

Threats

The principal threat to white-throated snapping turtles in all three catchments is the excessive loss of eggs and hatchlings due to predation (Threatened Species Scientific Committee 2014). Primary predators include feral (e.g. foxes, dogs, pigs and cats) and native (e.g. water rats and lizards) animals. Trampling of nests by cattle is also a major threat.

An additional threat to this species includes limited suitable habitat, which is highly fragmented across its distribution range due to dams and weirs. Waterway impoundments, such as dams, barrages and weirs, also form significant barriers to the passage of freshwater turtles. The number of dead and injured turtles can be much greater in pools immediately downstream of weirs than in pools distant from weirs, presumably a result of turtles being swept downstream and over impoundments during major and sudden water releases (Hamann et al. 2007).

Other threats to this species are:

- stocking of fish into dam impoundments for recreational fishing
- recreational fishing resulting in hook injuries
- boat strike
- loss of nesting habitat to weed infestation in the riparian zone
- dense aquatic weeds in the waterways, and
- water extraction for agriculture and irrigation (Limpus et al. 2011).

References

Arthington, A.H., 2009, 'Australian lungfish, Neoceratodus forsteri, threatened by a new dam', Environmental Biology of Fishes 84: 211-221.

Aurecon, 2013, River cod (Maccullochella mariensis) and Australia Lungfish (Neoceratodus forsteri), report prepared for Department of Transport and Main Roads.

Bunn, S.E., 2008, Review of EIS and supplementary materials on proposed Traveston Crossing Dam, Mary River, SE QLD: II: Final report, report prepared for Department of the Environment, Water, Heritage and the Arts.

Cann, J. & Legler, J.M., 1994, 'The Mary River Tortoise: A New Genus and Species of Short-Necked Chelid from Queensland, Australia (Testudines: Pleurodira)', Chelonian Conservation and Biology 1: 81-95.

DCCEEW, 2008. Approved Conservation Advice for Elusor macrurus (Mary River Turtle).

Espinoza, T., Marshall, S.M. & McGougall, A.J., 2012, 'Spawning of the endangered Australian lungfish (neoceratodus fosteri) in a heavily regulated river: A pulse for life.', River research applications QLD dept. of natural resources and mines QLD Aus.

Flakus, S., 2002, The ecology of the Mary River turtle, Elusor macrurus. M.Sc. thesis, Department of Zoology and Entomology, The University of Queensland, Brisbane.

Flakus, S. & Connell, M., 2008, 'The Mary River Turtle: Yesterday Today and Tomorrow, Landcare Tiaro & District.

frc environmental, 2008, Blackwater Creek Diversion, Aquatic Ecology; Impact Assessment and Baseline Monitoring, report prepared for Parsons Brinckerhoff Australia Pty Ltd.

GHD, 2012, Bruce Highway (Cooroy to Curra) Upgrade - Construction Environment Management Plan - Giant Barred Frog and Mary River Cod, report prepared for Department of Transport and Main Roads.

Hamann, M., Schauble, C.S., Limpus, D.J., Emerick, S.P. & Limpus, C.J., 2007. Management Plan for the conservation of Elseya sp. [Burnett River] in the Burnett River Catchment. Queensland Environmental Protection Agency: Brisbane.

Heppell, S.S., Crowder, L.B. & Crouse, D.T. 1996, 'Models to evaluate headstarting as a management tool for long-lived turtles', Ecological Applications 6: 556-565.

Hydrobiology, 2008a, Northern Pipeline Infrastructure Stage 2 EIS Six Mile Creek Study. Prepared for LinkWater.

Hydrobiology, 2008b, NPI Stage 2 EIS: Potential Effects of Water Abstraction on Aquatic MNES Species in the Mary River and Six Mile Creek. Prepared for LinkWater.

Kind, P.K., 2002. Movement patterns and habitat use in the Queensland lungfish, Neoceratodus forsteri (Krefft, 1870), PhD. University of Queensland, Brisbane.

Kuchling, G., 2008, Independent Expert Review of the Information Provided in the Traveston Crossing Dam EIS that Relates to the Mary River Turtle, Chelonia Enterprises, Subiaco.

Limpus, C.J., 2008, Freshwater Turtles in the Mary River: Review of biological data for turtles in the Mary River, with emphasis on Elusor macrurus and Elseya albagula, Queensland Government, Brisbane.

Limpus, C.J., D.J., L., Parmenter, C.J., Hodge, J., Forrest, M.J. & McLachlan, J.M., 2007, Proposal for raising Eden Bann Weir and construction of Rookwood Weir – An assessment of the potential implications and management measures for Fitzroy Turtles (Elseya albagula and Rheodytes leukops), report prepared for Environmental Protection Agency, Queensland Government.

Limpus, C.J., Limpus, D.J., Parmenter, C.J., Hodge, J., Forest, M. & McLachlan, J., 2011, The Biology and Management Strategies for Freshwater Turtles in the Fitzroy Catchment, with particular emphasis on Elseya albagula and Rheodytes leukops: A study initiated in response to the proposed construction of Rookwood Weir and the raising of Eden Bann Weir, report prepared for Department of Environment and Resource Management

LinkWater Projects, 2008, Northern Pipeline Connector – Stage 2 Environmental Impact Statement, LinkWater Projects.

McGrouther, M., 2013, Australian Lungfish, Neoceratodus forsteri (Krefft, 1870), http://australianmuseum.net.au/Australian-Lungfish-Neoceratodus-forsteri-Krefft-1870/, accessed July 2018.

Micheli-Campbell, M.A., Campbell, H.A., Connell, M., Dwyer, R. & Franklin, C.E., 2013, 'Integrating telemetry with a predictive model to assess habitat preferences and juvenile survival in an endangered freshwater turtle', Freshwater Biology 58: 2253-2263.

Sadlier, R., Shea, G. & Muir, G., 2004, Survey guidelines for Australia's threatened reptiles, Department of Sustainability, Environment, Water, Population and Communities.

Simpson, R. & Jackson, P., 1996, The Mary River Cod Research and Recovery Plan, Queensland Department of Primary Industries - Fisheries Group.

SKM, 2007, Traveston Crossing Dam Environmental Impact Statement, report prepared for Queensland Water Infrastructure Pty Ltd.

Threatened Species Scientific Committee, 2014, Conservation Advice for Elseya albagula White-throated snapping turtle, http://www.environment.gov.au/biodiversity/threatened/species/pubs/81648-conservation-advice.pdf, accessed July 2018.

Thomson, S., Georges, A. & Limpus, C.J., 2006, ' A new species of freshwater turtle in the genus Elseya (Testudines - Chelidae) from central coastal Queensland, Australia', Chelonian Conservation and Biology 5: 74-86.

Todd, E.V., Blair, D., Farley, S., Farrington, L., Fitzsimmons, N.N., Georges, A., Limpus, C.J. & Jerry, D.R., 2013, 'Contemporary genetic structure reflects historical drainage isolation in an Australian snapping turtle, Elseya albagula', Biological Journal of the Linnaean Society 169: 200-214.

16.1.1.1 Additional Studies of Relevance

Below are additional references that provide information on the ecological requirements, status and threats to Mary River cod and/or Australian lungfish, if required:

Espinoza T, Burke CL, Carpenter-Bundhoo L, Marshall S, Roberts D & Kennard MJ. (2020). Fine-scale acoustic telemetry in riverine environments: movement and habitat use of the endangered Mary River cod (*Maccullochella mariensis*). *Endangered Species Research* 42: 125–131 https://doi.org/10.3354/esr01046

Tao J, Kennard MJ, et al. (2020). Quality and contribution of food sources to Australian lungfish evaluated using fatty acids and stable isotopes. Aquatic Sciences 82: 8: 1-11

Brooks, S., Butler, G., Kennard, M. & Espinoza, T. 2019. *Maccullochella mariensis*. The IUCN Red List of Threatened Species 2019: e.T122906177A123382286. http://dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T122906177A123382286.en

Brooks, S., Espinoza, T., Kennard, M., Arthington, A. & Roberts, D. 2019. *Neoceratodus forsteri*. The IUCN Red List of Threatened Species 2019: e.T122899816A123382021. http://dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T122899816A123382021.en

DNRM (2016). Mary River cod – *Maccullochella mariensis*: An update on demography, habitat, movement, ageing and genetics to inform management. Department of Natural Resources and Mines, Brisbane. Available at: http://tinyurl.com/gsw5vw3

Dunlop, A. 2016. Ecology of Larval Freshwater Fish in the Mary River System, Southeastern Queensland, with a focus on the nationally threatened Mary River cod (*Maccullochella mariensis*). Honours Thesis, Griffith University.

Fallon SJ, McDougall AJ, Espinoza T, Roberts DT, Brooks S, Kind PK, Kennard MJ, et al. (2019). Age structure of the Australian lungfish (*Neoceratodus forsteri*). *PLoS* ONE 14(1): e0210168. https://doi.org/10.1371/journal.pone.0210168

Olden JD, Fallon SJ, Roberts DT, Espinoza T & Kennard MJ. (2019). Looking to the past to ensure the future of the world's oldest living vertebrate: isotopic evidence for multi-decadal shifts in trophic ecology of the Australian lungfish. *River Research and Applications* 35: 1629-1639

Schmidt DJ, Fallon S, Roberts DT, Espinoza T, McDougall A, Brooks SG, Kind PK, Bond NR, Kennard MJ & Hughes JM. (2018). Monitoring age-related trends in genomic diversity of Australian lungfish. *Molecular Ecology* 27: 3231–3241

Simpson, R. (1994). An investigation into the habitat preferences and population status of the endangered Mary River Cod (*Maccullochella peelii mariensis*) in the Mary River system, south-eastern Queensland. Department of Primary Industry, Fisheries Division, Brisbane. Queensland Government 1994

Simpson, R. and Jackson, P. (2000). The Mary River Cod Research and Recovery Plan. Queensland Department of Primary Industries, Brisbane.

Appendix D

Background Information – Drawdown Release Hydraulic and Geomorphic Assessment

Appendix D Background Information – Drawdown Release Hydraulic and Geomorphic Assessment

Assessment and Recommendations – Undertaken by Hydrobiology for Seqwater

It is noted that the proposed magnitude of lake lowering is significantly lower than that proposed at the time this hydraulic and geomorphic assessment was undertaken. Consequently, the results of the below assessment reflect a significantly worse case scenario than the currently proposed approach to dewatering.

The WMA Water (2018) hydraulic modelling of flood impacts report concluded that the constant release of 10 $m^3.s^{-1}$ would result in little to no out of bank flooding in the downstream reaches of Six Mile Creek (Figure D-3) and so was considered an appropriate maximum release volume. However, to understand what potential impacts the above release strategy (including the maximum 10 $m^3.s^{-1}$ flow) may have on downstream geomorphology, a number of hydraulic analyses were undertaken on data provided by Seqwater, as described below:

- Lake Macdonald (Six Mile Creek) Dam discharge and level data (1999-2019) (Figure D-1) were analysed using the River Analysis Package (RAP) software to analyse flow events and to determine the frequency and nature of 2-3 $m^3.s^{-1}$ events (proposed constant release over the 12-week period) and 10 $m^3.s^{-1}$ events (maximum release rate). This was undertaken to understand potential impacts that may occur from these events and to recommend a duration and frequency of releases for the Lowering Plan based on such past events. The analysis found:
  - Flows of less than or equal to 3 $m^3.s^{-1}$ occurred 7,165 times in the 21-year record, whereas flows of greater or equal to 3 $m^3.s^{-1}$ occurred 212 times in the record. However, flows of exactly 2 $m^3.s^{-1}$ occurred 86 times in the record and flows of exactly 3 $m^3.s^{-1}$ occurred 66 times in the record. This suggested that these flows were relatively frequent in the record.
  - Flows of less than or equal to 10 $m^3.s^{-1}$ occurred 7,320 times in the 21-year record, whereas flows of greater or equal to 10 $m^3.s^{-1}$ occurred 56 times in the record. Flows approximating 10 $m^3.s^{-1}$, occurred 33 times in the record, which was equivalent to about the 1 in 1.58 AEP event. Such flows typically lasted, on average, a duration of 1.697 days (and up to six days for total rise and fall of that sized event), with a mean rising limb of 1.751 days and a mean falling limb of 0.677 days. Hence, these types of events are relatively short in duration, with steep rising and falling limbs that occur over a matter of days. Examples of hydrographs of these types of flow events are shown in Figure D-2.
- Once the frequency had been developed, velocity hydraulic modelling outputs for the 10 $m^3.s^{-1}$ drawdown rate were analysed in ArcGIS and compared to DNRM (2019) guidelines. DNRM (2019) provide guidelines for any works that interfere with water in a watercourse for a resource activity and relate to watercourse diversions authorised under the *Water Act 2000*. Although specific to diversions and developed using one-dimensional hydraulic modelling, these were deemed useful in the absence of any other legislated guidelines. Given that the frequency identified above for 10 $m^3.s^{-1}$ peak flow events (1 in 1.58 AEP) roughly equated to the 50% AEP, the modelling outputs were compared to DNRM (2019) guidelines for a 50% AEP. DNRM (2019) recommends for a 50% AEP scenario (vegetated) that velocities should be <1.5 $m.s^{-1}$. The analyses showed the following:
  - Figure D-3 shows the output of the hydraulic analysis, displaying spatially where flows fall below or above the 1.5 $m.s^{-1}$ guideline. It shows that, for most of the creek, velocities fall within the DNRM (2019) guidelines, apart from the odd location where it is exceeded. These exceedance occurrences are likely to be associated with small local changes in bed level and are relatively minor. Given this, 10 $m^3.s^{-1}$ is considered an appropriate maximum drawdown rate.
  - At a release rate of 10 $m^3.s^{-1}$, it would take approximately 8.5 days to lower the lake from Full Supply Level if the release is constant. Although 10 $m^3.s^{-1}$ flows are frequent, they occur about twice a year and only for a short duration.

Given these analyses, and upon consultation with Seqwater, Hydrobiology notes and recommends the following:

- It is considered that a release at a rate of 2-3 m3.s-1 will be of limited concern from a geomorphic perspective. However, it is recommended that the planned five-day releases and two-day cessation will involve a slow rise and ebb (i.e. over the duration of a day), rather than sudden stop-starts. This will minimise the potential for rapid drawdown of water in the banks and resulting bank failures.

- In the case that the lake re-fills after an event and a larger release of up to 10 m3.s-1 is required to lower water levels, it is recommended that such releases aim to mimic the hydrographs presented in Figure D-2, and that the duration is no more than two days at the 10 m3.s-1 rate.
- In the circumstance that a large event occurs towards the end of the release schedule, it is recommended that at Week 10, the contingency plan is initiated to release at the maximum 10 m3.s-1. As outlined above, the original contingency plan involved releasing at this rate for between 8-10 days. Based on the assessment of hydrographs outlined above, this should be altered slightly to incorporate two releases with a peak of 10 m3.s-1 over five days with a two day break in between each release. As per the other releases and cessations, this should involve a slow rise and ebb (i.e. over the duration of a day) to minimise impacts to bank stability.
- It is important that any other releases (such as those during construction to maintain water levels) are also restricted to this release rate and duration design, to minimise potential geomorphic impacts within the creek.

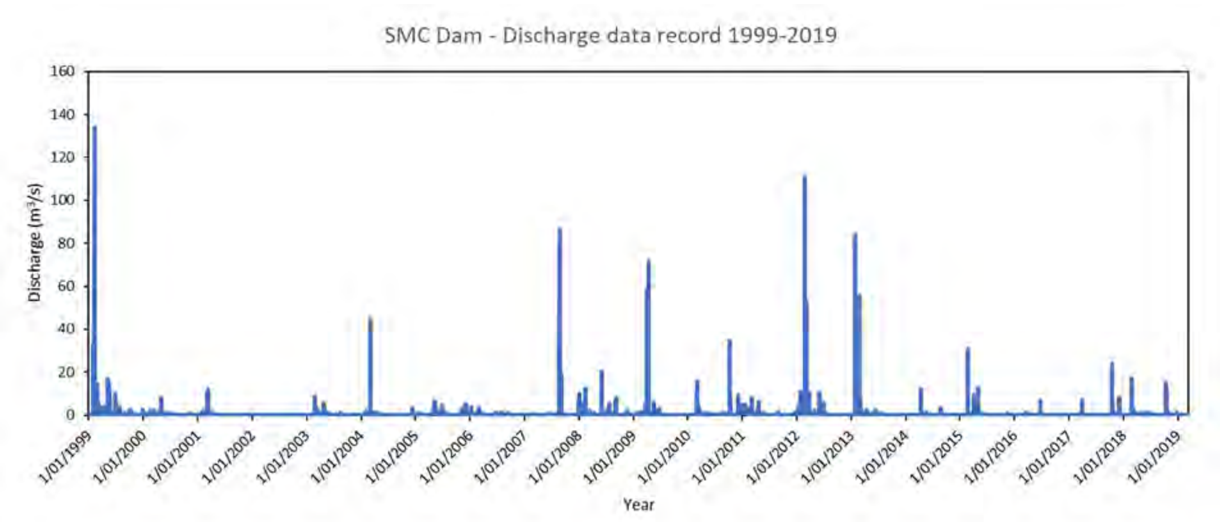


Figure 16-1: Discharge record for Six Mile Creek (SMC) Dam for the period 1999-2019

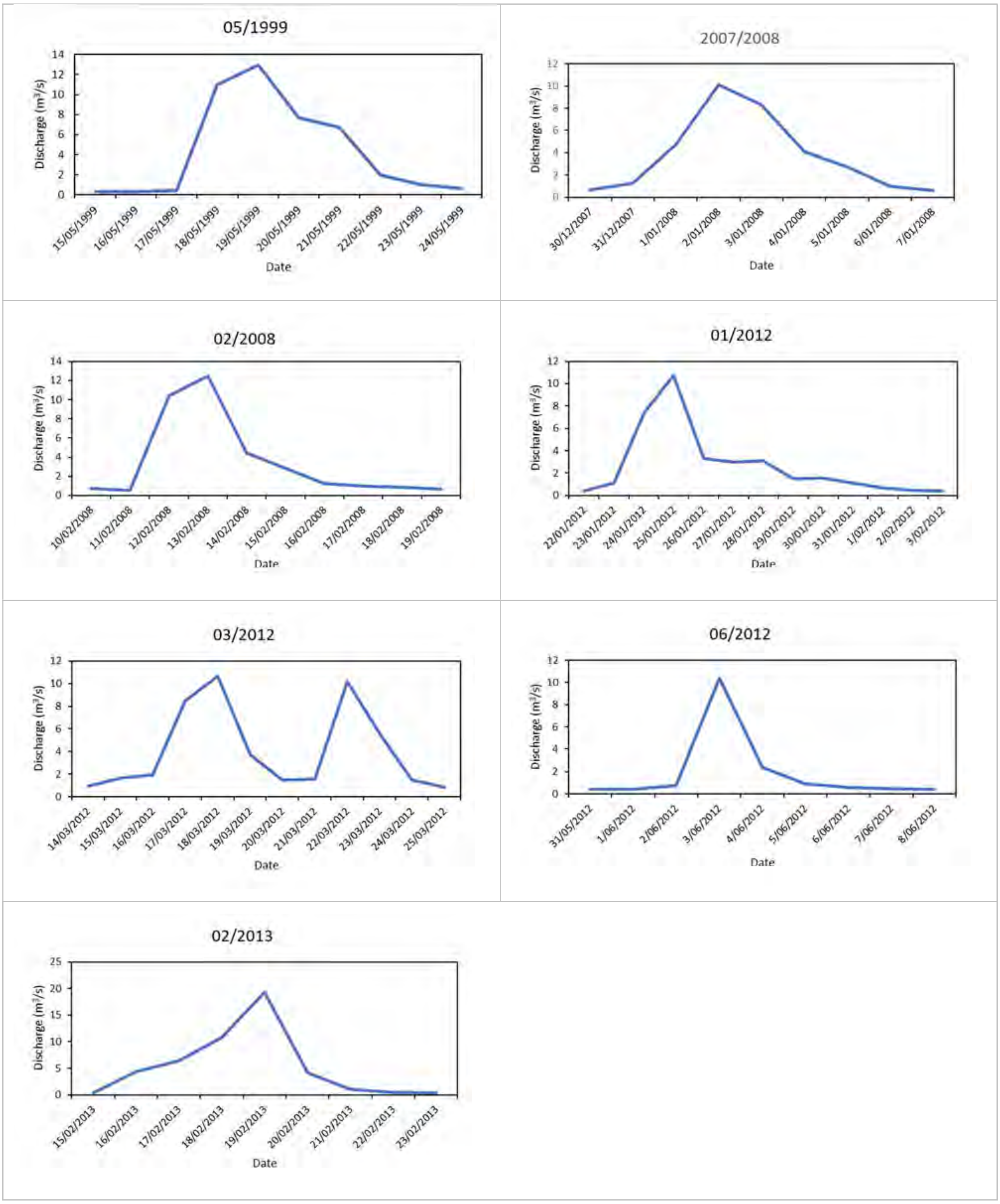


Figure 16-2: Hydrographs showing examples of flow events with peaks of ~10 m3/s that occurred in the Six Mile Creek Dam discharge record period 1999-2019

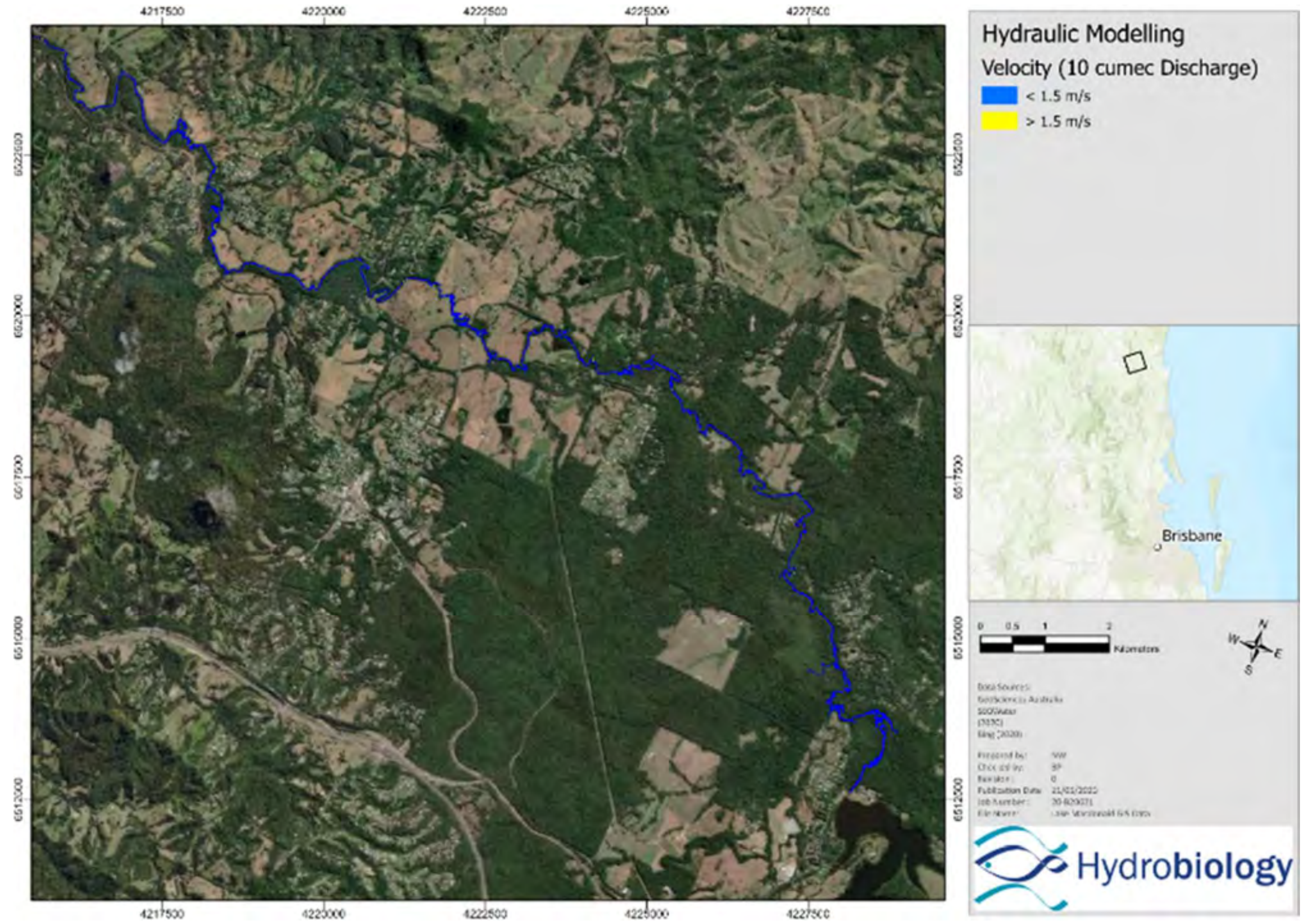


Figure 16-3: Hydraulic Modelling output for a 10 m3/s discharge in Six Mile Creek, representing a sunny day dam release, showing velocities above and below ACARP guidelines of 1.5 m/s for a 50% AEP. Hydraulic modelling data from WMA Water (2019)

References

Department of Natural Resources, Mines and Energy (DNRM). (2019). Guideline: Works that interfere with water in a watercourse for resource activity – watercourse diversions authorised under the Water Act 2000 (OSW/2019/4599 Version 2.00).

WMA Water. (2018). Lake Macdonald: Downstream Flood Impacts – Hydraulic Modelling. Prepared for Six Mile Creek Dam Impact Assessment Report (November 2018).

Appendix E

Summary of DPI Fish Salvage Guidelines

Appendix E Summary of DPI Fish Salvage Guidelines

The DPI's Fish Salvage Guidelines (DAF, 2018) present principles that are relevant to the planned aquatic fauna salvage operation. These principles are outlined below:

1. Remove as many fish as possible using appropriate nets.

Note: It is illegal to use certain types of nets, especially in freshwater. A General Fisheries Permit maybe required. Please call DPI for further information.

2. Lower the water level by 25% and remove as many fish as possible. Repeat at each subsequent 25% reduction. Removing fish at each reduction is important as overcrowding can result in a fish kill.

Note: Noxious and non-indigenous fish must be killed immediately with a quick sharp blow to the head, or by placing in an ice slurry. Their bodies must be disposed of away from the waterway in a bin or buried. They are not to be returned to the water. For a list of Noxious Fish species, see the *Biosecurity Act 1994*.

3. The following handling methods lessen damage to fish by reducing the risk of bacterial infections after handling:

- Use nets with a fine, soft, knotless mesh.
- Handle fish with wet hands or a wet towel. Gloves that are wet, open weaved and knotless are good for handling purposes.
- Handle large fish carefully. Fish of 2 kg or more need to be fully supported in a horizontal position with two hands or in a knotless net.

Fish should be placed into suitably sized receptacles as soon as possible to minimise the handling time. The fish holding containers should have good quality, well oxygenated water.

4. Remove, store and release the fish as quickly as possible.

- Use appropriately sized containers with a sufficient water depth to allow for comfortable swimming positions. The container should have soft, rounded surfaces and a lid.
- Size the container depending on the size and number of the fish that will be held. As a guide, 0.2 kg of fish per litre of water is acceptable for oxygen and stress levels.
- Observe fish for signs of stress such as increased gill movements or swimming at the surface.
- Monitor water conditions continuously. Regularly change water, to ensure oxygen levels are maintained, or release fish downstream if suitable conditions exist. As a guide, change 25% to 50% of water hourly, more frequently if conditions are hot. Alternatively, an aerating device that bubbles oxygen at a rate of 2 to 4 litres per second. If possible, keep the containers in the shade while working.
- If pumps are used to exchange water, ensure hoses are screened to prevent fish being injured or sucked through.
- Where practical sluicing fish directly is a better option than transportation. A sluice should:
  - Consist of large diameter PVC pipe with smooth joints or a smooth earthen channel lined with a continuous length of plastic.
  - Be sloped no more than a ratio of 1:10 and must be provided with an auxiliary flow of water.
  - Have a base pool deep enough to cushion the descent of the largest fish. A minimum depth of approximately 1 metre would be suitable for the receiving pool.

5. Release fish carefully by placing the container in the water and allowing the fish to swim away. Drops from height should be avoided. If water temperatures are equal, then a release by scoop net may be possible. Where there is a notable temperature difference water should be exchanged to equalise the temperature before release. These actions will minimise stress.
6. In the event of a fish kill call the hotline number on 1300 130 372.
7. Removing Temporary Bunds

- Remove the most downstream bund first.

- All barrier material to be removed from the waterway.
- Silt fences must be used to prevent erosion.
- Natural stream channel to be reinstated.
- Banks of stream reinstated to natural state, contours and vegetation.
- Aquatic environment similar to the prior state is to be reinstated.

Appendix F

Habitat Monitoring Program

Appendix F Habitat Monitoring Program

The development of the monitoring program was guided by:

- An initial habitat assessment of MNES and MSES species of interest, conducted by Hydrobiology,
- Information presented in the IAR and IAR supplementary report,
- The methods used in baseline aquatic habitat studies completed for the IAR, conducted by frc environmental,
- Advice contained in Seqwater's email correspondence with the Coordinator General's Office and the Department of Natural Resources, Mines and Energy,
- The conditions of the EPBC Act approval (EPBC 2017/8078).

Monitoring Sites

Monitoring sites are presented in Table 16-4. These sites were selected based on:

- Proximity to potential sources of impact
- Inclusion of habitats that would support communities of the listed species.
- Accessibility
- Inclusion of control sites to differentiate between catchment impacts and the dam works impacts.
- Existing baseline sites.

It is noted that the stilling basin is also a key monitoring site for the Project, but not for the purpose of aquatic habitat monitoring.

Six Mile Creek Downstream of the Dam

Monitoring sites to assess Six Mile Creek downstream of the dam are shown in Table 16-4. Three representative sites were selected on Six Mile Creek downstream of the dam. The sites are 200 m long, with coordinates identified for the central point.

Table 16-4: Monitoring sites for the Six Mile Creek downstream study reach

Site	Description	Easting*	Northing*
SMCDS01	Six Mile Creek; directly DS of the Lake Macdonald spillway within the spillway stilling basin	493026	7082149
SMCDS02	Six Mile Creek; approximately 1.5 km DS of the Lake Macdonald spillway	492715	7083047
SMCDS04	Six Mile Creek; approximately 7 km DS of the Lake Macdonald spillway	489171	7086480
Lake site	450 m upstream from dam	493395	7081844
SMCUS01	Upstream Control Site	496073	7079594
CU02	Upstream Control Site	493582	7078933

* Projection – WGS84 (Zone 56J)

Monitoring Components

The monitoring components adopted to assess these potential impacts are:

- Photo point monitoring
- Bank height, relative to water level

- In situ water quality measurements for temperature, pH, EC, dissolved oxygen and turbidity
- Bed substrate composition
- Water velocity
- Cross-sectional depth profiles
- Percent cover of instream aquatic plants
- Percent cover of riffles
- Bank erosion
- Percentage of large woody debris

Monitoring Methods

The habitat monitoring methods are described in Table 16-5.

Table 16-5: Monitoring methods

Monitoring Component*	Method
Photo point monitoring	Take photographs of: downstream view, right bank, upstream view, and left bank, rotating in a clockwise direction a described in the Monitoring and Sampling Manual (DES 2018)
Bank height (m)	Monitor for the duration of the monitoring period and measure height of bank (m) from water surface to top bank. Ensure this measurement coincides with a water depth measurement to normalise bank height measurements.
Velocity (m/s)	Measured using a flow meter
Cross-sectional depth profiles	Cross-section profiles are to be measured at the upstream end, mid-point and downstream end of each site, establish a starting and endpoint. Profiles should be measured perpendicular to the flow and include the entire channel cross-section (i.e. banks included, not just the active bed). Where possible, profiles should be measured using a differential GPS or manual survey techniques (e.g. dumpy level). During drawdown, an ADCP/echosounder can be used in replace of, in conjunction with other techniques to avoid entering high flow conditions. Vertical and horizontal accuracy should be <5 cm. Benchmark stakes should be installed on each bank for the start and end point of each cross-section and tagged with GPS coordinates on the first survey to ensure the same profile is surveyed each time.
Water quality measured in situ	As per *Monitoring and Sampling Manual* (DES 2018). Calibrate meter in accordance with manufacturer's instructions. Wait for reading to stabilise before recording. Take three readings (at least 5 m apart) at each site and take average of the three readings.
Bed substrate composition (percent of size classes)	Visually estimate the percentage of bedrock, boulders (>256 mm), cobble (64-256 mm), pebble (16-64 mm), gravel (4-16 mm), sand (1-4 mm) and silt/clay (<1 mm) along the 200 m site. Percentages of size classes to be documented in a pro forma as per *Monitoring and Sampling Manual* (DES 2018).
Aquatic plant (percent cover)	Visually estimate the percent cover of submerged, floating attached or emergent aquatic plants along the 100 m site Assess only plants rooted in the stream bed (i.e. exclude plants growing on banks and floating plants)
Riffles (percent cover))	Visually estimate the percent cover of riffles (using the definition of riffle presented in DES (2018)) along the 200 m of site.
Bank erosion (percent cover)	Visually record the extent and types of bank erosion (i.e. scour, notch, undercut banks, slump) along the 200 m site. Parameters to be documented in a pro forma and measured at multiple random locations throughout the site to avoid bias. Use cross-section profiles to record actual bank erosion rates at the upstream, mid-point and downstream locations at each site.

Monitoring Component*	Method
Percentage large woody debris	Visual estimation of percentage of large woody debris cover within the 200 m reach at each of the habitat monitoring locations.

* It is noted that high water levels and / or other factors (e.g. turbidity) may preclude the assessment of some indicators (e.g. substrate composition, cross-sectional profiles, aquatic plants and large woody objects) on some sampling occasions.

Habitat Triggers

Trigger values have been developed to provide early warning indicators for either further assessment or management response (e.g. reducing release rate). Non-compliance with the trigger values does not indicate that an impact has occurred.

The trigger values are presented in Table 16-6. However, monitoring results are also to be evaluated with respect to baseline, historical and control site data.

Table 16-6: Habitat Triggers

Monitoring Component	Trigger	Rationale for Trigger
Photo point monitoring	No trigger	Photos taken to aid interpretation of other indicators and as a permanent record of site conditions
Bank height (m)	Bank height must be >5% of water height.	Bank height is approaching bank full capacity.
Velocity (m/s)	At least one velocity reading (i.e. surface or bed at either mid-channel, left bank or right bank) at each site is <0.3 m/s or be comparable with baseline data recorded during similar sized events. Re-assess following *baseline phase*.	Based on prolonged swimming speed water velocity thresholds for native fish known from Six Mile Creek (Kapitzke, 2018)
Cross-sectional depth profile	Mean and maximum water depths at each site to be within baseline range, pending rainfall influences. Mean and maximum bank depths at each site to be within baseline range (top of bank to bed level)	Deep pools likely key habitat for Mary River cod, and important refugia for aquatic fauna during low flow periods.
Water Quality measured in situ	As per low and high triggers	Water quality conditions are maintained in baseline condition
Bed substrate composition (percent of size classes)	Percent cover of each substrate size class no more than 25% beyond baseline range	When substrate composition is >50% different from the baseline range it suggests a notable change in substrate composition.
Aquatic plant (percent cover)	Percent cover of aquatic plants no less than 25% of baseline minimum	Where aquatic plant cover is 25% lower than minimum baseline value, it suggests a notable decrease in aquatic plant cover.
Riffles (percent cover)	Percent cover of riffles no more/less than 25% of baseline range	When riffle extent is >50% different from baseline range it suggests a notable change in riffle extent
Bank erosion	No observed increase in erosion from baseline	Any observed area of new bank erosion requires investigation
Bed erosion	No observed increase in erosion from baseline	Any observed area of new bed erosion requires investigation
Percentage of large wood debris	Presence/cover of LWD within site reduces by >10%	This trigger indicates if the release has potential to change distribution and configuration of instream habitat features

Record Management, Reporting, Notification and Investigations

All monitoring data are to be stored in a suitable database or spreadsheet, which is to be kept up to date. Quality control documents (e.g. calibration records) and digital site photographs are to be stored electronically.

A brief monitoring data summary report is to be prepared on completion of:

- The baseline survey, and the triggers presented in this report are to be reviewed and revised if deemed necessary
- The drawdown phase
- The construction phase
- The post-construction monitoring phase (one-year post-construction), with discussion of post-construction condition compared to baseline conditions.

Post construction monitoring will continue for another year if there have been impacts to habitat that have not returned to baseline condition. If this occurs, another data summary report will be prepared upon completion of the second-year post-construction monitoring and post-construction condition will be compared to baseline conditions.

Appendix G

Habitat Assessment

Appendix G Habitat Assessment

A habitat assessment was undertaken by suitably qualified persons from Hydrobiology (Hydrobiology, 2020). The outcomes of this assessment are summarised below.

Scope

The purpose of the habitat assessment was to provide a better understanding of the habitat within both Six Mile Creek downstream of the dam and within Lake Macdonald to inform the development and design of the HMP, including selection of monitoring sites. Specific focus was placed on the potential for the habitat to support the MNES species of interest. The extent of the survey was limited to a 10 km reach downstream of the dam ('downstream study reach'), extending to the Louis Bazzo Drive crossing, and the Lake Macdonald impoundment ('impoundment study area'). It included both a geomorphology assessment and aquatic habitat assessment.

The scope of the geomorphology assessment was to:

- Review available information to develop a reach breakdown of different geomorphic 'River Styles' to inform monitoring site selection.
- Ground truth the reach breakdown to inform the site selection and describe the geomorphic basis for habitat, specifically in relation to listed species.

The aquatic habitat assessment aimed to demonstrate an adaptive management approach on the presumption of the potential presence of the listed species. This involved a design that focused on potential changes to channel and pool morphology (and in turn, available and suitable habitat) to ensure that it informed monitoring site selection as summarised below:

- Downstream Study Reach
  - Identification, via ground-truthing of potential waterhole traps. This focused on areas where changes to flow and sediment transport regimes will affect habitat connectivity and availability (i.e. riffle and run habitat between pools).
  - Rating different areas along the inspected reach for quality of habitat for each listed MNES species.
  - Use of the above to map good habitat locations and to inform monitoring site selection.
- Impoundment Study Area
  - Use existing data (hydroacoustics, bathymetry, Lidar, aerial imagery, etc.) and collected drone survey data of the lake margins to assess likelihood and quality of habitat for the listed species.

Methods

The methods for the habitat assessment included both a site visit and desktop tasks to inform both the geomorphology and aquatic habitat components, for both the downstream study reach and the impoundment study area. The site visit was conducted by Hydrobiology on 6-9 and 20-21 July. It involved a walk-through of the entire downstream study reach and drone image acquisition of a number of reaches of the dam margin within the impoundment study area.

River Styles Characterisation

The downstream study reach was characterized and split into distinct River Styles, using Stage One of the River Styles Framework, a geomorphic classification tool. Stage One of the framework involves a baseline survey of river character and behaviour, placing river types within their catchment context according to their valley setting, planform, bed material and assemblage of geomorphic units. This involved the analysis of several data sources including:

- Use of aerial photography, LiDAR and Google Earth Imagery to determine valley confinement
- Mapping of preliminary River Styles based on the above assessment

- Verification, adjustment and mapping of River Style boundaries during the site visit.

Morphological Mapping

In addition to River Styles, 'macro-habitat' and 'micro-habitat' were assessed and mapped. Macro-habitat refers to morphological features, such as pools, riffles, glides, and runs, while micro-habitat describes debris, such as leaf litter and large woody debris (LWD). All macro-habitat and LWD were geotagged with a GPS when walking the reaches during the site visit. Specific attention was placed on habitats that would be beneficial for the listed species. At the same time, any evidence of erosion (e.g. notch scour, bank collapse, undercut banks, bank exposures and other prominent scour) was also geotagged. Photographs were also taken. This geodatabase of features was then uploaded into a GIS and mapped to gain an understanding of physical habitat within the creek and the erosion that is currently present.

Downstream Study Reach

In order to determine what habitat was suitable for the species of interest, criteria for assessing the presence of each individual species were developed based on the most recent critical literature (Table 16-7). Field sheets designed to assess and rank the habitat for each species were used during the site visit. Each habitat criterion in the field sheets was assigned a ranking from 0-3 based on the following parameters:

- 0 ranking: 0-25% cover
- 1 ranking: 26-50% cover
- 2 ranking: 51-75% cover
- 3 ranking: 76-100% cover.

Monitoring of available habitat for listed species was conducted whenever a significant change in micro or macro habitat was observed. The scores for each species were then tallied for each site and ranked into potentially "poor", "good" and "excellent" habitat.

Impoundment Study Area

All relevant existing data were loaded into a GIS. Data included:

- Hydroacoustic data provided by Seqwater and collected by Infofish. This included bathymetry and shapefile outputs of LWD presence.
- LiDAR, satellite imagery and aerial imagery.
- Drone-generated orthomosaics collected during the site visit described above. Where access allowed, a Phantom 4 RTK drone was deployed to capture aerial imagery of the impoundment margins. Captured imagery was used to generate recent ortho-mosaics of the margins. Detailed methods of the drone image acquisition are provided in the Hydrobiology assessment report.

The above datasets were used to divide the impoundment into different habitat condition zones, using the same rating system of habitat quality as described above. For fish species, the entire area of the waterbody was categorised into the different habitat condition zones, while for all other species, the impoundment margins were categorised as these species were unlikely to inhabit the deeper open water of the impoundment.

Table 16-7: Habitat requirements of listed species

Species	Australian lungfish	Mary River cod	White-throated snapping turtle	Mary River turtle	Giant Barred Frog	Tusked Frog	Platypus
Still/ low flow water	✓	✓	✓	✓	✓	✓	✓
Permanent water	✓		✓	✓	✓	✓	✓

Species	Australian lungfish	Mary River cod	White-throated snapping turtle	Mary River turtle	Giant Barred Frog	Tusked Frog	Platypus
Submerged/ emergent vegetation	✓		✓	✓			
Overhanging vegetation		✓	✓	✓			
Dense canopy cover					✓	✓	
Low ground vegetation cover					✓	✓	
Unconsolidated banks			✓	✓			✓
Fine sediment							✓
Steep banks					✓	✓	
Leaf litter					✓	✓	
Riffles			✓	✓			
Large boulders			✓	✓			
Large woody debris	✓	✓	✓	✓			
Undercut banks	✓	✓					✓

Results – Geomorphic (Physical) Habitat Assessment

River Styles Characterisation Assessment

A total of four distinct River Styles were identified in the downstream reach in Six Mile Creek (Table 16-8, Figure 16-4). Although most of reaches contained similar geomorphic features (lots of LWD, glides, runs, pools, entrenched channel type), the reaches could be distinguished based on differences in valley confinement, bed material and prominent geomorphic features and channel characteristics. The locations of geomorphic habitat (pools, riffles, runs/glides), LWD, and bank erosion are shown in Figures G-2 to G-4. These were used to assist in the aquatic habitat assessment.

Table 16-8: River Styles characterisation of Six Mile Creek 10 km downstream of the dam

No.	River Style	River Style Full Name	Distance Down Stream (km)	Main features
1	PC_BrMC_FpCab_DcFp_Sbed Fbed	Partly confined, bedrock margin-controlled, floodplain channel anabranches (secondary or flood channels), discontinuous floodplain, sand and fine-grained bed	0 – 3	Bed material mostly fines with larger concrete blocks and rocks (local influence) that have washed down from the bridge at the dam. Sandy silty bed, long runs. Large clusters of LWD with big logs crossing the channel. Sand bar deposition on the inside of bends. Large bank exposures on the outside of bends with erosion and deep pools on outside of bends. Discontinuous floodplain pockets Flood/secondary chute channels Large sand consolidated vegetated islands that divert flows. Sandy pool-riffle sequences. Deeper incised slot channel with high vertical banks towards mid-reach with high vertical banks – good habitat for platypus. Sandy banks, but trending towards more fine-grained clays and silts towards end of reach.

No.	River Style	River Style Full Name	Distance Down Stream (km)	Main features
2	C_BrMC_Ru_Sbed	Confined, bedrock margin-controlled, runs (glide, plane-bed), sand bed	3 – 4.5	Trending towards more confined valley compared with upstream, with the channel abutting the right bank valley margin, and only occasional floodplain pockets where valley is locally wider. Tributary joins in the upper sections of this reach, resulting in change of bed material, bringing in fine-coarse sands and some gravel. Incised slot channel with high banks. Longer continuous pools and run/glide features. Bed material mostly sands with small bank attached sandy bars. Some fines in the channel. Towards end of reach, the valley becomes fully confined providing constriction– channel occupies the valley floor with only small bank attached bars. Large clusters of LWD.
3	PC_BrMC_f[Ru_DcFp_Fbed	Partly confined, bedrock margin-controlled, runs, discontinuous floodplain, fine-grained bed	4.5 – 6.5	Incised slot channel with long continuous run-glide-pools. Channel widens as confinement changes. High steep banks and deeper cross channel. Channel boundary material comprising mostly fines, including silts, clays and sands. Large clusters of LWD. Occasional secondary/flood channel.
4	PC_PC_LSin_DcFp_FpMCu_Fbed	Partly confined, planform-controlled, low sinuosity, meander cutoff (neck cutoff, billabong), fine-grained bed	6.5 – 10	Incised slot channel with long continuous run-glide-pools. Low sinuosity driven by proximity to valley margins. Channel boundary material comprising mostly fines, including silts, clays and sands. Large clusters of LWD. Occasional secondary/flood channel. Gullying of valley margin.

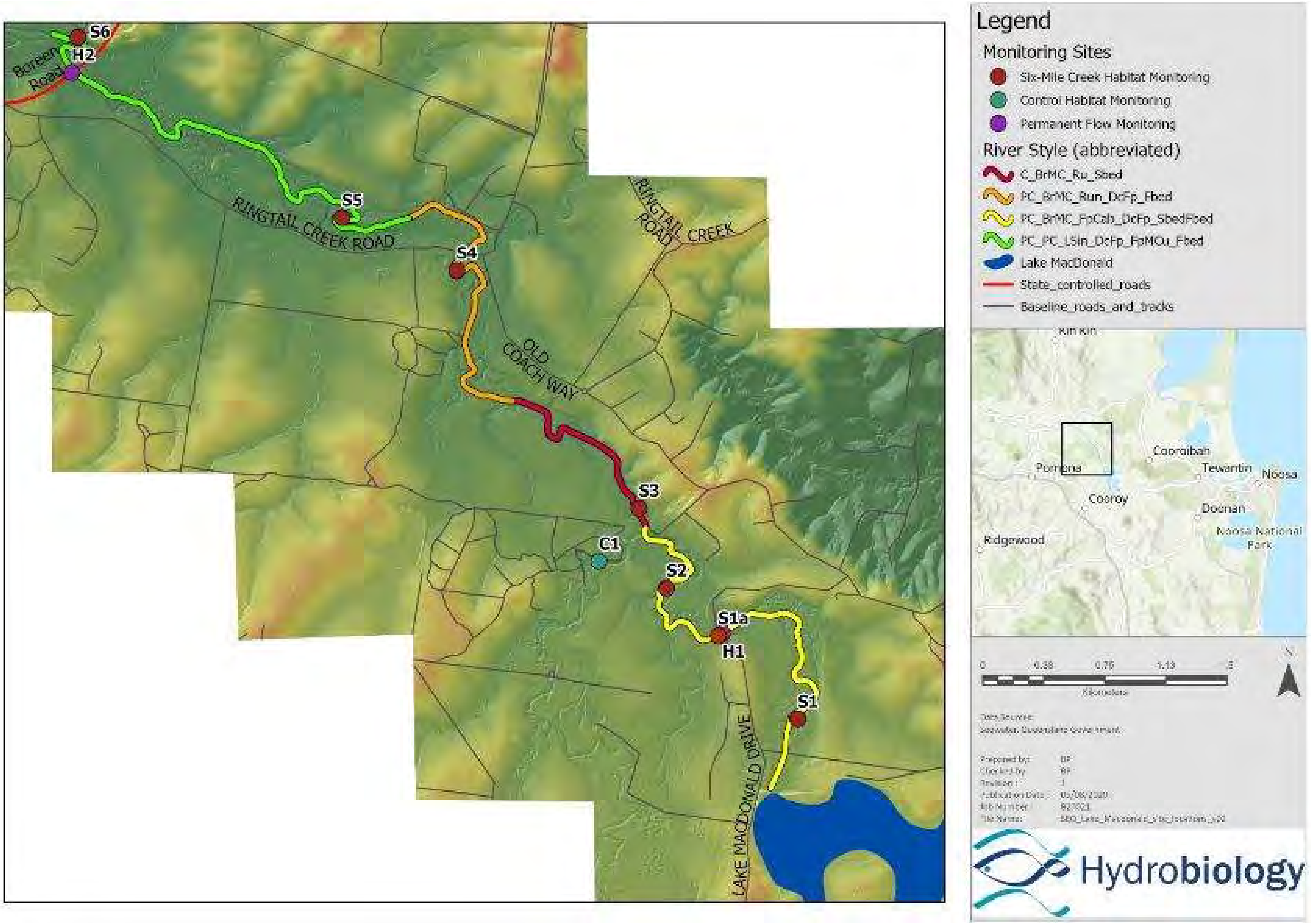


Figure 16-4: River styles and proposed monitoring site locations in the downstream study reach

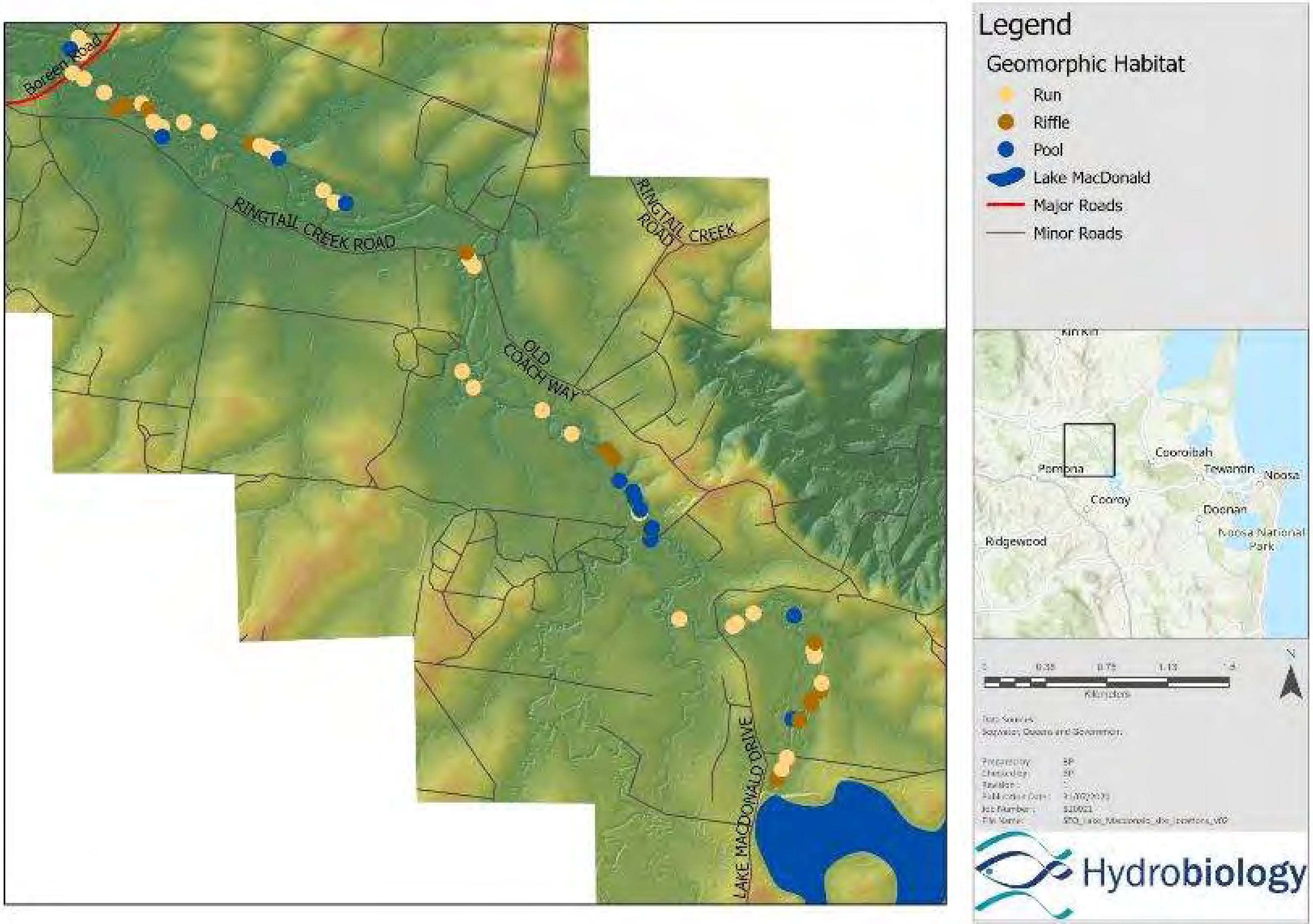


Figure 16-5: Geomorphic habitat features in the downstream study reach. Points indicate habitat until next downstream point

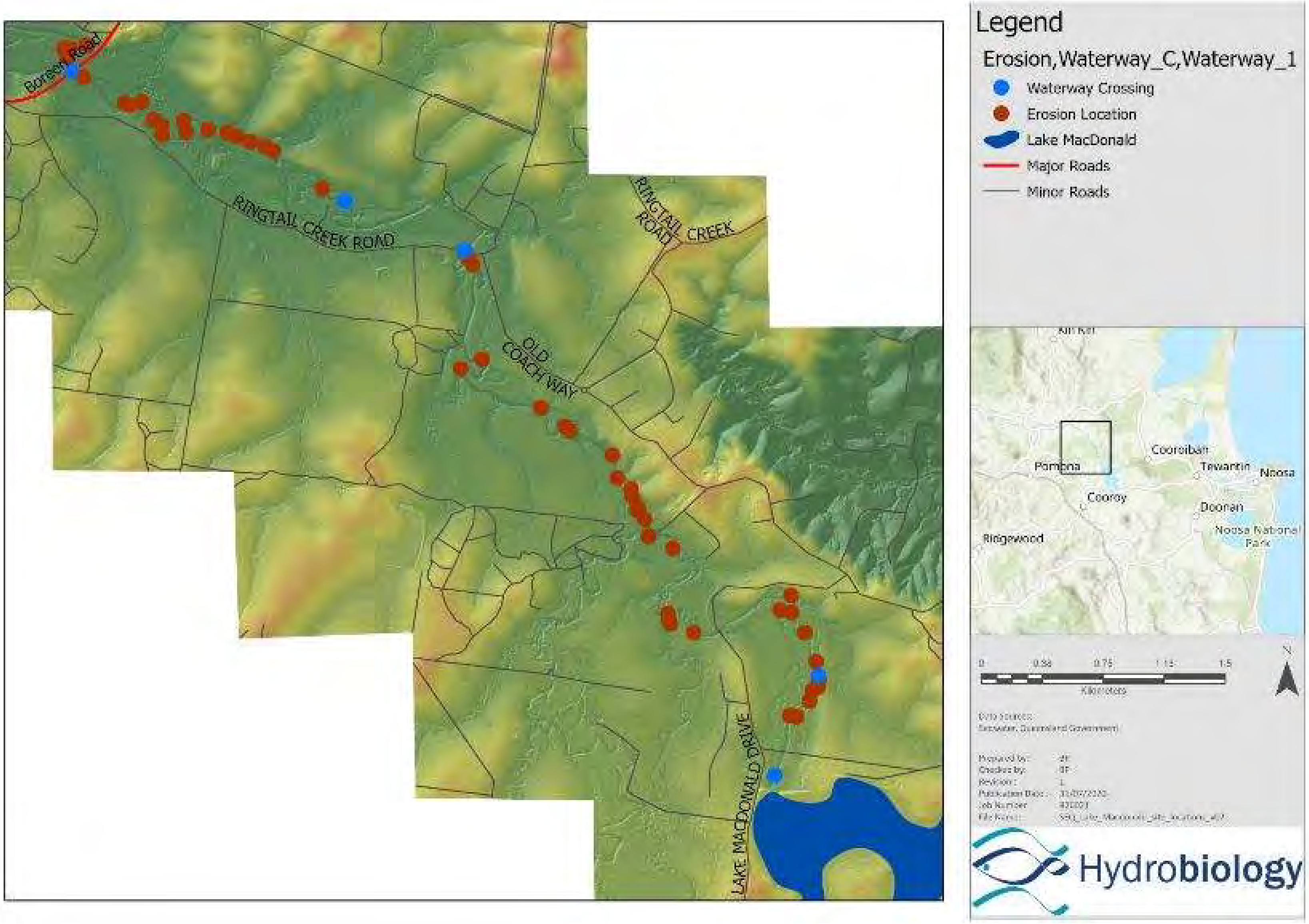


Figure 16-6: Bank erosion in the downstream study reach

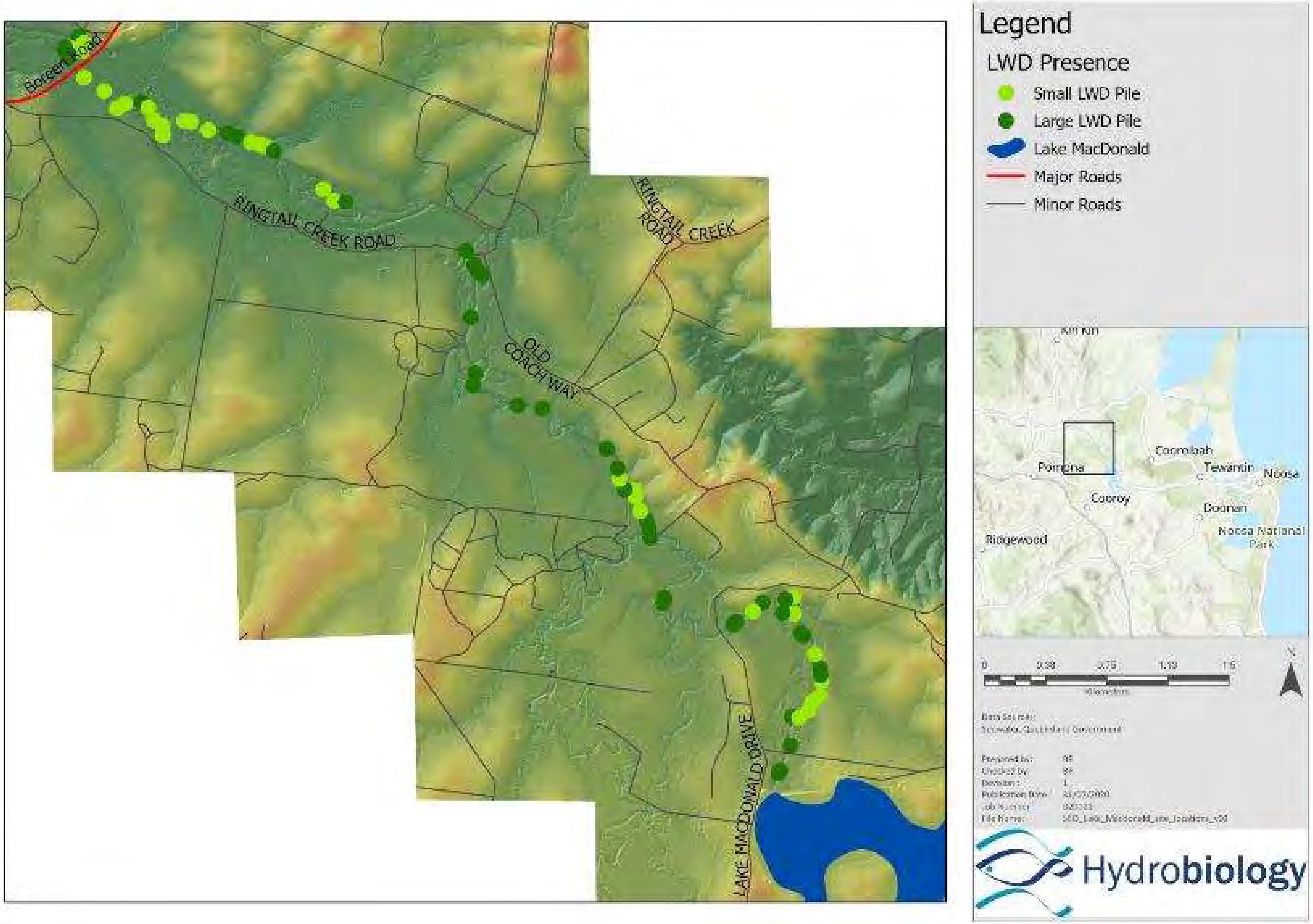


Figure 16-7: Distribution of LWD and large LWD clusters in the downstream study reach

Results – Aquatic Habitat Assessment

Downstream Study Reach

The habitat ratings for the listed species are shown in Figures G-5 to G-9 and a summary of key features is provided below:

- Mary River cod
  - The majority of upstream surveyed sites contained “excellent” potential habitat with further downstream sites on Six Mile Creek containing potentially “good” habitat. Sites closer to the dam are often characterised by complex microhabitat with a high incidence of LWD in channel and undercut banks at bends. The downstream sites have less LWD availability.
- Australian lungfish
  - Most sites contained “good” Australian lungfish habitat due to the presence of LWD and undercut banks. The presence of perennial still/ low flow waters also assured suitable habitat. The majority of “excellent” sites were located closer to the dam where the channels were wider, and pools were generally deeper. One of the main contributing factors to potential lack of habitat at sites further downstream was the depth of pools available, which may be a result of natural seasonal variations.
- Mary River and white-throated snapping turtles
  - Sites were largely characterised by “good” habitat in the upper 5 km and “poor” habitat further downstream. Although the LWD and undercut banks provided habitat throughout the downstream reach, submerged/emergent macrophytes were only at the more downstream sites, likely contributing to the absence of suitable habitat. Where there are adjacent urban areas downstream the incidence of predation is likely to reduce distribution.
- Giant Barred and Tusked Frogs
  - Habitat requirements for the giant barred frog and tusked frog were grouped together as they share similar criteria. The majority of sites surveyed contained either “excellent” or “good” potential habitat. Vegetation density, channel incision, leaf litter and ground cover were the parameters that dictated habitat scores for this species.
- Platypus
  - Most surveyed habitat along Six Mile Creek was classified as “excellent”. Water was generally clear at all sites, although there is potential for higher turbidity during flow events. Despite the presence of riparian clearing at some downstream locations, habitat remained ideal due to the substrate composition. The likely limiting factor to their presence would be periods of low/no rainfall.

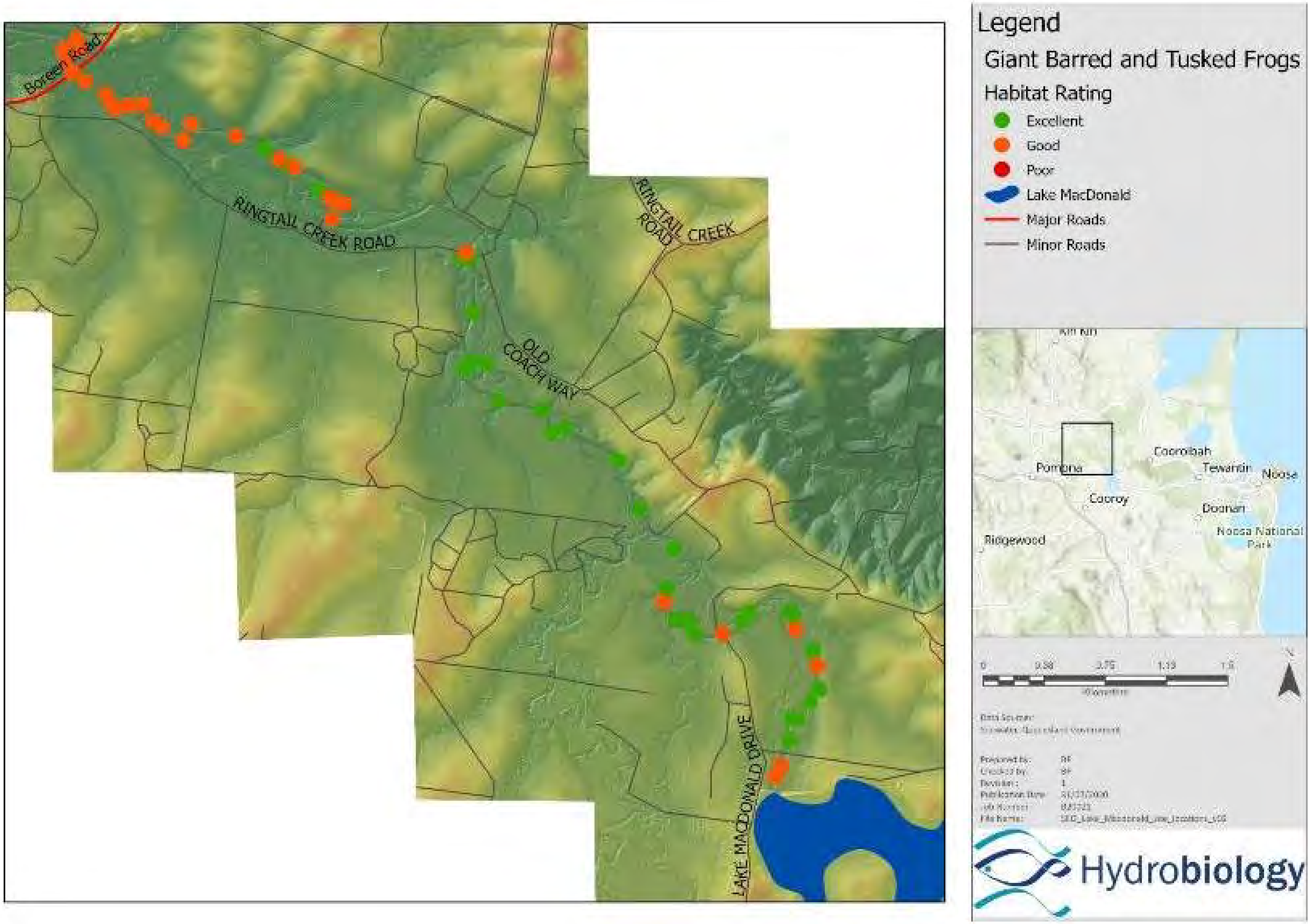


Figure 16-8: Habitat rating scores for giant barred and tusked frogs in the downstream study reach. Points indicate rating to the next downstream point.

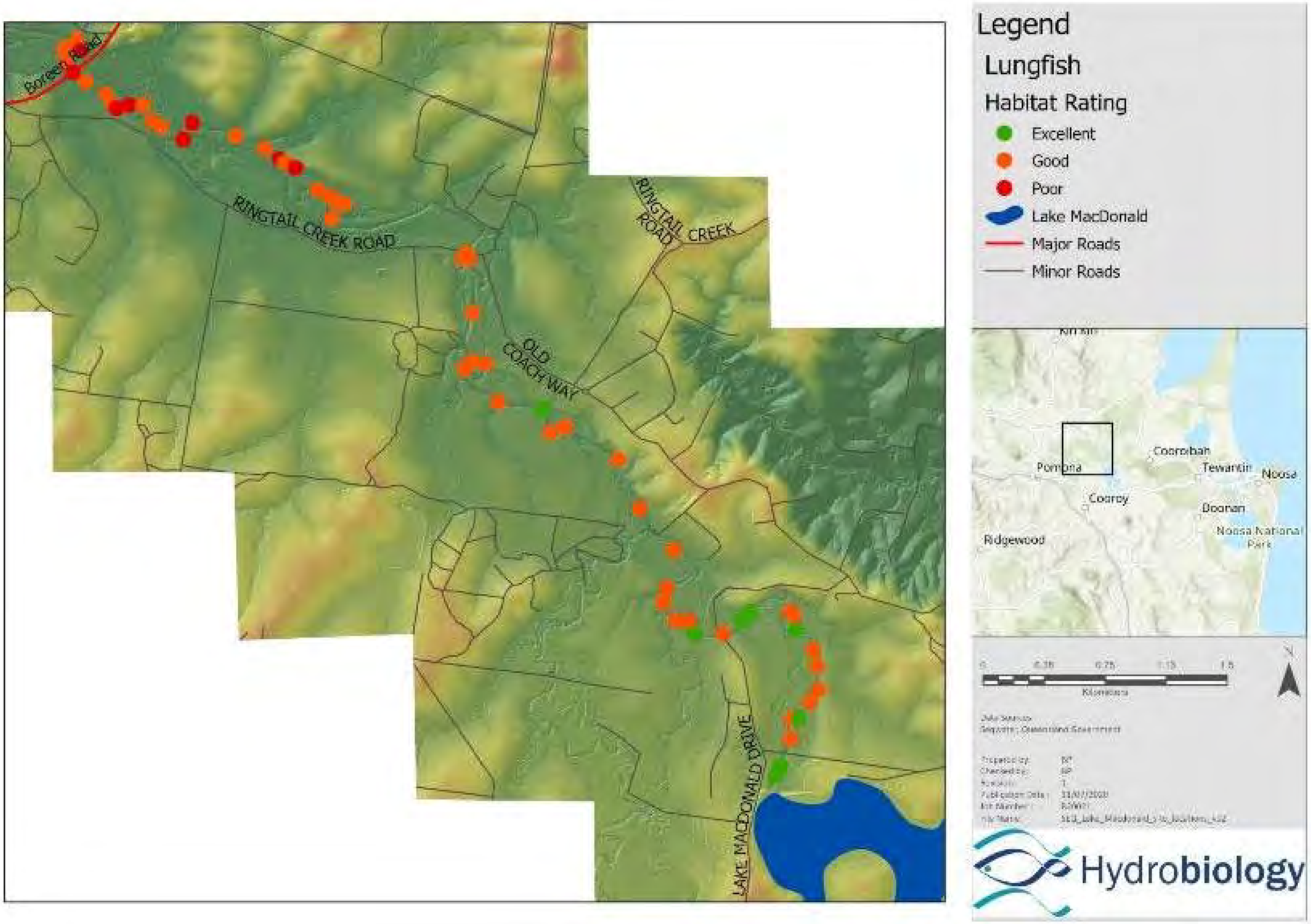


Figure 16-9: Habitat rating scores for the lungfish in the downstream study reach. Points indicate rating to the next downstream point.

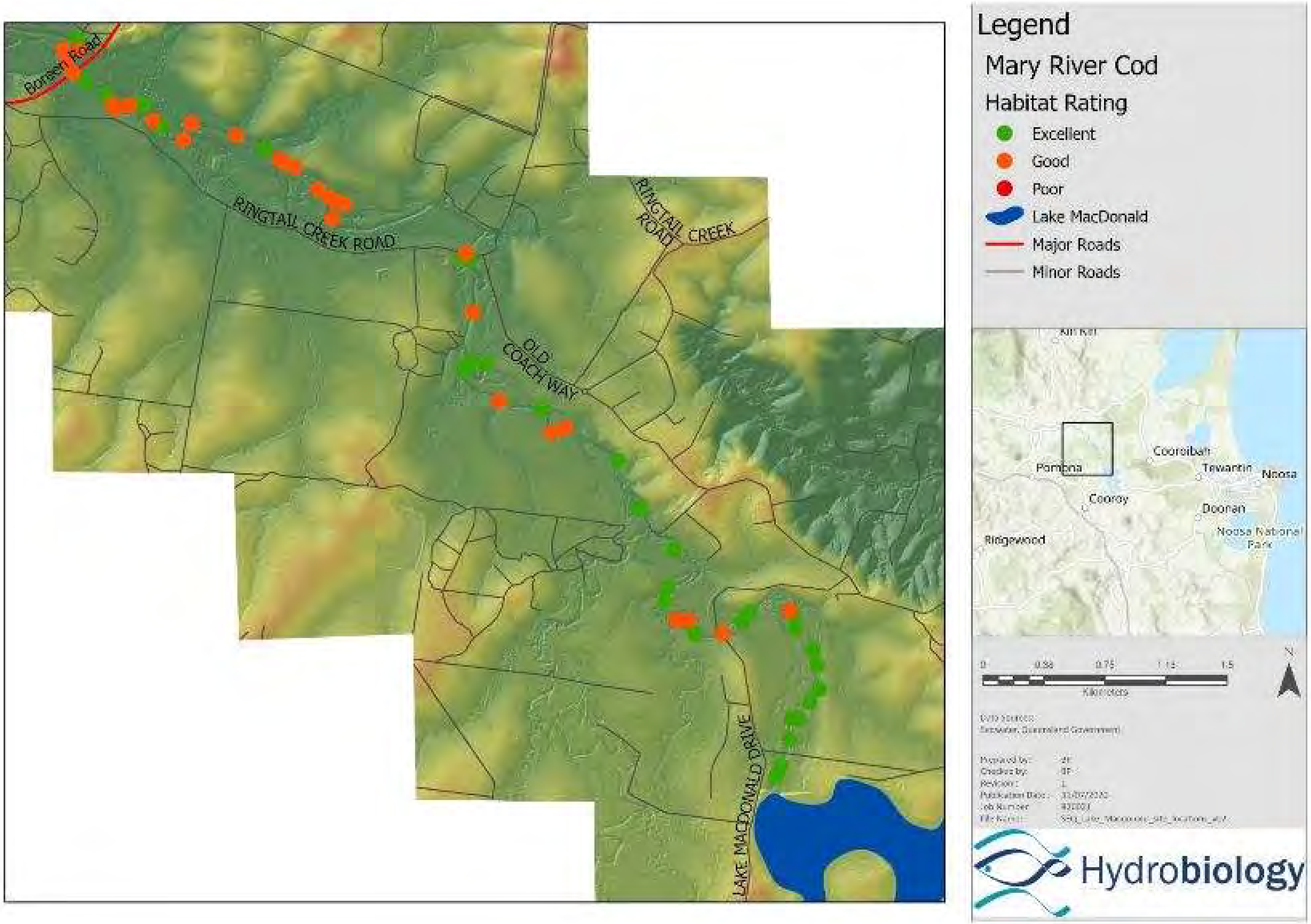


Figure 16-10: Habitat rating scores for Mary River cod in the downstream study reach. Points indicate rating to the next downstream point.

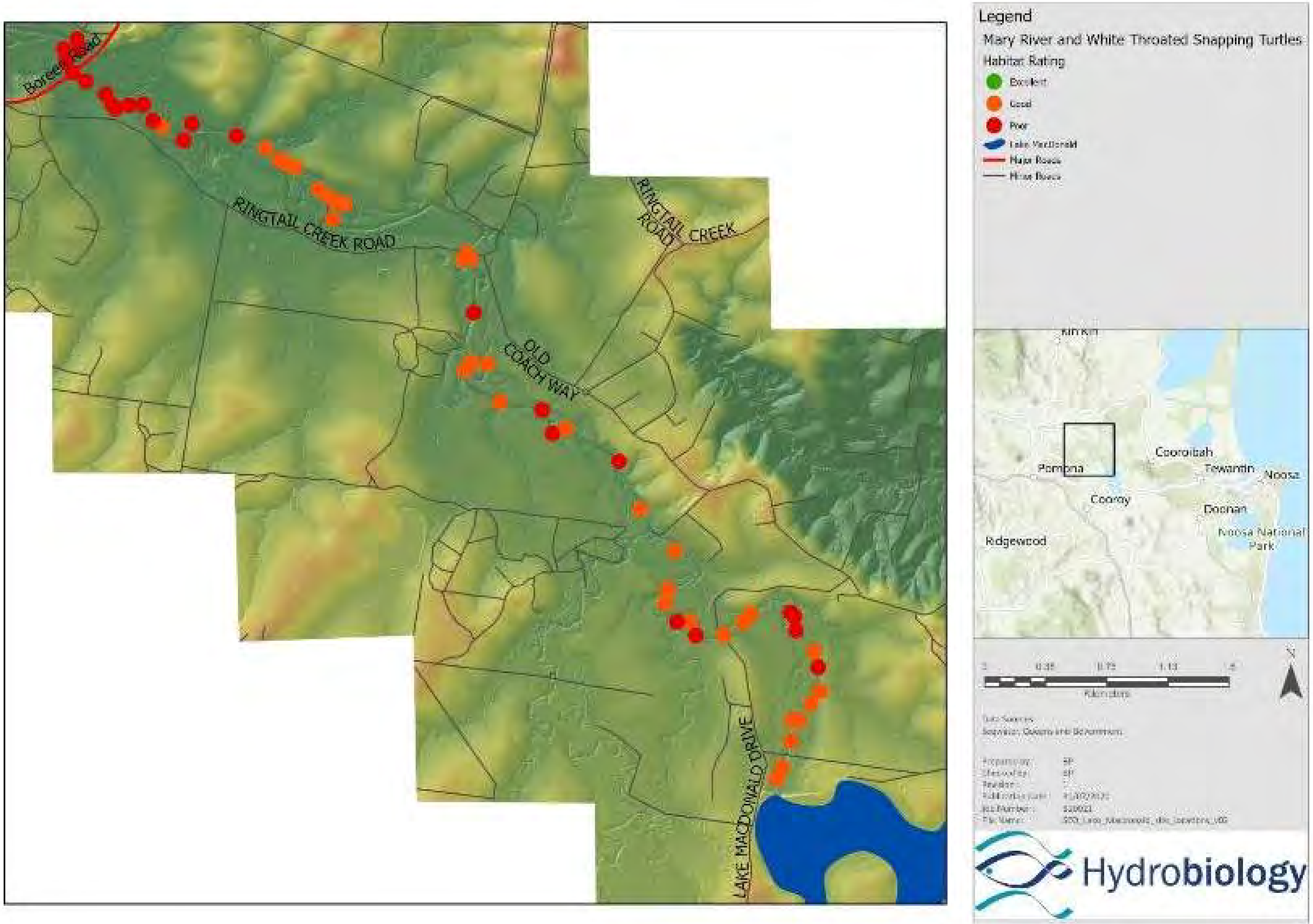


Figure 16-11: Habitat rating scores for both turtle species assessed in the downstream study reach. Points indicate rating to the next downstream point.

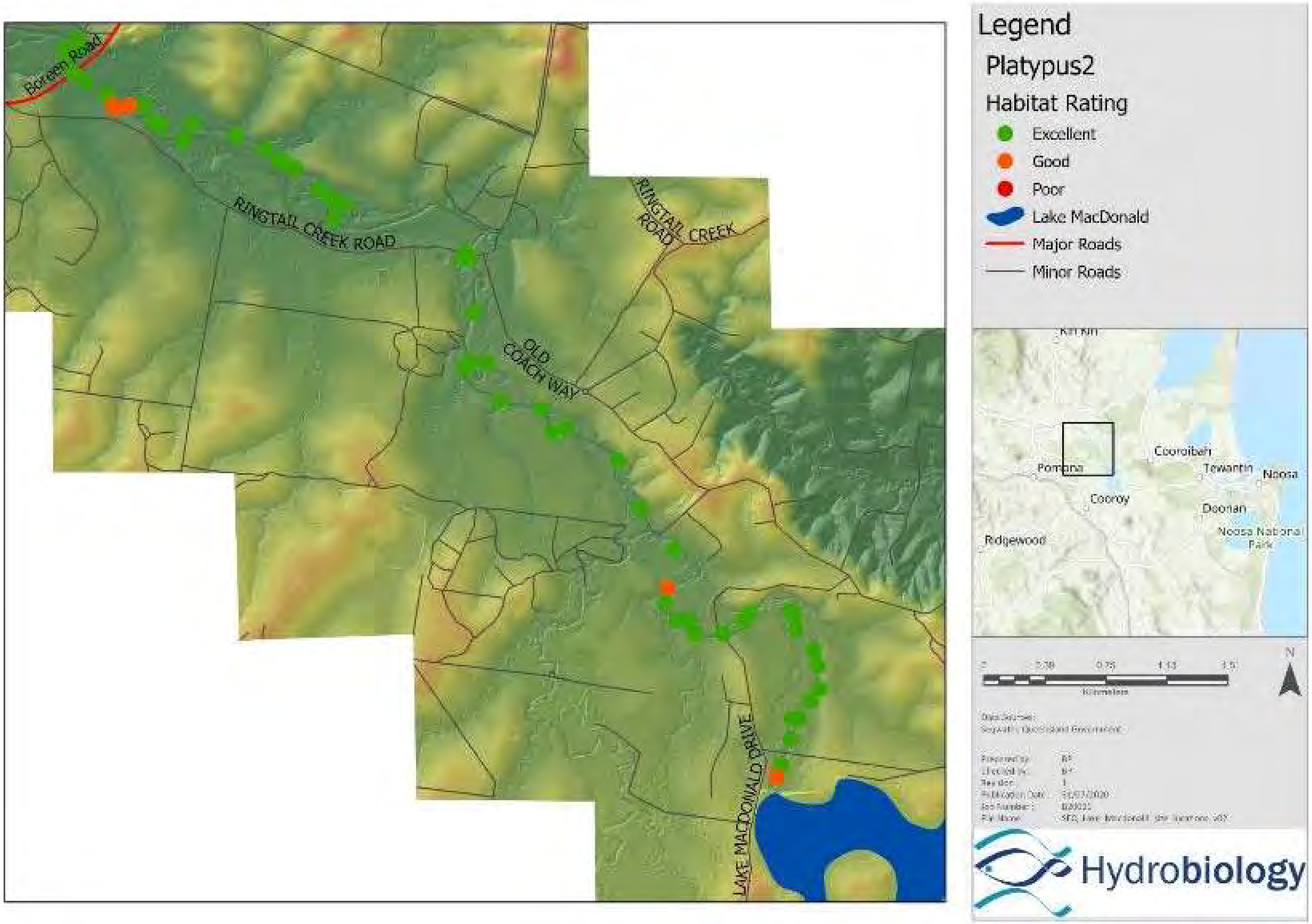


Figure 16-12: Habitat rating scores for the platypus in the downstream study reach. Points indicate rating to the next downstream point.

Lake Macdonald

Habitat rating assessment results for relevant species are shown in Figures G-10 to G-13. Key results were:

- Much of the lake provides excellent subsistence habitat for Mary River cod and lungfish, but is unlikely to provide habitat for their entire lifecycles.
- There are small areas of excellent habitat and large areas of good habitat for turtles.
- The majority of the lake margins provide poor habitat for the frog species.
- The majority of the lake consists of poor habitat for platypus, although some of the upper reaches are rated as excellent.

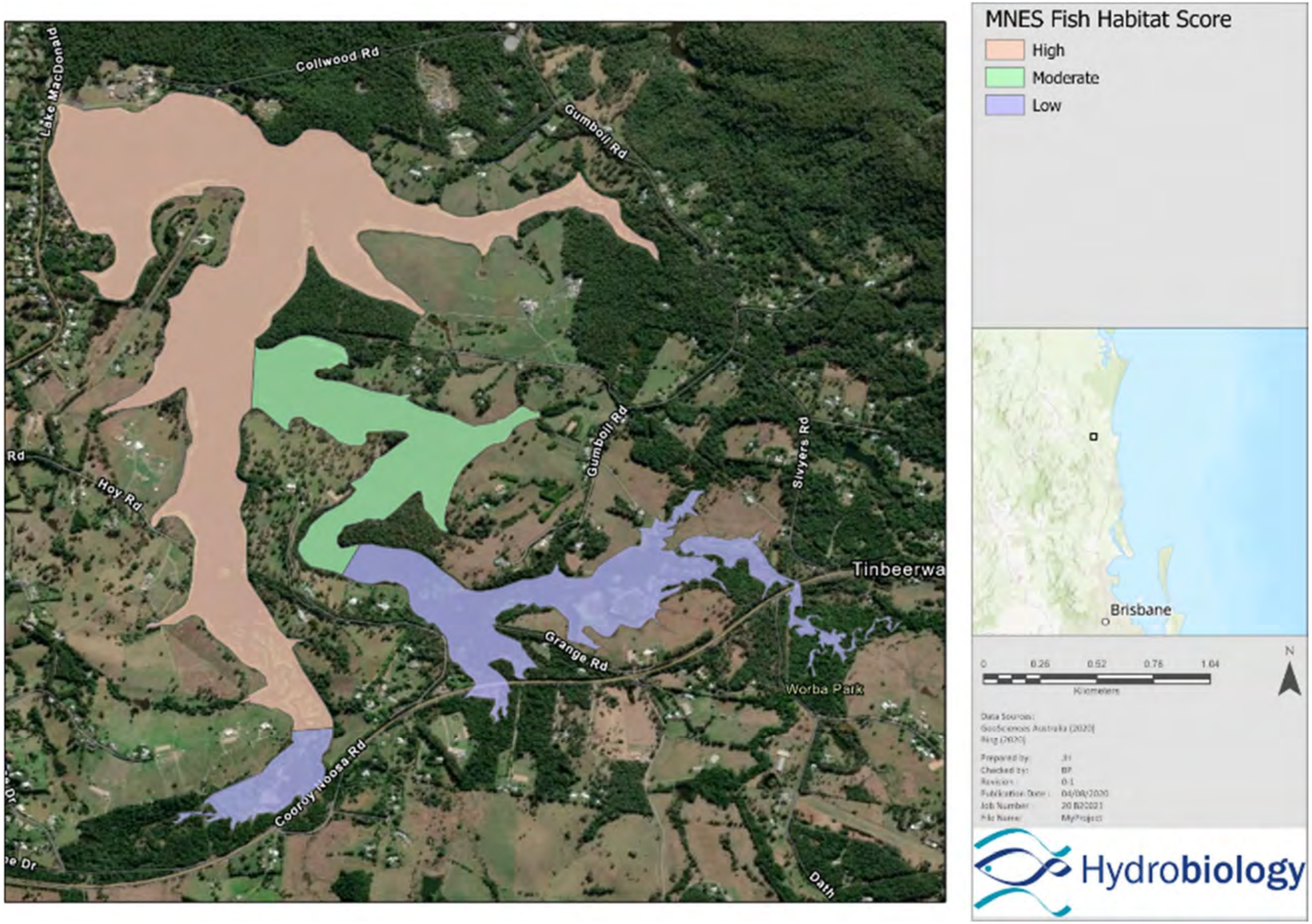


Figure 16-13: Habitat rating scores for Mary River cod and lungfish in the impoundment study area.

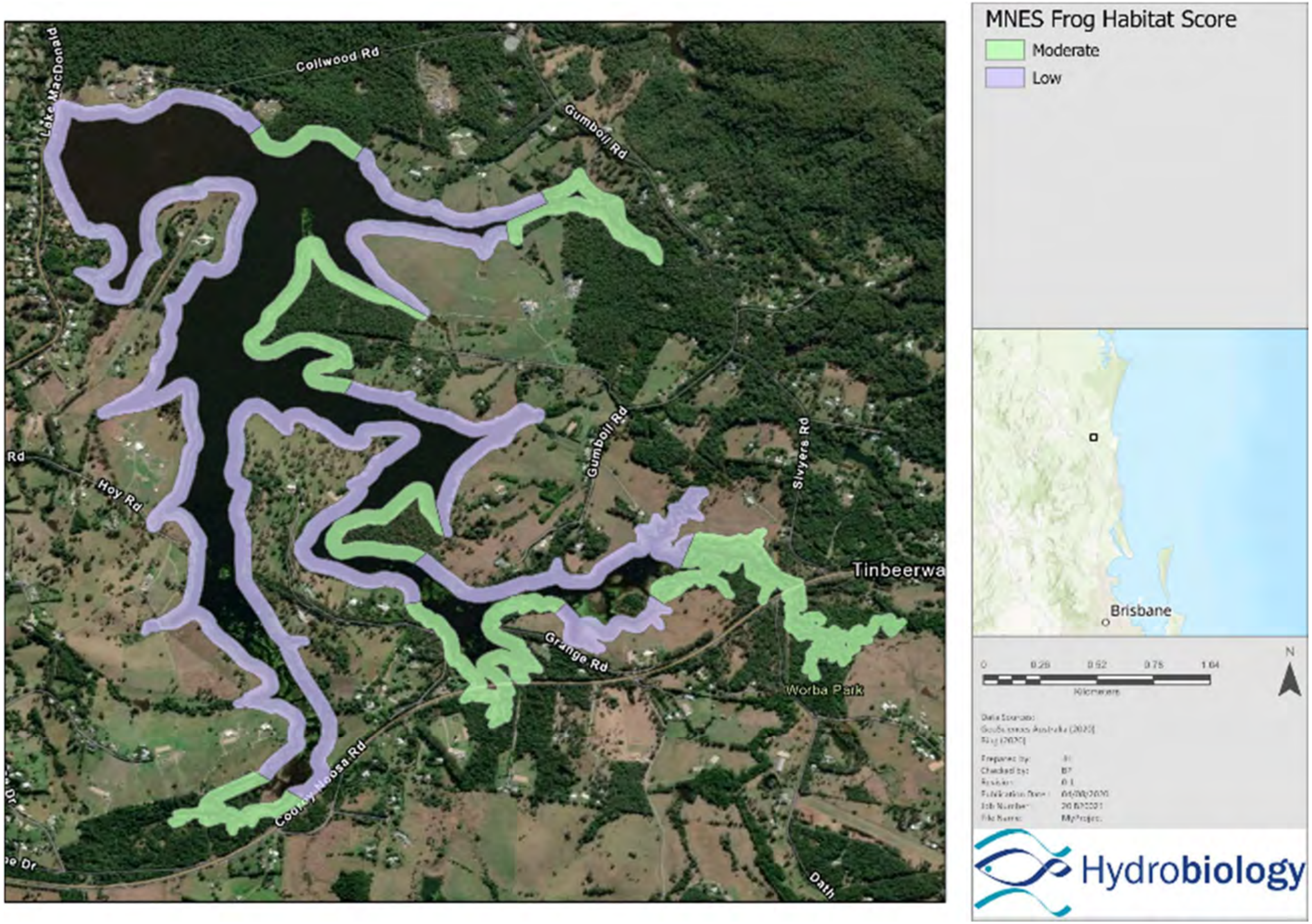


Figure 16-14: Habitat rating scores for the Giant barred frog and tusked frog in the impoundment study area

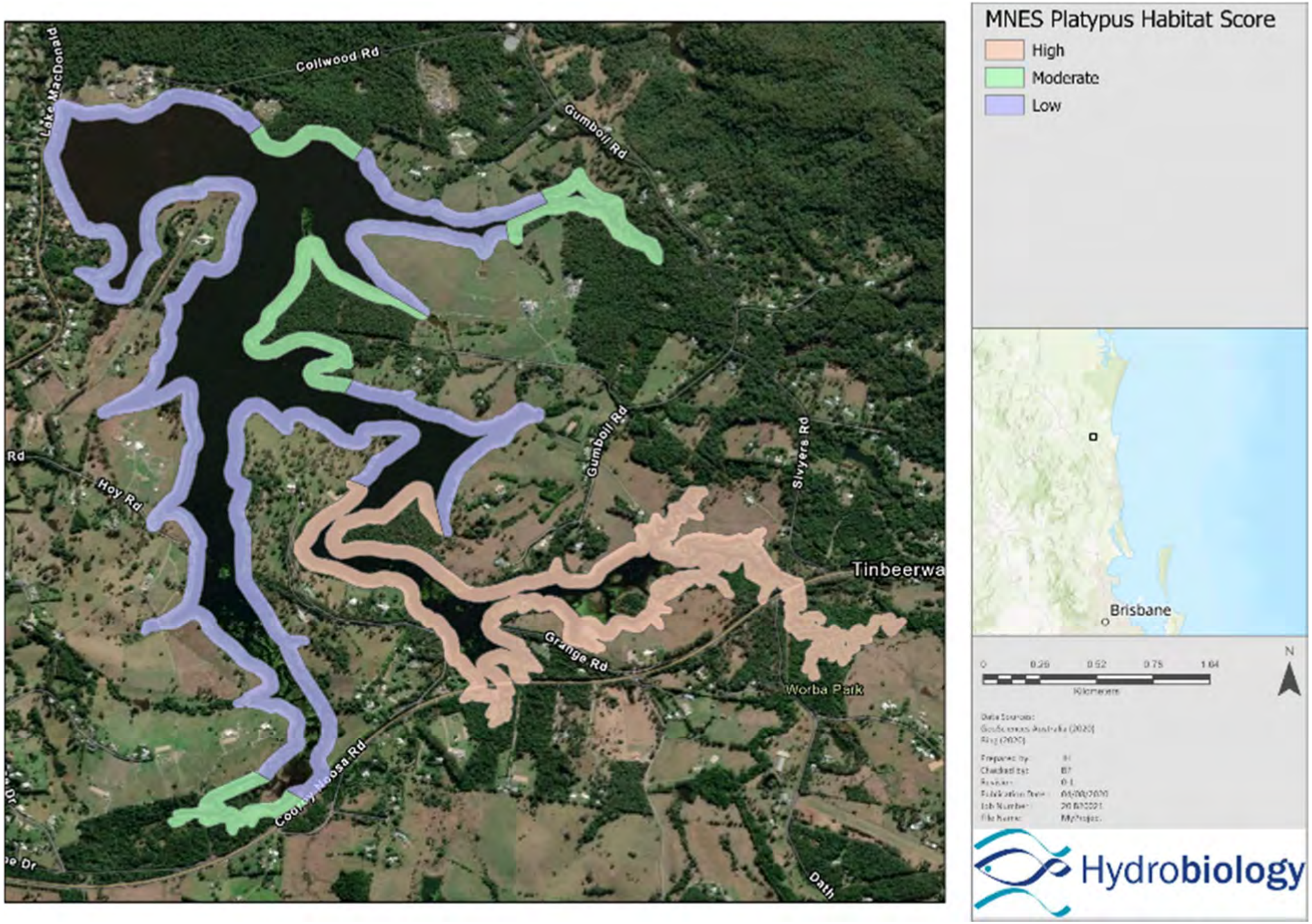


Figure 16-15: Habitat rating scores for the platypus in the impoundment study area

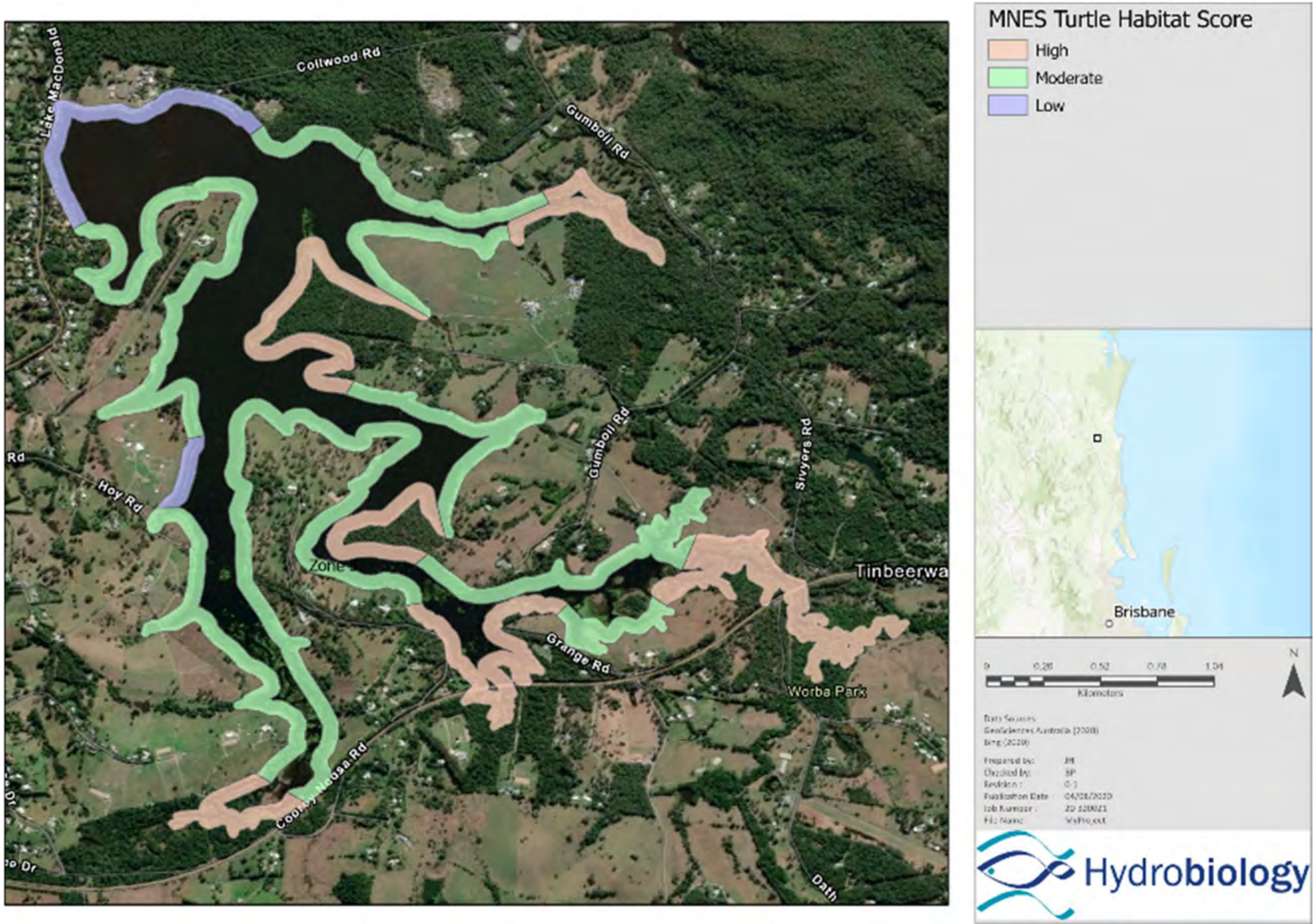


Figure 16-16: Habitat rating scores for the Mary River and white-throated snapping turtles in the impoundment study area.

Appendix H

Relocation Site Assessment Report

Freshwater Ecology Pty Ltd

Lake Macdonald
Aquatic Fauna Relocation Sites
Preliminary Assessment

Prepared for Seqwater
January 2020

Document Control Summary

Document Revisions

Project Title		Lake Macdonald Aquatic Fauna Relocation Sites Preliminary Assessment		
Project Manager		Dr Timothy Howell		
Document Title		FE19039_LakeMacdonald		
Electronic File Name	**Status**	**Prepared by**	**Reviewed**	**Date**
FE19039_LakeMacdonald_relocation_DRAFT	Draft	TDH	HQT	14/04/2020
FE19039_LakeMacdonald_relocation_FINAL	Final	TDH	HQT	27/04/2020

Document Distribution

Electronic File Name	Status	Issued to	Format	Issued by
FE19039_LakeMacdonald_relocation_DRAFT	Draft	Steven Cox	MS Word	TDH
FE19039_LakeMacdonald_relocation_FINAL	Final	Steven Cox	PDF	TDH

Cover photo: Mary River at Moy Pocket.

Executive summary

To facilitate construction upgrades on the Six Mile Creek Dam wall, Lake Macdonald will need to be partially dewatered and will require the salvage and relocation of aquatic fauna. Lake Macdonald has a surface area of approximately 260 hectares and 8,818 megalitres at full supply levels and is stocked for recreational angling, as well as supporting indigenous fish species. The salvage operation will require a range of potential release sites available to facilitate the relocation of aquatic fauna. This report provides a preliminary assessment of the potential carrying capacity of aquatic fauna relocation sites.

A number of constraints were placed on the selection of aquatic fauna relocation sites from both federal and Queensland government authorities to ensure the protection of listed threatened species.

A desktop review was undertaken on the existing information available about the life cycles and habitat requirements of aquatic fauna known, or with potential, to be present in Lake Macdonald. This included the known distribution of threatened aquatic fauna species that occur within the Mary River catchment.

Seqwater provided Freshwater Ecology with a preliminary list of 20 potential aquatic fauna relocation sites. Further sites were identified and added to the potential site list. A visual assessment was made of each site. This provided a short list of the potentially suitable sites that were sampled to assess their suitability as relocation sites for aquatic fauna salvaged from Lake Macdonald.

Field surveys were undertaken in January 2020 following an extended period of low rain fall and low water levels. While these conditions did not represent ‘normal’ conditions they allowed an assessment of the potential release sites under the more extreme conditions that relocated fauna would likely have to survive under. Sites were assessed for aquatic habitat, *in situ* water quality, aquatic macrophytes, macroinvertebrates, fish, turtles and platypus at various levels of effort based on site conditions at the time and potential suitability identified in the preliminary visual assessment.

Desktop and field surveys were further informed by members of Queensland Fisheries, Mary River Catchment Coordinating Committee (MRCCC), Noosa Landcare and Tiaro Landcare. Their local knowledge of the aquatic flora / fauna and waterways provided valuable inputs into the development of this assessment.

Contents

Tables

Figures

1. Project background

Lake Macdonald is located on Six Mile Creek, approximately 10 km from the centre of Cooroy on the northern end of the Sunshine Coast. Six Mile Creek is one of the larger tributaries of the Mary River. Lake Macdonald is formed by the Six Mile Creek Dam which is scheduled for an upgrade as part of Seqwater's asset maintenance program. Capital works are required to upgrade the dam to meet the national guidelines set by the Australian National Committee on Large Dams (ANCOLD). Water levels in Lake Macdonald will be lowered to about 5-10 per cent of its full supply level prior to commencement of dam upgrade construction activities. During the dam lowering process aquatic fauna will need to be captured and relocated.

The aquatic fauna recovery plan (SMEC 2019) identifies the aquatic fauna known, or with potential, to be present in Lake Macdonald. The term aquatic fauna refers to large bodied fish species, turtles and platypus only. It is understood that smaller fish species will remain in the lake at the lowered water levels during dam wall reconstruction.

The lowering of the water levels in Lake Macdonald is planned to be undertaken over approximately three months to minimise rapid reduction in water quality, aquatic fauna stranding and bank erosion (SMEC 2019). Prior to dewatering a baseline assessment will be undertaken of aquatic fauna assemblages in Lake Macdonald and a quantitative method for evaluating aquatic fauna salvage will be finalised and baseline.catch per unit effort (CPUE) will be calculated. The aquatic fauna salvage is planned to be undertaken in accordance with the quantitative method but will be adaptive in response to observations and subsequent quantitative measurements. The aquatic fauna salvage may be undertaken in a staged approach, or may be undertaken continuously, depending on the preferred methodology to be determined closer to commencement of the project. three phases: at 30% lake capacity, 10% lake capacity and 2-5% lake capacity. Salvage of each phase will be continued until 20% or less of the CPUE of the previous phase has been achieved.

A preliminary assessment of potential aquatic fauna relocation sites is required to inform the Lake Macdonald Water Lowering – Adaptive Management Plan (SMEC 2019). Immediately prior to commencement of the dewatering of Lake Macdonald baseline surveys of the proposed relocation sites will be undertaken again to provide an understanding of the baseline conditions at that time.

2. Desktop Review

2.1. Aquatic fauna species

The aquatic fauna species considered in this assessment include threatened and non-threatened aquatic fauna known, or with the potential to, occur in Lake Macdonald. A list of fish and turtle species known, threatened species that have the potential to, occur in Lake Macdonald is provided in Tables 1 and 2 respectively.

Table 1: Fish species known, and threatened species with potential to, occur in or upstream of Lake Macdonald

Scientific name	Common name	Status
Large bodied indigenous fish		
Anguilla australis	southern shortfin eel	Known
Anguilla reinhardtii	longfin eel	Known
Leiopotherapon unicolor	spangled perch	Known
Maccullochella mariensis	Mary River cod	Known
Nematolosa erebi	bony bream	Known
Neoceratodus forsteri	Australian lungfish	Potential
Tandanus tandanus	eel-tailed catfish	Known
Large bodied translocated native fish		
Amniataba percoides	banded grunter	Known
Arrhamphus sclerolepis	snubnose garfish	Known
Bidyanus bidyanus	silver perch	Known
Macquaria novemaculeata	Australian bass	Known
Macquaria ambigua	golden perch	Known
Scleropages leichardti	southern saratoga	Known
Small bodied indigenous fish		
Ambassis agassizii	Agassiz's glassfish	Known
Craterocephalus fulvus	unspecked hardyhead	Known
Hypseleotris spp.	carp gudgeon species	Known
Melanotaenia duboulayi	crimson-spotted rainbowfish	Known
Mogurnda adspersa	purple spotted gudgeon	Known
Philypnodon macrostomus	dwarf flathead gudgeon	Known
Philypnodon grandiceps	flathead gudgeon	Known
Retropinna semoni	Australian smelt	Known
Exotic pest fish species		
Gambusia holbrooki	gambusia	Known
Oreochromis mossambicus	tilapia	Potential
Xiphophorus maculatus	platy	Known
Xiphophorus hellerii	swordtail	Known

Table 2: Turtle species known, and with potential to, occur in or upstream of Lake Macdonald

Scientific name	Common name	Status
Chelodina longicollis	Eastern long-necked turtle	Known
Chelodina expansa	Broad-shelled turtle	Potential
Elusor macrurus	Mary River turtle	Potential
Elseya albagula	White-throated snapping turtle	Potential
Emydura krefftii krefftii	Krefft's turtle	Known
Wollumbinia latisternum	Saw-shelled turtle	Known

2.1.1. Threatened species

The five species of aquatic fauna identified as threatened under the national Environment Protection and Biodiversity Conservation Act 1999 (the EPBC Act) (1999) and the Queensland Nature Conservation Act (NC Act) (1992) known, or with the potential to, occur in Lake Macdonald are Mary River cod (*Maccullochella mariensis*), Australian lungfish (*Neoceratodus forsteri*), Mary River turtle (*Elusor macrurus*), white-throated snapping turtles (*Elseya albagula*) and platypus (*Ornithorhynchus anatinus*). Species profiles for each threatened species are provided in Appendix A.

Mary River cod are listed under the EPBC Act as Endangered. While not listed as a threatened species under the NC Act (1992), they are a protected as no-take species in Queensland. They only occur naturally in the Mary River catchment but have been stocked in other catchments. The current distribution in the Mary River catchment has been estimated to be 30% of historical ranges. More than 110,000 juveniles have been stocked into Lake Macdonald between 1983 and 2016 (MRCCC pers. comm.). Survivability of juveniles and current numbers of Mary River cod in Lake Macdonald are not known, however they are occasionally caught by recreational anglers targeting other species.

Australian lungfish are listed under the EPBC Act as Vulnerable. While not listed as a threatened species under the NC Act (1992), however, they are protected as no-take species in Queensland. They occur in the Burnett, Mary and Brisbane River catchments with small numbers translocated in several other smaller catchments in south-east Queensland. While past sampling has failed to detect them in the lake there have been anecdotal reports of Australian lungfish sighted in the lake.

Mary River turtles are listed as Endangered under both the EPBC Act (1999) and the NC Act (1992). White-throated snapping turtles are listed as Critically Endangered under the EPBC Act (1999) and Endangered under the NC Act (1992). While there are no records of either species from Lake Macdonald there is the potential for them to be found there.

Platypus is a Special Least Concern species under the NC Act (1992) but is not threatened at National or State levels. Platypus are known to occur in the lake, as well as in Six Mile Creek both above and below the lake. There does not appear to be suitable burrowing habitat in Lake

Macdonald and it is considered likely the lake is used as foraging habitat, although the numbers of that utilise the lake and the extent and type of use of the lake habitat is unknown.

2.1.2. Non-threatened species

The non-threatened aquatic fauna species present in Lake Macdonald are comprised of translocated and naturally occurring species. Some of the translocated species are self-sustaining populations, while other species populations are maintained by stocking for recreational angling purposes. While there have been six species of indigenous small bodied fish recorded in Lake Macdonald, these will not be discussed further as it is planned to leave these species in the lowered waters in the lake during the construction period of the planned dam wall upgrades.

In addition to the Mary River cod, large numbers of Australian bass (*Macquaria novemaculeata*), golden perch (*Macquaria ambigua*) and silver perch (*Bidyanus bidyanus*) are stocked annually into Lake Macdonald but none reproduce under lake conditions. Southern saratoga (*Scleropages leichardti*) have been translocated into the lake and appear to have a self-sustaining small population. All these species are commonly targeted by recreational anglers.

Also targeted by recreational anglers are eel-tailed catfish whose populations appear to be self-supporting and likely represent fish that were in Six Mile Creek prior to the construction of the Six Mile Creek Dam. The other large bodied fish that are known to occur in, or upstream of, Lake Macdonald are shortfin eel (*Anguilla australis*), longfin eel (*Anguilla reinhardtii*), spangled perch (*Leiopotherapon unicolor*), bony bream (*Nematalosa erebi*), banded grunter (*Amniataba percoides*) and snubnose garfish (*Arrhamphus sclerolepis*). Banded grunter and snubnose garfish are not endemic to the catchment and have been released or have spread from accidental or deliberate introductions.

Three species of non-threatened turtles have been recorded in Lake Macdonald (eastern long-necked turtle, Krefft's turtle and saw-shelled turtle). Of these species the Krefft's turtle is known to thrive in lacustrine conditions and often dominate assemblages in large permanent lakes (Freshwater Ecology pers. obs.).

2.1.3. Pest species

There are four species of introduced pest species that have been recorded in Six Mile Creek or Lake Macdonald. Tilapia (*Oreochromis mossambicus*) and gambusia (*Gambusia holbrooki*) are restricted noxious fish under the Queensland Biosecurity Act (2014). Tilapia are not currently known to have been caught in Lake Macdonald but have been present in the causeway below the lake for some time (Timothy Howell pers. obs.). Gambusia are widespread and well established both in Lake Macdonald and Six Mile Creek. Swordtails (*Xiphophorus helleri*) have only been recorded in tributaries upstream of Lake Macdonald, but platys (*Xiphophorus maculatus*) are widespread and abundant through the lake. Neither species are listed as noxious species but both are considered pest species.

While a native species to Australia, banded grunter (*Amniataba percoides*) have been translocated outside their natural range are often considered to be a pest species. A juvenile banded grunter was recorded in Lake Macdonald by Freshwater Ecology staff on the 19th of February 2019. This would suggest that they are not only now in Lake Macdonald but are also reproducing in there.

2.2. Potential relocation waterways

2.2.1. Mary River and tributaries

The Mary River headwaters arise in the Conondale Ranges near the town of Maleny in south-east Queensland. It is approximately 290 kilometres in length and drains into the Great Sandy Strait near the town of Maryborough. The Mary River catchment supports several aquatic species that have restricted distributions and are considered threatened. This includes two species that do not occur naturally elsewhere (i.e. Mary River cod and Mary River turtle).

Only the upper reaches of the Mary River catchment (i.e. upstream of the town of Gympie) were considered for relocation of aquatic fauna due to the presence of existing populations of the threatened species, as well as close proximity to Lake Macdonald. The main tributaries that were considered, alongside the Mary River main channel, for potential release locations were Six Mile, Traveston, Belli, Coonan-Gibber, Yabba, Kandanga and Amamoor Creeks.

The Mary River catchment typically experiences a subtropical summer dominated rainfall pattern, although this is variable across the catchment. There are only two impoundments on the Mary River itself, although there are several on tributaries with the most significant being Baroon Pocket Dam on Obi Obi Cree, Borumba Dam on Yabba Creek, and Lake Macdonald on Six Mile Creek.

Six Mile Creek is one of the larger tributaries of the Mary River, that begins near the town of Cooroy and flows for approximately 60 km north-west before it joins the Mary River approximately 4.5 km south of Gympie. Lake Macdonald is located on Six Mile Creek.

Yabba Creek is an eastern flowing tributary of the Mary River. Borumba Dam is located in the upper reaches of the catchment and stores water for drinking as well as irrigation as part of the Mary Valley irrigation scheme. Water released for irrigation artificially maintains flow within the creek. Borumba Dam itself is a popular recreational fishery and is heavily stocked with fish and supports a self-sustaining southern saratoga population. Fish stocked into Borumba Dam are also found in Yabba Creek with southern saratoga, Australian bass, golden perch, silver perch and Mary River Cod having been recorded.

Kandanga and Amamoor Creeks were the other two main eastern flowing tributaries assessed for potential release sites. Both creeks have a smaller catchment area than Yabba Creek and do not have regulated flows, although there is a small weir on Kandanga Creek near the town of Kandanga).

Three smaller waterways in the Mary River catchment were also assessed for potential relocation sites; Coonan-Gibber Creek which confluences with Yabba Creek near the Mary River main channel, and Traveston and Belli Creeks which flow westerly into the Mary River main channel.

2.2.2. Cooloolabin Dam

Cooloolabin dam is located to the west of the town of Yandina in the headwaters of the South Maroochy River. It is managed by Seqwater. This lake was chosen as a potential relocation site due to it being a large water body with little to no known fish stockings and with a noxious aquatic weed in common with Lake Macdonald (Cabomba) already present. It was considered a good potential relocation site for the relocation of stocked large bodied fish that cannot be released into the Mary River catchment waterways (see section 3.1 on constraints on relocation sites). However, as Cooloolabin Dam is outside the Mary River catchment it is not a suitable site for the release of any freshwater turtles. There have been no official fish stocking events in the lake, however, there is anecdotal evidence that golden perch, silver perch and Australian bass may have been stocked unofficially more than ten years ago. There was no current information on the fish assemblages present in Cooloolabin Dam prior to the current study.

2.2.3. Hatchery

Mary River cod are bred to stock waterways for both recreational and conservation purposes. A private hatchery is currently performing the previous role of the Gerry Cook hatchery and has permits to collect fish for broodstock and the facilities to hold at least 20 adult Mary River cod individuals.

3. Site selection

3.1. Constraints on aquatic fauna relocation sites

An EPBC referral was submitted by Seqwater to the federal Department of Environment and Energy (DEE) for the proposed dam upgrade works in 2017. Approval was granted with a range of conditions, the following of which are relevant for the selection of potential aquatic fauna relocation sites:

- No Mary River Cod or Australian Lungfish are relocated to Tinana Creek or Obi Obi Creek.
- The Mary River Cod is the only protected matter that may be temporarily relocated (until Lake Macdonald is deemed suitable for restocking by a suitably qualified and experienced person). All other protected matter(s) including (but not limited to) the Australian Lungfish, must be permanently relocated
- Temporary relocation of the Mary River Cod can only be to the Gerry Cook Fish Hatchery, or other location that is approved by the Queensland Department of Agriculture and Fisheries prior to the commencement of the lake drawdown
- No Australian lungfish is relocated to farm dams

Discussion with Queensland Department of Agriculture and Fisheries (DAF) and relevant state government experts provided further direction on aquatic fauna relocation:

- The temporary relocation of Mary River Cod to a private hatchery that is currently performing the role that Gerry Cook hatchery performed in breeding fish for conservation and recreational stocking purposes has been approved
- Stocked non-EVNT fish species are not to be relocated into the Mary River catchment to prevent adversely impacting recovering populations of Mary River Cod
- No turtles are to be relocated outside of the catchment

Aside from the constraints by state and federal regulatory authorities was the inclusion of site suitability constraints suggested by various experts from DAF, Noosa Landcare, Tiaro Landcare and the Mary River Catchment Coordinating Committee. These included:

- An understanding that Six Mile Creek already supports an existing population of Mary River cod that is likely at carrying capacity.
- Most smaller creeks in the Mary River catchment have been stocked with juvenile Mary River cod in recent years and the introduction of large adults could negatively impact on any established populations.
- There is a high likelihood of a large number of Krefft’s turtles being present in Lake Macdonald and relocating this species to rivers and creeks in the Mary River catchment could exceed the carrying capacity negatively impacting both this species and other turtle species.
- Eastern long-neck turtles tend to be more common in wetlands and, if necessary, should be relocated to suitable wetland sites.

- Saw-shelled and broad-shelled are likely to present in lower abundance in Lake Macdonald and, where possible, riverine relocation sites should be sought.

Consideration for the potential spreading of Cabomba (*Cabomba caroliniana*) was given in the assessment of relocation sites.

3.2. Long list of potential sites

Twenty sites were provided by Seqwater at the initiation of this assessment. Nineteen of these sites were within the Mary River catchment and one in the Maroochy River catchment (Figure 1 sites 1-20). Following an initial site visual assessment, it was determined that a broader range of sites should be considered. A further 18 sites were added to the long list for consideration as potential aquatic fauna relocation sites (Figure 1, sites 21-38).

3.3. Site reconnaissance

Visual site assessments of the long list of potential sites were undertaken on the 21st of November 2019 and followed up with additional potential sites on the 4th of December 2019. At each site a visual assessment of twelve nominated criteria was made using the site suitability grading categories described in Table 3. Each assessment was made visually from a single point where there was clear and safe access. A site photograph was taken for all but one site (site 23 for which access was not considered safe).

A relocation site suitability summary is provided in Tables 4 (site reconnaissance 21/11/2019) and 5 (site reconnaissance 4/12/2019) showing the ratings assigned to the 12 assessment criteria and the overall site suitability rating. The overall site rating was made taking into consideration all the assessment criteria. Sites that rated as ‘good’ or ‘fair’ were considered for further assessment, while sites that rated as ‘poor’ were not considered further in this assessment. Site photographs and general comments on site suitability are provided in Appendix B.

Nine sites were considered to have ‘good’ potential for aquatic fauna relocation, and a further nine sites were considered to have ‘fair’ potential. However, several of these sites are likely to be able to support only relatively small numbers of individuals.

Five sites along Six Mile Creek, one on Yabba Creek and one on the Mary River were determined to have both good potential foraging and burrowing habitat for platypus. A further six sites were noted as having either good or fair habitat for both foraging habitat and burrowing habitat.

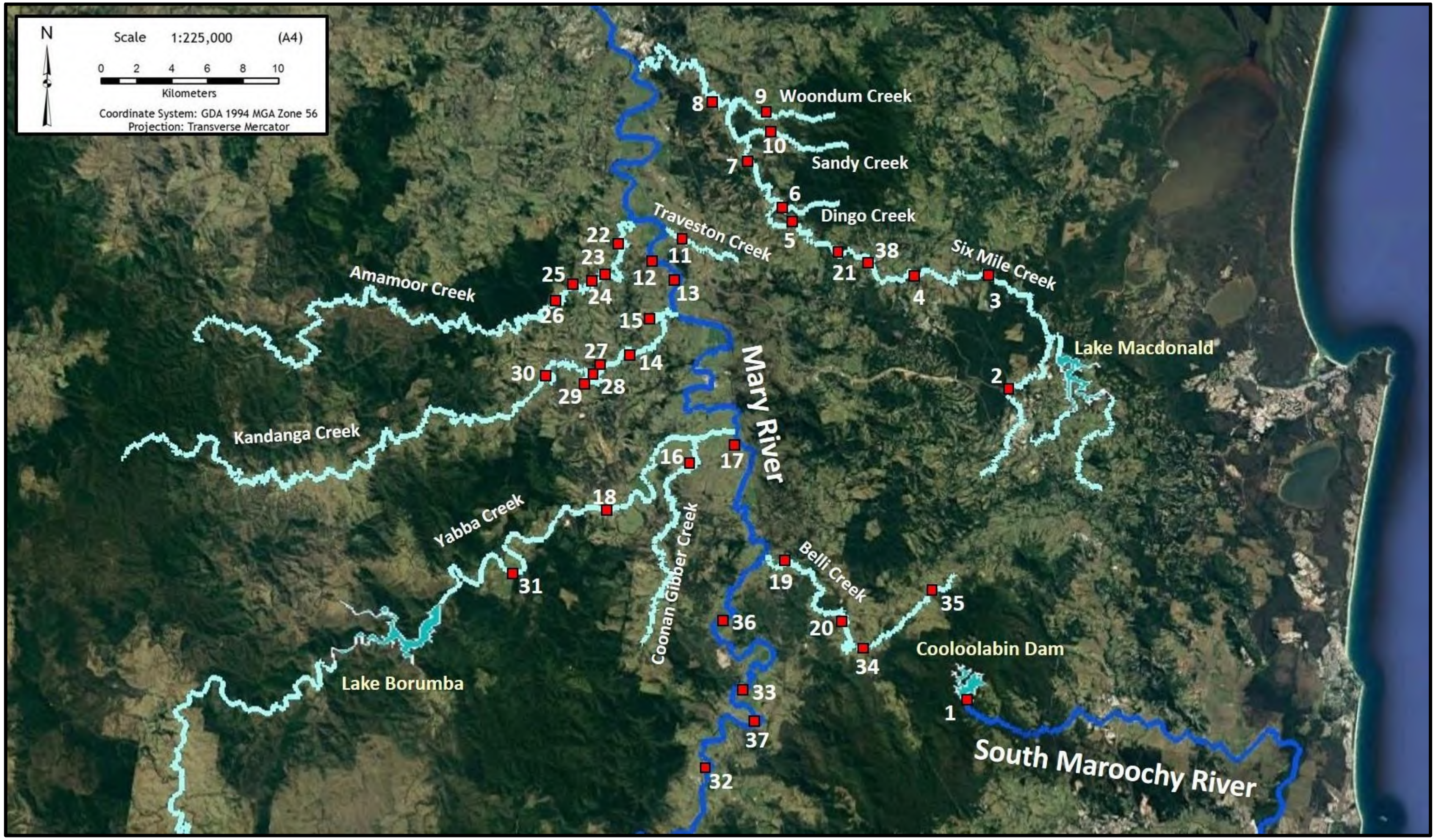


Figure 1: Location of the long list of potential sites

Table 3: Relocation site suitability grading category descriptions

Assessment criteria	Good	Fair	Poor
Parking access	Safe parking for a car and trailer away from passing traffic.	Reasonable parking for a single car, restricted for trailers.	Dangerous to park with little room from passing traffic.
Point access to site	Safe and reasonably easy access to water at a given point.	Accessible but potentially difficult with aquatic fauna transporting equipment.	Difficult with or without aquatic fauna transporting equipment.
Access along reach	Safe and reasonably easy access to water across the reach.	Safe and easy access at more than one point, however, deep water may be an issue.	Little access along the reach and deep water makes most of the reach inaccessible.
Boat launching	A suitable boat launching area is present.	-	Not possible to launch a boat.
Water permanency	Flowing and/or likely to contain large permanent pools.	Water restricted to mid - small sized pools.	Ephemeral.
Volume of water at the site	Good potential to be able to support relocated species. Typically, one or more large pools present.	A suitable volume to potentially take a small number of individuals of any species.	Little to no water present or likely to be present over an extended period of time.
Volume of water adjacent	Good potential to be able to support relocated EVNT species. Typically, one or more large pools present.	A suitable volume to potentially take a small number of individuals of any species. Or site access limited for aquatic ecosystem assessment.	Little to no water present or likely to be present over an extended period of time.
Water quality	Water quality that would be considered in the optimal range for fish and turtles.	Water quality that would be considered sufficient to support individual particular aquatic fauna species.	Little or no water present after an extended dry period.
Microhabitat diversity	A diverse variety of aquatic microhabitats present, with at least some with a high site coverage.	Several microhabitats present with various amounts of site coverage.	Little or no water present after an extended dry period.
Submerged macrophytes	Present with greater than 10% coverage of water surface area.	Present with less than 10% surface water coverage.	Not present.
Platypus foraging habitat	Good mesohabitat diversity in and adjacent the reach, good flow, good aquatic microhabitat diversity.	At least mid-sized pools with regular flows creating runs and riffles, some microhabitat diversity.	Low mesohabitat diversity, occasional flows, low microhabitat diversity.
Platypus burrowing habitat	Good overhanging bank vegetation, steep undercut consolidated banks and root tangles.	Some overhanging bank vegetation, steep undercut consolidated banks and root tangles.	No overhanging bank vegetation, steep undercut consolidated banks and root tangles.
OVERALL RATING	**Good site, consider relocation capacity.**	**Potential relocation site.**	**Poor capacity for aquatic fauna relocation.**

Table 4: **Relocation site suitability summary (site reconnaissance 21/11/2019)**
[green] – good, [yellow] – fair, [red] – poor. Category descriptions are provided in Table 3.

Sub-catchment			Six Mile Creek									Mary River and central section tributaries									
Waterway		Cooloolabin Dam	Six Mile Creek	Six Mile Creek	Six Mile Creek	Six Mile Creek	Dingo Creek	Six Mile Creek	Six Mile Creek	Woondum Creek	Sandy Creek	Traveston Creek	Mary River	Mary River	Kandanga Creek	Kandanga Creek	Coonan-Gibber	Mary River	Yabba Creek	Belli Creek	Belli Creek
	Site number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Access	Safe parking at site	good	good	fair	good	good	good	good	good	good	good	good	good	poor	poor	poor	fair	good	good	good	poor
	Point access to site	good	good	fair	good	good	good	fair	fair	good	good	good	good	poor	poor	fair	fair	fair	good	good	poor
	Access along reach	good	fair	fair	fair	good	fair	fair	fair	good	fair	good	good	poor	poor	fair	fair	fair	fair	fair	fair
	Boat launching access	good	poor	poor	poor	poor	poor	poor	poor	poor	poor	poor	good	poor	poor	poor	poor	poor	good	poor	poor
Site qualities	Water permanency	good	good	good	good	good	poor	good	good	poor	poor	fair	good	good	fair	fair	poor	good	good	poor	poor
	Volume of water at the site	good	good	good	fair	fair	poor	good	good	poor	poor	fair	good	good	fair	good	poor	good	good	poor	poor
	Volume of water adjacent	good	good	good	fair	fair	poor	good	good	poor	poor	fair	good	good	fair	good	poor	good	good	poor	poor
	Water quality	good	fair	fair	fair	fair	poor	fair	fair	poor	poor	poor	good	good	fair	fair	poor	good	good	poor	poor
	Microhabitat diversity	good	fair	good	good	good	poor	good	good	fair	poor	fair	good	good	fair	fair	poor	good	good	fair	fair
	Submerged macrophytes	good	poor	poor	poor	poor	poor	poor	poor	poor	poor	poor	good	fair	poor	good	poor	good	good	poor	poor
Platypus	Foraging habitat	fair	fair	fair	good	good	poor	good	good	fair	poor	poor	good	fair	poor	fair	poor	good	good	poor	poor
	Burrowing habitat	poor	good	good	good	good	poor	good	good	poor	poor	good	fair	fair	fair	good	fair	fair	good	fair	fair
Overall assessment		good	fair	good	fair	fair	poor	fair	good	poor	poor	poor	good	poor	poor	poor	poor	fair	good	poor	poor

Table 5: **Relocation site suitability summary (site reconnaissance 4/12/2019)**
– good, – fair, – poor. Category descriptions are provided in Table 3.

Waterway		Six Mile Creek	Amamoor Creek	Amamoor Creek	Amamoor Creek	Amamoor Creek	Amamoor Creek	Kandanga Creek	Kandanga Creek	Kandanga Creek	Kandanga Creek	Yabba Creek	Mary River	Mary River	Belli Creek	Belli Creek	Mary River	Mary River	Six Mile Creek
	Site number	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
Access	Safe parking at site	Good	Good	Fair	Good	Good	Good	Good	Good	Fair	Fair	Good	Good	Fair	Fair	Good	Fair	Good	Good
	Point access to site	Good	Poor	Poor	Good	Fair	Good	Poor	Good	Good	Good	Good	Poor	Good	Good	Good	Good	Good	Poor
	Access along reach	Fair	Poor	Poor	Fair	Poor	Fair	Fair	Good	Poor	Poor	Fair	Poor	Fair	Fair	Good	Good	Fair	Poor
	Boat launching access	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Good	Poor	Poor	Good	Poor	Good	Poor	Poor	Good	Good	Poor
Site qualities	Water permanency	Good	Good	Good	Good	Good	Fair	Fair	Good	Poor	Poor	Good	Good	Good	Fair	Fair	Fair	Good	Good
	Volume of water at the site	Fair	Fair	Fair	Good	Fair	Fair	Fair	Good	Poor	Poor	Good	Fair	Fair	Fair	Good	Fair	Good	Good
	Volume of water adjacent	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Poor	Poor	Good	Fair	Fair	Fair	Poor	Fair	Good	Good
	Water quality	Fair	Fair	NA	Fair	Fair	Fair	Fair	Fair	Poor	Poor	Good	Fair	Good	Poor	Poor	Poor	Good	Fair
	Microhabitat diversity	Good	Good	Good	Good	Fair	Fair	Fair	Fair	Poor	Poor	Good	Fair	Fair	Fair	Fair	Fair	Good	Good
	Submerged macrophytes	Poor	Good	Good	Good	Good	Good	Good	Good	Poor	Poor	Good	Good	Good	Poor	Poor	Fair	Good	Poor
Platypus	Foraging habitat	Fair	Fair	Fair	Good	Fair	Good	Fair	Fair	Poor	Poor	Good	Fair	Good	Fair	Fair	Fair	Good	Good
	Burrowing habitat	Good	Good	Fair	Fair	Fair	Fair	Fair	Good	Poor	Poor	Fair	Fair	Fair	Fair	Fair	Fair	Good	Good
Overall assessment		Fair	Poor	Poor	Fair	Fair	Poor	Poor	Good	Poor	Poor	Good	Poor	Good	Poor	Poor	Fair	Good	Poor

3.4. Short list of relocation sites

The sites short-listed to be surveyed to assess aquatic fauna carrying capacity potential are summarised in Table 6. General comments on the site suitability is provided based on the constraints discussed in section 3.1.

Table 6: Relocation site suitability summary short list
[green] – good, [yellow] – fair. Category descriptions are provided in Table 3.

Site	Waterway	General comments about potential as a relocation site
1	Cooloolabin Dam	Large waterbody. Good potential for stocked non-endemic fish and non-threatened large bodied species.
2	Six Mile Creek	Saw-shelled and broad-shell turtles only.
3	Six Mile Creek	Saw-shelled and broad-shell turtles only.
4	Six Mile Creek	Saw-shelled and broad-shell turtles only.
5	Six Mile Creek	Saw-shelled and broad-shell turtles only.
7	Six Mile Creek	Saw-shelled and broad-shell turtles only. Steep banks and deep water making safe sampling of the site difficult.
8	Six Mile Creek	Saw-shelled and broad-shell turtles only.
12	Mary River	At Traveston, good access. Popular public area. Potential to relocate threatened fish species as well as threatened, saw-shelled and broad-shell turtles.
17	Mary River	Good deep pool with good point access but hard to sample. Potential to relocate small numbers of threatened fish species as well as threatened, saw-shelled and broad-shell turtles.
18	Yabba Creek	Good flow from Borumba Dam. Potential to relocate threatened fish species as well as threatened, saw-shelled and broad-shell turtles.
21	Six Mile turtle	Saw-shelled and broad-shell turtles only.
24	Amamoor Creek	Saw-shelled and broad-shell turtles only.
25	Amamoor Creek	Saw-shelled and broad-shell turtles only.
28	Kandanga Creek Weir	Single large pool. Potential for a small number of Mary River cod.
31	Yabba Creek	Good flow from Borumba Dam. Potential to relocate threatened fish species as well as threatened, saw-shelled and broad-shell turtles.
33	Mary River	Good access but small pools. Good deep pool with good point access but hard to sample. Potential to relocate small numbers of threatened fish species as well as threatened, saw-shelled and broad-shell turtles.
36	Mary River	Good access but small pools. Good deep pool with good point access but hard to sample. Potential to relocate small numbers of threatened fish species as well as threatened turtles, saw-shelled and broad-shell turtles.
37	Mary River	A large permanent pool. Potential to relocate threatened fish species as well as threatened turtles, saw-shelled and broad-shell turtles.

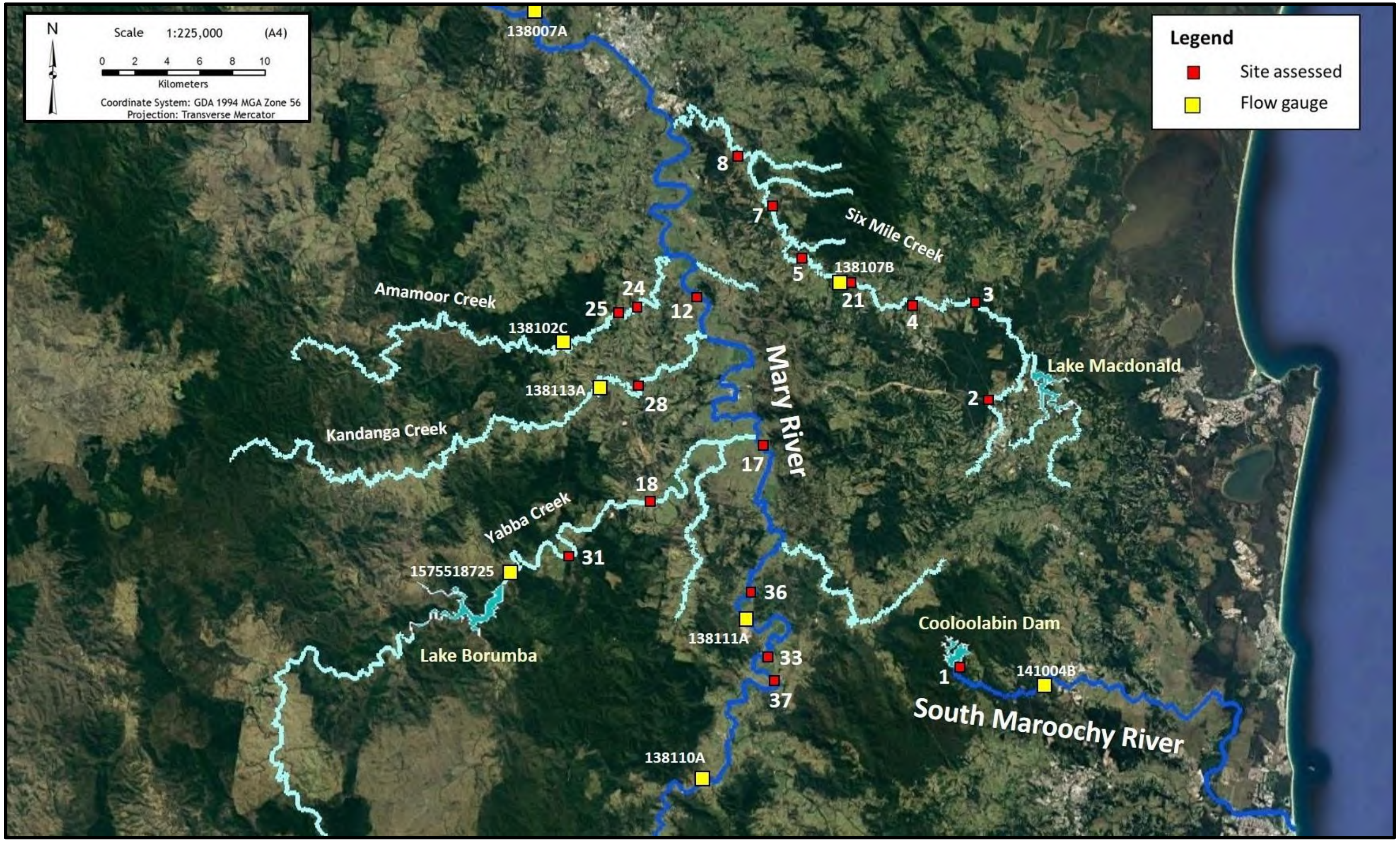


Figure 2: Location of the short list sites assessed and flow gauges

4. Methods

4.1. Timing and flow conditions

Field surveys of the short listed sites were undertaken between the 13th and 18th of January 2020. Prior to sampling there had been an extended period of little rainfall across the region. This is reflected in the flow graphs for the gauging stations (see Figure 2 for locations) provided in Appendix C.

Prior to the 2020 sampling there had been few or no notable flow event across the region for more than 12 months. The smaller flows that did occur between March and July 2019 appeared to have come from the coastal catchments (i.e. Six Mile Creek, Obi Obi Creek and the South Maroochy River), with no significant flow events from the streams draining from the west of the catchment (i.e. Yabba, Kandanga and Amamoor Creeks). The flows from the coastal tributaries between March and July 2019 did reach and influence flow in the Mary River main channel over that time. Some base flows were maintained from releases of water from Borumba Dam into Yabba Creek from the end of August 2019 until after the sampling had been completed (when notable amounts of rain had fallen across the region). However, above the confluence with the Yabba Creek the Mary River had ceased to flow and there were many sections close to drying up completely (Timothy Howell pers. obs.).

The extended period of low flows combined with the inherent hot conditions that occur in January combined to create conditions that were likely impacting on fish assemblages to variable extents across the catchment. This was particularly notable in the water quality results in the low (or highly variable) dissolved oxygen levels, and the high pH levels noted at some of the Mary River sites (see section 5.3).

4.2. Field methods

Sampling at each site was consistent with the habitat conditions, site access and potential as a relocation site identified in the site reconnaissance. Following the site reconnaissance, the water quality had deteriorated in sites 24 and 25 on Amamoor Creek, site 28 on Kandanga Creek, and site 36 on the Mary River. At these sites' assessments were limited to visual assessments and *in situ* water quality as disturbing the water column was considered likely to negatively impact on any surviving fish assemblages. This was most notable for the dissolved oxygen, and while sites in Six Mile Creek had lower dissolved oxygen levels, the diel variations were considered likely to be less variable (hence detrimental to aquatic fauna) due to the apparently negligible levels of instream primary production.

A summary of the sampling methods used across all sites is provided in Table 7.

Table 7: Sampling methods used at each potential relocation site

Parameter		Habitat	Water quality	Macrophytes	Macroinvertebrates	Fish			Turtles
Site number	**Waterbody**	**Visual assessment**	***In situ***	**Visual assessment**	**Dip net (10 meter sweep)**	**Backpack electrofisher**	**Boat electrofisher**	**Unbaited Trap**	**Cathedral trap**
1	Cooloolabin Dam	•	•	•	•		•	•	•
2	Six Mile Creek	•	•	•	•	•		•	
3	Six Mile Creek	•	•	•	•	•		•	•
4	Six Mile Creek	•	•	•	•	•		•	
5	Six Mile Creek	•	•	•	•	•		•	
7	Six Mile Creek	•	•	•					•
8	Six Mile Creek	•	•	•	•	•		•	
12	Mary River	•	•	•	•	•	•	•	
17	Mary River	•	•	•					
18	Yabba Creek	•	•	•	•		•	•	
21	Six Mile Creek	•	•	•	•	•		•	
24	Amamoor Creek	•	•	•					
25	Amamoor Creek	•	•	•					
28	Kandanga Creek	•	•	•					
31	Yabba Creek	•	•	•	•	•	•	•	
33	Mary River	•	•	•					
36	Mary River	•	•	•					
37	Mary River	•	•	•	•	•	•	•	

4.2.1. Aquatic habitat

For each of the sites, a range of habitat characteristics were estimated at the reach scale including:

- Channel characteristics
  - reach length, bankfull bank height, bankfull stream width, mean water depth, mean wetted width.
- Riparian vegetation characteristics
  - riparian vegetation height (max.), riparian zone width (both banks), bare ground, grass, shrubs, trees (< 10 m and > 10 m), canopy cover, exotic riparian species.
- Mesohabitat composition (%)
  - riffle, run, rocky pool, sandy pool, dry.
- Substrate composition (%)
  - bedrock, boulder (>256 mm), cobble (64-256 mm), pebble (4-64 mm), gravel (2-4 mm), sand (2-4 mm), silt/clay (<0.05 mm).
- Macrophytes (None, Little 1-10%, Some 10-50%, Moderate 50-75%, Extensive >75%)
  - free floating, attached floating, submerged, emergent (Sainty & Jacobs 2003).
- In-stream wood (None, Little 1-10%, Some 10-50%, Moderate 50-75%, Extensive >75%)
  - detritus (leaves etc), sticks (<2 cm diameter), branches (<15 cm diameter), logs (>15 cm diameter).
- Microhabitat (None, Little 1-10%, Some 10-50%, Moderate 50-75%, Extensive >75%)
  - periphyton, filamentous algae, bank overhang vegetation, trailing bank vegetation, blanketing silt, substrate anoxia, bank undercuts.

4.2.2. Water quality

All water sample collection was completed in accordance with the *Monitoring and Sampling Manual* (DES 2018) and *AS/NZ 5667.6:1998 (Guidance on sampling of rivers and streams)* (AS/NZS 1998). Physico-chemical analysis of surface samples consisted solely of *in situ* measurements. A summary of the parameters measured, and their associated measurement precision, are presented in Table 8. Temperature, pH and conductivity (µS/Cm) using a TPS Aqua-CP/A, dissolved oxygen saturation (DO) with a TPS Aqua-DY, and turbidity measured with a Eutech TN-100, which were calibrated, maintained and operated within the manufacturer's specifications.

Table 8: *In situ* water quality measurement parameters

Parameter	Units	Measurement Precision
Water temperature	ºC	± 0.1
pH	pH Units	± 0.1
Dissolved oxygen	% saturation	± 0.1
Electrical conductivity	µS/cm	± 1
Turbidity	NTU	±0.1

4.2.3. Macrophytes

Macrophyte surveys were undertaken following completion of the fish surveys to increase the chance of observing submerged macrophytes that were not abundant throughout the reach. All native and exotic macrophyte species at the site were recorded. Species were identified using Sainty & Jacobs (2003), Stephens & Dowling (2002), Grantley *et al*. (2009), Heavey & MacDonald (2013) and MacDonald & Haslam (2016). The approximate area covered by each macrophyte species was recorded. Free-floating, floating, attached and submerged macrophyte percentage coverage was based on stream wetted area across the reach, whereas emergent macrophyte coverage was recorded as a percentage of the riparian zone (note that non-macrophyte species also contributed to riparian vegetation but were not assessed within the scope of this project).

Macrophyte species were categorised by growth form in accordance with definitions provided in Sainty and Jacobs (2003), as follows:

- **Free floating** – Species that are normally unattached and float on the surface but may become attached and rooted in drying mud when water levels drop.
- **Floating attached** – Species that are rooted in the substrate but normally have at least the mature leaves floating on the water surface.
- **Submerged**– Species rooted in the substrate or free-floating submerged.
- **Emergent** – Species rooted in the bank substrate with stems, flowers and most of the mature leaves projecting above the water surface.

4.2.4. Macroinvertebrates

Field macroinvertebrate surveys was undertaken following AusRivAS protocols at eleven sites. A single sample of the two predominant habitat types (edge, bed, macrophyte, composite) at each site were collected and live picked (Table 9). In our experience a single sample of each predominant habitat type collected by an experienced aquatic ecologist will be sufficient to provide a representative rapid assessment snapshot of aquatic macroinvertebrate communities at a given site.

Macroinvertebrate samples were collected at each monitoring location in line with the approach outlined in the *Monitoring and Sampling Manual* (DES 2018) which defaults to those methods adopted by the Queensland Australian River Assessment System (AusRivAS) *Sampling and Processing Manual* (DNRM 2001). All sampling was undertaken by suitably trained and AusRivAS experienced field operators. Following the AusRivAS conventions, macroinvertebrate samples were collected at each site using a standard 250 µm mesh AusRivAS dip net.

Table 9: Habitat types which macroinvertebrate samples were collected from each site

Site no.	Waterway	Habitat			
		Bed	Edge	Macrophyte	Composite
1	Cooloolabin			•	
2	Six Mile Creek				•
3	Six Mile Creek				•
4	Six Mile Creek				•
6	Six Mile Creek				•
8	Six Mile Creek				•
12	Mary River		•	•	
18	Yabba Creek		•	•	
31	Yabba Creek		•	•	
21	Six Mile Creek				•
37	Mary River	•	•		

Samples were “live picked” on site following the AusRivAS protocols and the animals collected preserved in 70 percent alcohol. In the laboratory, macroinvertebrates were sorted, identified to the family taxonomic level and relative abundance enumerated. Organisms were identified to family level with the exception of lower phyla (e.g. porifera, nematoda), oligochaetes (freshwater worms), acarina (freshwater mites) and microcrustacea (ostracoda, copeopoda and cladocera). Chironomids were identified to sub-family level in accordance with standard AusRivAS protocols (DNRM 2001).

Macroinvertebrates were sorted, identified to family taxonomic level (where applicable) and enumerated by Susan Jones, an experienced AusRivAS accredited ecologist. Sorting, enumeration and data entry was cross-checked by a second ecologist for 10% of the samples.

4.2.5. Fish

Fish sampling was undertaken to assess community composition at each site. Backpack electrofishing and box trapping were the primary fish survey techniques. Boat electrofishing was conducted at sites where a suitable boat launch and habitat was present. All electrofishing was undertaken in compliance with the Australian Code of Electrofishing Practice (NSW Fisheries 1997), with the minimum power setting used to effectively attract and stun the fish. Unbaited box traps were used at most sites, where it was considered there was any potential to capture species not recorded by the backpack electrofisher.

Backpack electrofishing was undertaken at nine sites, using a Smith-Root LR20B backpack electrofisher. Settings for the backpack electrofisher varied between sites, depending on water conductivity, depth, fish size and species. The settings used for each site are detailed in Appendix D. Backpack electrofishing was conducted from downstream to upstream, covering all mesohabitats present within each reach. Where there was sufficient stream width for fish to avoid the electric field, sampling was conducted upstream along one bank and then in a downstream direction on the opposite bank. In deeper waters and in complex habitat areas, a swirling motion of the net was used to draw fish to the surface for capture or visual identification.

Boat electrofishing was undertaken at five sites, with a Smith-Root 7.5 GPP electrofishing unit. In stream sites boat electrofishing was conducted from downstream to upstream in a zig-zag motion while ensuring that bank habitat was suitably surveyed. In Cooloolabin Dam the entire margin of the lake was electrofished. Once a reasonable number of a given species were captured, netting was focussed toward observing and capturing rarer species while concurrently making note of general abundance of more common species for observational data.

Electrofishing ‘on-time’ varied between sites and was determined by the appropriate amount of time required to adequately sample each reach. It also aimed to minimise unnecessary electrofishing effort that could cause harm to fish within the reach, particularly any fish that may have been trapped in complex habitat and unable to be observed.

Unbaited box trapping is a passive fish sampling technique that targets small bodied pelagic and benthic species. Five unbaited box traps were strategically placed at all sites for between 30 minutes and 2 hours at eleven sites. Extensive field survey experience has shown most fish enter the traps within the first 30 minutes and removing them after 2 hours minimises the chance of predation within the traps (by both predatory fish and larger macroinvertebrates).

At each site, abundance was recorded for each species for which identification was verified. Native fish were returned to the water, while exotic species were euthanized humanely in accordance with Freshwater Ecology’s animal ethics and fisheries scientific collection permits’ and disposed of in an environmentally sensitive manner.

Fish lengths were recorded for a sub sample of all large bodied species and estimated for the remaining individuals sighted. This was done to gain an estimate of biomass at each site while minimising the handling time of fish, thus reducing stress under the conditions in which sampling was undertaken. All fish sampled with the methods used were intermediate to adults (more typically adults), hence life history stage was not distinguished.

All equipment was inspected at completion of sampling at each site, cleared of any plant matter and allowed to dry to ensure aquatic plants and terrestrial weeds were not inadvertently transferred between sites.

Fish sampling was conducted under General Fisheries Permit No. 191062, scientific user permit for non-protected areas WISP18336317, and Animal Ethics Approval No. CA 2017/02/1042, held by Freshwater Ecology.

4.2.6. Turtles

Turtle sampling was undertaken with cathedral traps at three sites, with observations made at all other sites. Visual assessments included assessing for turtles breaching the surface to breathe or basking on banks prior to disturbance at the site, as well as individuals observed during electrofishing operations. These assessments were considered cursory as more thorough assessments would require significantly more effort, particularly as the white throated snapping turtle and Mary River turtle can remain underwater for extended periods utilising cloacal breathing.

5. Field assessment results

5.1. Site access and travel times

A summary of the site access details and travel times for all sites sampled is provided in Appendix E. The time and distance from Lake Macdonald was calculated from the dam wall on Lake Macdonald Drive using google maps to provide consistency between sites. Based on knowledge of the roads to each site obtained during the field sampling an estimated multiplication factor has been provided to factor in additional time for travelling to the sites with a trailer loaded with water.

During the field sampling site 33 was removed from the potential relocation site list due to concerns with heavy large truck traffic along the road at the site. While good parking access was available at the site, several trucks loaded with rocks from the nearby quarry were noted as driving very fast past the access turnoff points. These concerns were supported by discussions with local residents while inspecting the site.

5.2. Aquatic habitat

Site profiles for the fixed site sampled are provided in Appendix F. The site summaries provide details of channel characteristics, riparian vegetation, mesohabitat composition, substrate composition, instream wood, macrophyte and microhabitat attributes, as well as a summary of aquatic macrophytes, macroinvertebrates and fish.

5.3. Water quality

In situ water quality was variable between sites across the study area (Table 10). This is not unexpected considering the geographical range across which sites were located, and the varied land use and other factors potentially influencing water quality. Water temperature ranged from 23.5°C to 31.8°C, with a mean of 27.0°C. The variation in temperature was largely related to the waterway and riparian coverage with generally lower temperatures in the tributaries than in the Mary River main channel and Cooloolabin Dam. Dissolved oxygen (DO) varied extensively between sites, ranging from 11.0% to 173.0% saturation with a mean of 55.4.5% saturation. Dissolved oxygen was lowest in tributaries of the Mary River, with the exception of Yabba Creek which had artificially sustained flows from release from Borumba Dam. Most freshwater fish are capable of tolerating a large range of DO concentrations (e.g. Pusey et al. 2004), however, if there is a sudden and significant drop in dissolved oxygen then there can often be fish kills. Sites along Six Mile Creek had low levels of instream primary production (i.e. submerged macrophytes and suspended algae) in comparison to sites along Amamoor and Kandanga Creeks. It is therefore likely that any diel fluctuations in DO would likely be far lower in Six Mile Creek than Amamoor or Kandanga Creeks and thus more likely to be able to sustain fish assemblages in the conditions noted at the time of sampling.

Table 10: *In situ* water quality measurements

Site	Waterway	Date	Time	Temperature (°C)	Dissolved oxygen (%)	Conductivity (µs/cm@25°C)	pH	Turbidity (NTU)
Site 1	Cooloolabin Dam	15/01/2020	1200	28.7	71.6	79	7.8	3.5
Site 2	Six Mile Creek	17/01/2020	0800	25.6	30.8	791	7.7	9.5
Site 3	Six Mile Creek	17/01/2020	0915	26.3	16.0	189	7.3	5.8
Site 4	Six Mile Creek	17/01/2020	1020	26.4	20.1	238	7.4	8.4
Site 5	Six Mile Creek	17/01/2020	1245	26.2	21.6	247	7.5	5.0
Site 7	Six Mile Creek	17/01/2020	1420	25.9	23.5	301	7.4	6.5
Site 8	Six Mile Creek	14/01/2020	0930	24.5	11.0	337	7.8	9.3
Site 12	Mary River	13/01/2020	0930	27.4	96.5	269	8.9	2.5
Site 17	Mary River	14/01/2020	1520	31.8	137.0	544	9.0	2.4
Site 18	Yabba Creek	14/01/2020	1450	28.1	94.8	274	7.5	0.9
Site 21	Six Mile Creek	17/01/2020	1135	25.1	20.1	244	7.5	4.4
Site 24	Amamoor Creek	14/01/2020	1115	24.1	30.8	622	7.9	2.3
Site 25	Amamoor Creek	14/01/2020	1130	23.9	23.9	512	7.2	4.8
Site 28	Kandanga Creek	13/01/2020	1230	26.3	23.2	550	7.9	4.1
Site 31	Yabba Creek	13/01/2020	1400	23.5	68.0	248	7.8	2.6
Site 33	Mary River	16/01/2020	1420	31.4	82.0	341	7.6	3.9
Site 36	Mary River	16/01/2020	1300	31.6	173.0	381	9.4	22.0
Site 37	Mary River	16/01/2020	0930	28.4	52.6	293	7.5	11.8

Electrical Conductivity (EC) ranged from 79 to 791 µS/cm @ 25°C with a mean of 359 µS/cm. Cooloolabin Dam had the lowest conductivity, with the highest EC recorded at site 2 on Six Mile Creek. The higher EC at site 2 likely reflects the reaches immediately upstream being located within an urban context. Elevated EC's were also noted in all Amamoor and Kandanga Creek sites which is likely due to the low water levels.

The pH was alkaline at all sites ranging from 7.5 to 9.4. The highest pH was recorded at site 36 which had extremely low water levels. Turbidity ranged from 0.9 to 22 NTU. Turbidity only exceeded 10 NTU at sites 36 and 37 on the Mary River, where algal blooms were noted as the reason for the elevated turbidity.

5.4. Macrophytes

A total of 37 species of macrophytes were identified and the percent macrophyte coverage was recorded at all sites (Appendix G). A summary of species diversity within growth forms and relative coverage is shown in Table 11. Macrophyte diversity was lowest in sites along Six Mile Creek and site 36 on the Mary River. At these sites aquatic macrophytes were restricted to emergent species except for a single species of submerged macrophyte recorded at site 2. For the sites along Six Mile Creek this was due to the reduced light penetration from the extensive canopy cover, while at site 36 on the Mary River this was due to the extremely low water levels and poor water quality. At all other sites, species within at least three of the four growth forms were noted and between six and 18 species were recorded. The highest diversity of aquatic macrophytes was recorded at site 12 on Yabba Creek with all four growth forms present.

Table 11: Macrophyte diversity and coverage for each growth form for all sites sampled in January 2020

Site No.		1	2	3	4	5	7	8	12	17	18	21	24	25	28	31	33	36	37
Free floating	Species	-	-	-	-	-	-	-	3	3	-	-	2	3	2	-	1	-	1
	Coverage	-	-	-	-	-	-	-	<1	<1	-	-	20	100	<1	-	15	-	1
Floating attached	Diversity	2	-	-	-	-	-	-	2	-	3	-	1	1	-	1	1	-	1
	Coverage	4	-	-	-	-	-	-	<1	-	16	-	10	1	-	<1	2	-	<1
Submerged	Diversity	5	1	-	-	-	-	-	3	5	3	-	1	1	2	4	2	-	3
	Coverage	25	5	-	-	-	-	-	27	17	37	-	10	15	25	45	4	-	7
Emergent	Diversity	6	4	3	1	1	1	2	10	1	4	2	3	4	2	5	7	2	4
	Coverage	92	18	21	40	15	20	37	20	1	19	21	42	41	<1	15	28	7	44

5.5. Aquatic macroinvertebrates

A total of 1,719 aquatic macroinvertebrate individuals from 62 taxa (mainly family level) were collected from the 15 samples and 11 sites surveyed in January 2020 (Table 12). In addition, three groups of microcrustacean were recorded across the sites. The highest abundances of macroinvertebrates were collected in both samples at site 18. However, it must be noted that abundance values were not absolute but in line with the live picking procedures of the AusRivAS methodology (DNRM 2001). Taxa richness varied across all sites with the only clear trend noted was the higher taxa diversity in sites sampled along Yabba Creek than all other waterways.

Some of the more notable trends in the data were; a lower diversity and abundance of gastropods (snails) in sites along Six Mile Creek, widespread presence of Atyidae (shrimps) and Paelmonidae (freshwater prawns) across all sites (although prawns were more often noted during electrofishing not all macroinvertebrate samples), a reasonable diversity of Coleoptera (beetles) and Hemiptera (true bugs), and a higher diversity and abundance of Plecoptera-Ephemeroptera-Tricoptera (PET) taxa in the Yabba Creek sites.

While no data were collected from Lake Macdonald in this assessment, it was noted that the macroinvertebrate taxa in Lake Cooloolabin Dam were remarkably similar to those typically found in Lake Macdonald (Timothy Howell pers. obs.).

Table 12: Aquatic macroinvertebrates taxa groups and family diversity (in brackets) recorded in January 2020

Site	1	2	3	4	5	8	12	12	18	18	21	31	31	37	37
Habitat	**Macrophyte**	**Composite**	**Composite**	**Composite**	**Composite**	**Composite**	**Macrophyte**	**Edge**	**Macrophyte**	**Edge**	**Composite**	**Macrophyte**	**Edge**	**Bed**	**Edge**
GROUP															
Cladocera	P	P	P	P	P	P	P	-	P	P	P	-	-	P	P
Copepoda	P	P	P	P	P	P	P	-	P	P	P	P	P	-	-
Ostracoda	P	P	P	P	P	P	P	P	P	P	-	P	P	-	P
Hydrozoa	-	-	5 (1)	-	1 (1)	-	-	-	-	-	1 (1)	-	-	-	-
Turbellaria	-	3 (2)	1 (1)	1 (1)	-	1 (1)	1 (1)	-	3 (1)	5 (2)	-	-	-	-	-
Nematoda	-	-	1	-	-	1	-	-	4	5	1	-	-	-	-
Gastropoda	-	6 (1)	1 (1)	-	-	5 (1)	16 (2)	16 (4)	21 (3)	19 (3)	-	6 (3)	9 (3)	4 (2)	3 (1)
Bivalvia	-	-	-	-	-	-	-	-	-	-	-	1 (1)	-	-	-
Hirudinea	6 (2)	-	-	-	-	-	-	-	-	2 (2)	-	-	-	-	-
Oligochaeta	-	9	7	3	2	5	1	7	100	47	6	4	17	3	3
Acarina	19	7	11	8	3	2	5	3	26	37	4	3	2	10	1
Isopoda	-	-	-	-	-	-	-	-	-	-	-	1 (1)	-	-	2 (1)
Decapoda							1								
Atyidae	9	6	8	8	3	4	3	4	9	5	4	3	6	5	12
Palaemonidae	1	-		-	-	1	3	4	-	1	3	-	2	1	-
Parastacidae	-	1	1	1	-	2	-	-	-	-	1	-	-	-	-
Coleoptera	10 (3)	7 (1)	9 (2)	9 (2)	11 (2)	6 (1)	1 (1)	6 (2)	-	8 (2)	1 (1)	16 (3)	12 (3)	2 (1)	2 (2)
Diptera	8 (2)	13 (2)	36 (2)	26 (2)	34 (2)	55 (2)	20 (3)	9 (2)	40 (5)	61 (4)	15 (2)	14 (3)	32 (3)	20 (3)	19 (1)
Ephemeroptera	1 (1)	8 (2)	12 (2)	3 (2)	3 (1)	7 (2)	16 (2)	12 (2)	21 (2)	15 (2)	10 (2)	21 (3)	13 (3)	1 (1)	2 (2)
Hemiptera	6 (2)	9 (4)	8 (2)	7 (3)	5 (2)	11 (4)	3 (2)	9 (3)	11 (3)	19 (7)	-	-	16 (7)	12 (1)	14 (5)
Megaloptera	-	-	-	3 (1)	1 (1)	-	-	-	-	-	-	-	-	-	-
Odonata															
S.O. Zygoptera	26 (1)	18 (2)	4 (1)	2 (1)	-	-	9 (1)	8 (1)	17 (1)	9 (1)	5 (1)	-	6 (1)	-	7 (1)
S.O. Epiproctiphora	3 (2)	2 (1)	9 (2)	2 (2)	-	5 (2)	3 (1)	1 (1)	-	4 (1)	-	-	4 (1)	-	-
Trichoptera	1 (1)	14 (1)	15 (2)	17 (1)	8 (1)	4 (1)	-	6 (1)	9 (3)	20 (2)	5 (2)	22 (2)	50 (5)	-	-
Abundance	**90**	**103**	**128**	**90**	**71**	**109**	**82**	**86**	**261**	**257**	**56**	**92**	**171**	**58**	**65**
Taxa Richness	**17**	**20**	**21**	**19**	**13**	**20**	**18**	**21**	**22**	**31**	**15**	**20**	**31**	**12**	**16**

5.6. Fish

A total of 4,833 fish from 31 species were recorded across the 11 sites sampled in January 2020 (Table 13). Of these fish 1,184 were from 21 native species, 16 were from translocated native species and 734 were from three introduced pest species. Individuals of the genus *Hypseleotris* were clumped together for site comparisons as they can be difficult to distinguish to species level in the field, particularly when juveniles. However, positive identifications were made for individuals of firetail gudgeon (*Hypseleotris galii*) in all Six Mile Creek sites, western carp gudgeon (*Hypseleotris klunzingeri*) in both Mary River sites and on Yabba Creek site 18, and both western carp gudgeon and Midgely's carp gudgeon (*Hypseleotris* Sp.1) in Cooloolabin Dam.

The lowest fish diversity was recorded in sites along Six Mile creek with between five and seven species recorded. The only introduced pest fish species recorded in Six Mile Creek in the current survey was gambusia. Longfin eel, firetail gudgeon, crimson-spotted rainbowfish and eel-tailed catfish were the most commonly recorded species in Six Mile Creek. Abundances were generally lower than other sites as well, but electrofishing effort was also substantially lower (between 377-528 seconds electrofishing on time) than the large sites along Yabba Creek and the Mary River (with between 1,200-1,577 and 826-1,956 seconds respectively).

The most diverse fish communities were recorded in Yabba Creek (15 and 18 species per site) and the Mary River (14 and 18 species per site) which is to be expected considering the size of the waterways and the more permanent flows. These fish assemblages were all relatively diverse with grazers (e.g. bony bream and mullet), ambush predators (e.g. Mary River cod, Australian bass), pelagic predators (e.g. saratoga) and benthic foragers (e.g. Australian lungfish, eel-tailed catfish) represented in the large bodied fish and both pelagic (e.g. hardyhead species, Pacific blue-eyes) and benthic (e.g. gudgeon species) species represented in the small bodied fish.

The most extensive electrofishing sampling effort was used in sampling Cooloolabin Dam with 3,600 seconds electrofishing on-time. A total of nine species were recorded with small bodied species accounting for 97% of all fish. Despite the extensive sampling effort only a single southern saratoga, ten eels and 19 eel-tailed catfish were recorded across the entire lake shoreline.

Table 13 (a): Fish species and abundance recorded in January 2020

Scientific name	Common name	1	2	3	4	6	8	12	18	21	31	37	Totals
Ambassis agassizii	**Olive perchlet**	57	-	-	-	-	-	3	1	-	2	-	**63**
Anguilla reinhartii	**Longfin eel**	10	28	5	5	10	15	24	8	10	5	12	**132**
Arrhamphus sclerolepis	**Snubnose gar**	-	-	-	-	-	-	-	-	-	1	-	**1**
Craterocephalus marjoriae	**Marjorie's hardyhead**	-	-	-	-	-	-	66	-	-	1	-	**67**
Craterocephalus fulvus	**Unspecked hardyhead**	471	-	2	-	-	-	46	95	6	40	1	**661**
Glossamia aprion	**Mouth almighty**	-	-	-	-	-	-	-	1	-	-	-	**1**
Hypseleotris spp.	**Carp gudgeon species**	189	20	44	31	18	27	6	3	18	16	173	**545**
Leiopotherapon unicolor	**Spangled perch**	-	-	-	-	-	-	11	-	-	-	-	**11**
Macquaria novemaculeata	**Australian bass**	-	-	-	-	-	-	-	3	-	18	4	**25**
Maccullochella mariensis	**Mary River cod**	-	-	-	-	-	-	-	-	3	3	7	**13**
Melanotaenia duboulayi	**Crimson-spotted rainbowfish**	69	43	16	5	7	38	101	85	31	34	23	**452**
Mogurnda adspersa	**Purple-spotted gudgeon**	-	7	5	-	-	-	-	-	-	-	-	**12**
Mugil cephalus	**Sea mullet**	-	-	-	-	-	-	28	-	-	-	80	**108**
Nematalosa erebi	**Bony bream**	-	-	-	-	-	-	12	141	-	29	455	**637**
Neoceratodus fosteri	**Australian lungfish**	-	-	-	-	-	-	20	46	-	70	35	**171**

Table 13 (b): Fish species and abundance recorded in January 2020

Scientific name	Common name	1	2	3	4	6	8	12	18	21	31	37	Totals
Ophisternon spp.	Swamp eel	-	-	-	-	1	-	-	-	-	-	-	**1**
Philypnodon grandiceps	Flathead gudgeon	-	-	-	-	-	-	-	-	-	16	-	**16**
Philypnodon macrostomus	Dwarf flathead gudgeon	-	-	-	-	1	-	-	-	-	-	-	**1**
Pseudomugil signifer	Pacific blue-eye	-	-	-	1	7	1	6	18	20	177	-	**230**
Retropinna semoni	Australian smelt	-	-	-	-	-	-	211	620	-	51	-	**882**
Tandanus tandanus	Eel-tailed catfish	19	2	1	-	1	3	4	1	1	22	-	**54**
Hephaestus fuliginosus	Sooty grunter	-	-	-	-	-	-	1	-	-	1	7	**9**
Macquaria ambigua	Golden perch	-	-	-	-	-	-	1	1	-	-	1	**3**
Scleropages leichardti	Southern saratoga	1	-	-	-	-	-	-	1	-	-	2	**4**
Gambusia holbrooki	Gambusia	369	44	-	36	-	-	121	-	-	4	55	**629**
Oreochromis mossambicus	Tilapia	-	-	-	-	-	-	36	59	-	-	1	**96**
Xiphophorus maculatus	Platy	-	-	-	-	-	-	8	-	-	1	-	**9**
Total abundance		**1185**	**144**	**73**	**78**	**45**	**84**	**705**	**1083**	**89**	**491**	**856**	**4833**
Species richness		**9**	**6**	**6**	**5**	**7**	**5**	**18**	**15**	**7**	**18**	**14**	**29**

Biomass of large bodied fish at each site was estimated. Lengths were obtained for as many fish as was practical while not impeding on fish assemblage assessments and causing unnecessary stress on fish from handling in the hot weather that was prevalent. Where not all fish could be practically measured estimates of length were made. Weight estimates were calculated using known length weight relationships obtained from the literature. Weight estimates were derived from length-weight relationships for the following species *Anguilla reinhartii* (Pusey *et al.* 2004), *Leiopotherapon unicolor* (Bishop *et al.* 2001), *Macquaria novemaculeata* (Schneirer 1982), *Maccullochella mariensis* (as none available for this species the relationship for *Maccullochella peeli was used,* Llewellyn 2011), *Mugil cephalus* (Gehrke *et al.* 2001), *Nematalosa erebi* (Llewellyn 2011), *Neoceratodus fosteri* (Brooks & Kind 2002), *Tandanus tandanus* (Llewellyn 2011), *Hephaestus fuliginosus* (Bishop *et al.* 2001), *Macquaria ambigua* (Llewellyn 2011), *Scleropages leichardti* (Merrick *et al.* 1983) and *Oreochromis mossambicus* (Froese & Pauly 2019).

Biomass estimates (kg/minute electrofishing on time) for large bodied fish species at each site is presented in Table 14. Biomass varied substantially across all sites. Biomass per electrofishing on-time effort was lowest in sites along Six Mile Creek and in Cooloolabin Dam. The highest biomass estimates were recorded from sites along Yabba Creek and the Mary River. These biomass estimates were largely dominated by Australian lungfish, although notable contributions were made by Mary River cod, sea mullet and bony bream at site 37 on the Mary River and by tilapia at site 18 on Yabba Creek.

Table 14: Biomass estimates for each large bodied fish species at each site (kg/minute electrofishing on time)

Scientific name	Common name	1	2	3	4	6	8	12	18	21	31	37
Anguilla reinhartii	Longfin eel	0.09	0.63	0.16	0.17	0.47	0.41	0.66	0.16	0.32	0.12	0.35
Leiopotherapon unicolor	Spangled perch	-	-	-	-	-	-	0.07	-	-	-	-
Macquaria novemaculeata	Australian bass	-	-	-	-	-	-	-	0.12	-	0.32	0.14
Maccullochella mariensis	Mary River cod	-	-	-	-	-	-	-	-	0.14	0.05	1.62
Mugil cephalus	Sea mullet	-	-	-	-	-	-	0.16	-	-	-	1.39
Nematalosa erebi	Bony bream	-	-	-	-	-	-	0.04	0.66	-	0.09	2.91
Neoceratodus fosteri	Australian lungfish	-	-	-	-	-	-	4.69	15.37	-	15.51	15.89
Tandanus tandanus	Eel-tailed catfish	0.14	0.11	0.02	-	0.04	0.03	0.02	0.02	0.08	0.24	-
Hephaestus fuliginosus	Sooty grunter	-	-	-	-	-	-	0.01	-	-	0.06	0.44
Macquaria ambigua	Golden perch	-	-	-	-	-	-	0.02	0.03	-	-	0.34
Scleropages leichardti	Southern saratoga	0.02	-	-	-	-	-	-	0.02	-	-	0.10
Oreochromis mossambicus	Tilapia	-	-	-	-	-	-	0.41	2.17	-	-	0.11
Total biomass large bodied species		**0.25**	**0.74**	**0.18**	**0.17**	**0.51**	**0.45**	**6.08**	**18.55**	**0.54**	**16.40**	**23.30**

5.7. Turtles

No turtles were captured in the cathedral trapping at the three sites they were deployed in Six Mile Creek. Further no turtles were observed during sampling at any sites along Six Mile Creek. A single adult saw-shelled turtle (*Wollumbinia latisternum*) was captured in the cathedral traps in Cooloolabin Dam.

The most commonly observed species of turtle observed in the Mary River and tributaries was Krefft's turtle (*Emydura krefftii krefftii*) which was observed basking or on the water surface at sites 12 (Mary River), 28 (Kandanga Creek), 28 (Yabba Creek, 31 (Yabba Creek), 17 (Mary River) and 37 (Mary River). This species was particularly abundant at sites 12 (Mary River) and site 18 (Yabba Creek) where more than twenty individuals were observed at each site.

A single specimen believed to be a white-throated snapping turtle (*Elseya albagula*) was observed while electrofishing at site 37 on the Mary River. While not captured for close examination, the tentative identification was made based on the large size of the turtle, as well as the shape and coloration of the head.

5.8. Platypus

Five sites along Six Mile Creek, one on Yabba Creek and one on the Mary River were determined to have both good potential foraging and burrowing habitat for platypus. A further six sites were noted as having either good or fair habitat for both foraging habitat and burrowing habitat.

5.9. Biosecurity

Cabomba is currently not known from the Mary River catchment outside of Lake Macdonald, including upstream and downstream in Six Mile Creek. Cabomba does not appear to persist in Six Mile Creek downstream of Lake Macdonald being recorded in low abundance and not having become permanently established despite large amounts being washed over the dam wall during dam spilling events. This is attributed to the low light conditions from the well developed canopy combined with the substrate that is not conducive to establishment (i.e. firm clay and sand rather than soft sediment) (Phil Moran pers. comm.). Cabomba was not noted in any of the sites assessed for reconnaissance or sampling in the Mary River catchment.

The likelihood of establishment of Cabomba in the Mary River catchment is considered low for most of the catchment as it does not grow well on stony, clay or sandy sediments or when the water pH is above 7 (DPI 2020).

Cabomba is known to occur, and was recorded during the January 2020 sampling, in Cooloolabin Dam.

6. Discussion and recommendations

6.1. Site suitability recommendations

The following site suitability recommendations for aquatic fauna release were derived with the following considerations:

- The constraints outlined in section 3.1
- The desktop assessment
- Site sampling and advice from members of Queensland Fisheries, Mary River Catchment Coordinating Committee (MRCCC), Noosa Landcare and Tiaro Landcare.

The recommended relocation sites for each large bodied fish species considered are presented in Table 15.

Table 15: Recommended release sites for large bodied fish species

Large bodied native fish species	Good	Fair
Mary River cod	Hatchery, Mary River Sites (12, 37)	Mary River (sites 17, 33), Yabba Creek (sites 18, 31)
Australian lungfish	Mary River Sites (12, 37)	Mary River (sites 17, 33), Yabba Creek (sites 18, 31)
shortfin eel	Cooloolabin Dam	-
longfin eel	Cooloolabin Dam	-
eel-tailed catfish	Cooloolabin Dam	-
bony bream	Cooloolabin Dam	-
snubnose garfish	Cooloolabin Dam	-
spangled perch	Cooloolabin Dam	-
Australian bass	Cooloolabin Dam	-
golden perch	Cooloolabin Dam	-
silver perch	Cooloolabin Dam	-
southern saratoga	Cooloolabin Dam	-

It is noted that bony bream and snubnose garfish are typically adversely affected by handling and attempts to relocate them could result in high mortalities which could in turn foul water both for them and any other fish species in transportation vessels. Consideration should be given to not attempting to relocate them and to having suitable disposal facilities available to collect any mortalities during the recovery phase of the project.

A number of sites were considered suitable for the threatened turtle species and for small numbers of saw-shelled and broad-shelled turtles (Table 16). Field observations (Timothy Howell pers. obs.) and discussions with Tiaro Landcare turtle experts suggested that the most abundant turtle species in Lake Macdonald is likely to be Krefft's turtle. We recommend that further investigation into potential relocation sites be undertaken prior to commencement of dewatering to identify relocation sites if required. Although it is understood that where possible this species will be allowed to remain in the lowered water remaining in Lake Macdonald. Some potential options for consideration are large farm dams on private property and council lakes within the Mary River catchment.

Table 16: Recommended release sites for turtle species

Turtles	Potential release sites
Mary River turtle	Mary River Sites (12, 17, 33, 37), Yabba Creek (sites 18, 31)
white-throated snapping turtle	Mary River Sites (12, 17, 33, 37), Yabba Creek (sites 18, 31)
Krefft's turtle	Not determined
saw-shelled turtle	Small numbers at all sites along Six Mile, Amamoor and Kandanga Creeks.
eastern long-necked turtle	Not determined
broad-shelled river turtled	Small numbers at all sites along Six Mile, Amamoor and Kandanga Creeks.

It is understood that the intention is to not relocate any platypus individual unless necessary. If platypus relocation is required, site 37 on the Mary River would likely be the best option due to suitable habitat and the size of the waterbody reducing negative interactions with established individuals at a given site and more opportunity to move into areas with lower densities. The four sites identified as having suitable foraging and burrowing habitat on Six Mile Creek are less likely to provide the opportunity for any relocated platypus to be able to move into areas not already within home ranges of existing individuals.

6.2. Site inspection intervals

The current assessment should be considered a snapshot assessment and may not reflect the condition of the sites at the time of the relocation of the aquatic fauna. Most notably the surveys were undertaken in summer and the proposed dewatering and aquatic fauna relocation is proposed for the winter months. We recommend that, as a minimum, a water quality and fish assemblage assessment be undertaken of key sites prior to commencement of the dewatering of Lake Macdonald.

In addition, a relocation site visual assessment should be conducted immediately prior to commencement of any potential relocation activities. This should include an assessment of the streamflow conditions at the time and how this would influence the potential aquatic fauna carrying capacity (e.g. flow, water quality, submerged macrophytes, connectivity). The site visual assessments should be conducted regularly during the translocation of aquatic fauna, with a follow-up assessment at least two weeks after the translocation.

6.3. Biosecurity

6.3.1. Cabomba

While the risk of Cabomba spreading is considered to be relatively low, the consequences of such an event are potentially high. Therefore, all precautions should be taken to ensure that no Cabomba is released into the relocation sites inadvertently with aquatic fauna. It is recommended that a protocol is designed and enacted for quarantining and checking all aquatic fauna prior to relocation.

6.3.2. Aquatic fauna

Tilapia and gambusia are restricted invasive fish species under the Biosecurity Act 2014 and as such are required by DAF pest to be euthanised if collected. Banded grunter are a native fish species that have spread outside their natural range. They are not listed as a pest, although have the potential to negatively impact on indigenous species. We recommend that approval is sought from DAF for euthanising banded grunter.

As Lake Macdonald is located near a small town and in proximity to larger population of along the Sunshine Coast, it is considered possible that other turtle species may be present in the lake as deliberately released pets. We recommend that suitably trained experienced operators are used to identify all turtles prior to any relocation.

7. References

AS/NZS (1998). AS/NZS 5667.12:1998: Water quality – Sampling. Part 12: Guidance on Sampling of Bottom Sediments. Standards Australia, New South Wales.

Atlas of Living Australia (2020). Accessed between January and March 2020.

Berghuis, A.P. and Broadfoot, C.D. (2004). Upstream passage of Queensland lungfish at Ned Churchward Weir Fishlock. Queensland Government Department of Primary Industries, Queensland Fisheries Service, Bundaberg. Report for the Department of State Development, March 2004.

Bishop, K.A., S.A. Allen, D.A. Pollard, and Cook, M.G. (2001). Ecological studies on the freshwater fishes of the Alligator Rivers Region, Northern Territory: Autecology. Office of the Supervising Scientist Report 145, Supervising Scientist, Darwin.

Brooks, S.G. and Kind, P.K. (2002). Ecology and demography of the Queensland lungfish (*Neoceratodus forsteri*) in the Burnett River, Queensland with reference to the impacts of Walla Weir and future water infrastructure development. Queensland Department of Primary Industries. Queensland, Queensland Agency for Food and Fibre Services.

Clark, N. J., Gordos, M. A. and Franklin, C. E. (2008). Diving behaviour, aquatic respiration, and blood respiratory properties: a comparison of hatchling and juvenile Australian turtles. Journal of Zoology (London)275,399-406.

Department of the Environment and Energy (2017). National Recovery Plan for the White-throated Snapping Turtle (*Elseya albagula*), Commonwealth of Australia 2017.

Department of the Environment (2014). Conservation Advice *Elseya albagula* White-throated snapping turtle. Canberra: Department of the Environment. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/81648-conservation-advice.pdf.

Department of Science and the Environment (2018). Monitoring and Sampling Manual: Environmental Protection (Water) Policy. Brisbane: Department of Environment and Science Government.

Department of the Environment, Water, Heritage and the Arts (2008). Approved Conservation Advice for *Elusor macrurus* (Mary River Turtle). Canberra: Department of the Environment, Water, Heritage and the Arts. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/64389-conservation-advice.pdf

Department of Natural Resource Management (2001). Queensland Australian River Assessment System (AUSRIVAS) Sampling and Processing Manual, August 2001, Queensland Department of Natural Resources and Mines, Rocklea.

Department of Primary Industries (2020). https://weeds.dpi.nsw.gov.au/Weeds/Cabomba. New South Wales.

Flakus, S. (2000). Ontogenetic dietary shifts in an Australian chelid turtle, Elusor macrurus. Tucker, A.D., ed. Cumulative Effects of Dams and Weirs on Freshwater Turtle Populations: Fitzroy, Burnett and Mary River Catchments. Queensland Parks and Wildlife Service. Unpublished report to the Queensland Department of Natural Resources.

Flakus, S. (2002). Ecology of the Mary River Turtle, *Elusor macrurus*. M.Sc. Thesis. University of Queensland.

Froese, R. and Pauly, D. (2019) .FishBase. World Wide Web electronic publication. www.fishbase.org, (12/2019).

Gehrke, P.C., D.M. Gilligan, and Barwick, M. (2001). Fish communities and migration in the Shoalhaven River – Before construction of a fishway. New South Wales Fisheries, Cronulla. Final Report Series No. 26

Grant, T. R. (2007). Platypus, CSIRO Publishing, Colliingwood, Victoria.

Grantley, J., McPherson, F. and Petroeschevsky, A. (2009). Recognising water weeds. Plant identification guide. Industry and Investment NSW.

Hamman, M., Schauble, C.S., Limpus, D., Emerick, S.P., and Limpus, C.J. (2007). Management plan for the conservation of *Elseya* sp. [Burnett River] in the Burnett River Catchment. Environmental Protection Agency.

Heavey, J. and MacDonald, S. (2013). Weeds of the Sunshine Coast. Noosa Integrated Catchment Association Inc.

Kemp, A. (1981). Rearing of embryos and larvae of the Australian Lungfish, *Neoceratodus forsteri*, under laboratory conditions. Copeia. Page(s) 776-784.

Kemp, A. (1987). The biology of the Australian lungfish, *Neoceratodus forsteri* (Krefft 1870). In: Bemis, W .E, W.W Burggren and N.E. Kemp, eds. The biology and evolution of lungfishes. Page(s) 181-198. New York: A.R. Liss.

Kind, P.K. (2002). Movement patterns and habitat use in the Queensland lungfish *Neoceratodus forsteri* (Krefft 1870). Ph.D. Thesis. PhD Thesis, University of Queensland.

Llewellyn, L.C. (2011). Length - weight relationships of freshwater fish from the Murray-Darling River System in inland New South Wales, with particular reference to the Golden Perch *Macquaria ambigua*. Zoologist 35:3.

Limpus, C. (2008). Freshwater Turtles in the Mary River: Review of biological data for turtles in the Mary River, with emphasis on *Elusor macrurus* and *Elseya albagula*. Brisbane: Queensland Government.

Limpus, C. J., Limpus, D. J., Parmenter, C. J., Hodge, J., Forest, M. and McLachlan, J. (2011). The Biology and Management Strategies for Freshwater Turtles in the Fitzroy Catchment, with particular emphasis on *Elseya albagula* and *Rheodytes leukops*: A study initiated in response to the proposed construction of Rookwood Weir and the raising of Eden Bann Weir. Department of Environment and Resource Management Brisbane.

Lintermans, M. Stuart Rowland, S. Koehn, J. Butler, G. Simpson, B. and Wooden, I. (2004). The status, threats and management of freshwater cod species *Maccullochella* spp. in Australia. Management of Murray Cod in the Murray-Darling Basin Workshop, Canberra 2004.

MacDonald, S. and Haslam, S. (2016). Sedges, rushes & restiads of the Noosa Biosphere Reserve & surrounding regions. Noosa Integrated Catchment Association Inc.

Mathie N. J. and Franklin C. E. (2006). The influence of body size on the diving behaviour and physiology of the bimodally respiring turtle *Elseya albagula*. Journal of Comparative Physiology B176,739-474.

Merrick, J.R., S.H. Midgley, and Rimmer, M.A. (1983). Preliminary studies on growth of two spotted barramundi species, *Scleropages leichardti* and *S. jardini* (Pisces: Osteoglossidae). Aquaculture 32: 195–199.

NSW Fisheries (1997). The Australian Code of Electrofishing Practice. NSW Fisheries Management Publication No. 1.

Sainty, G. and Jacobs, S. (2003). Waterplants In Australia: A Field Guide. Sainty and Associates.

Simpson, R. (1994). An investigation into the habitat preferences and the population status of the endangered Mary River cod (*Maccullochella peeli mariensis*) in the Mary River system, south-eastern Queensland. QDPI Information Series QI94011.

SMEC (2019). Lake Macdonald Water Lowering – Adaptive Management Plan. Six Mile Creek Dam Safety Upgrade Project.

Stephens, K.M. and Dowling, R.M. (2002). Wetland Plants of Queensland: A Field Guide. CSIRO publishing.

Tucker, A.D. (2000). Population structure and function of turtles of southeast Queensland. Tucker, A.D., ed. Cumulative Effects of Dams and Weirs on Freshwater Turtles: Fitzroy, Kolan, Burnett and Mary Catchments. Page(s) 28-46. Qld Parks & Wildlife Service, Bundaberg.

Schneirer, S.B. (1982). The biology of the Australian bass *Macquaria novemaculeata* (Steindachner) in the Richmond River, northern New South Wales. Ph.D. Thesis, University of Queensland, Brisbane.

Simpson, R. and Jackson, P. (1996). The Mary River Cod Research and Recovery Plan. Queensland Department of Primary Industries - Fisheries Group. Available from: http://www.environment.gov.au/resource/mary-river-cod-research-and-recovery-plan.

Appendix A – EVNT species profiles

Mary River cod **(*Maccullochella mariensis*)** **Photo: Tim Howell**	
Legislative listing	Listed as **Endangered** under the EPBC Act (1999). They are not listed as threatened under the Nature Conservation Act (1992), however, are a protected as no-take species except in stocked impoundments.
Species distribution	Endemic to the Mary River catchment but have been introduced elsewhere in south-east Queensland. A closely related species that once existed in the Brisbane and Logan-Albert Rivers is now extinct.
Distribution in the Mary River catchment	The historic range has been estimated to have been reduced to less than 30% largely due to overfishing by the early European settlers, massive siltation of their habitats from land-use activities and dams / weirs blocking migration (Simpson & Jackson 1996). The strongest populations currently appear to be in the Mary River between Kenilworth and Amamoor, Obi Obi, Tinana and Six Mile Creeks (ALA 2020).
Life history	There is little available information on the spawning habitat and behaviour of wild fish, with most information derived from hatchery observations (Simpson & Jackson 1996). Mary River cod form pairs and spawn annually around spring. In hatchery conditions they spawn in hollow pipes or purpose-built nesting boxes, therefore it is presumed that hollow logs are used as nests in the wild. The male continues to guard the brood until they disperse to search for food around seven to nine days after hatching.
Movement patterns	Fish tend to have a home range where they spend to the majority of the time but may move as far as 30 km either up or downstream depending on flows and time of the year (Simpson & Jackson 1996). Mary River cod have been recorded returning to a home range after long absences (Simpson & Jackson 1996). The Mary River cod is known to migrate into smaller tributaries from the main river in late winter (Simpson & Jackson 1996).
Habitat	Inhabits from high gradient, rocky, upland streams in Obi Obi Creek, to large, slow-flowing pools in lowland areas along the Mary River, to deep tannin stained pools in Tinana and Six Mile Creeks. Cover is considered important for concealment from potential prey and as resting sites, and woody material, especially hollow logs, also provides sites for spawning (Simpson 1994).
Diet	Carnivorous. There is no published quantitative dietary information on the diet but adults of this species, like other percichthyids, are fully carnivorous; they consume a range of relatively large food items such as crustaceans and fish, and possibly also frogs, snakes, waterbirds and mice (Pusey et al. 2004).
Key threats	Impoundment of streams changing flow regimes. Loss of riparian vegetation and in-stream timber and vegetation. Channel infilling with sand from eroded banks. Competition with, and predation from, invasive fish species. Competition from non-indigenous Australian fishes stocked into impoundments that overflow into natural waterways. Angling mortalities and specimens not being released.

Australian lungfish
(*Neoceratodus forsteri*)

Photo: Tim Howell

Legislative listing	Listed as **Vulnerable** under the EPBC Act (1999). Australian lungfish are not listed as threatened under the Nature Conservation Act (1992), however, are a protected as no-take species.
Species distribution	The natural distribution is the Mary, Burnett and Brisbane River systems, and possibly the Pine River system. It has also been translocated to the Coomera, Condamine, Albert and Logan Rivers. It is uncertain whether the population in North Pine River is natural or a result of translocation.
Distribution in the Mary River catchment	They are found from the Mary River Barrage to the town of Conondale, a distance of approximately 160 kilometres. They are found in both the Mary River itself as well as several large tributaries including Yabba, Tinana and Coondoo Creeks (ALA 2020).
Life history	Spawning occurs between August and December with peak spawning in the Mary River catchment (Brooks & Kind 2002). Fish spawn in a variety of mesohabitats in rivers including pools, riffles and runs, typically amongst aquatic macrophytes (Brooks & Kind 2002). Juveniles develop quickly and resemble adult fish when they are six or seven months old (Kemp 1981). Recruitment appears to be higher in years where there is macrophyte algae in shallow water, and high concentrations of microcrustaceans and invertebrates for juveniles to eat (Kemp 1987).
Movement patterns	Largely sedentary with a small home range (Berghuis & Broadfoot 2004). Have been recorded moving 48 km under flow conditions (Kind 2002).
Habitat	Use a range of mesohabitats but are generally within close proximity to water over a metre deep. Adult Lungfish in the Mary River are associated with overhanging riparian (riverside) vegetation, woody debris in the water, and dense macrophyte beds. They shelter in complex, shaded habitat. They most prefer habitat with overhanging vegetation and macrophytes in relation to their availability, and often use habitat with instream wood. They tend to select aquatic macrophyte species that form dense submerged banks. Juveniles are almost always found in dense cover such as submerged macrophyte beds (Kind 2002).
Diet	Adult lungfish are benthic carnivores feeding largely on molluscs and other aquatic macroinvertebrates. They ingest masses of material that they do not digest, particularly plant matter and sand (Spencer 1892). Hatchling and juvenile lungfish feed on small invertebrates (Kemp 1981) and are active predators, at least when young.
Key threats	Impoundments through changes to flow regimes and stranding of fish following flow events. Erratic recruitment. Unintentional capture injury by anglers. Competition with, and predation on larvae and juveniles by pest fish species. A reduction in the water quality downstream on the Mary River downstream of the township of Gympie (Brooks & Kind 2002)

Mary River turtle
(*Elusor macrurus*)

Photo: Marilyn Connell

Legislative listing	Listed as **Endangered** under both the EPBC Act (1999) and the Nature Conservation Act (1992).
Species distribution	Endemic to the Mary River catchment. While popular in the aquarium trade for some time no known populations appear to have established elsewhere.
Distribution in the Mary River catchment	Found throughout the mainstream of the Mary River from Kenilworth in the upper reaches, to the saltwater tidal barrage downstream of Tiaro, and in several of the larger tributaries including Tinana Creek, Yabba Creek and Obi Obi Creek (Limpus 2008, ALA 2020).
Life history	The Mary River turtle takes around 25 years for females and 30 years for males to reach maturity (Tucker 2000). Nesting occurs from October to January each year, with most of the nesting occurring in November and early December All known breeding banks for Mary River turtle are along two reaches of the Mary River proper, the first near Tiaro and the second between Traveston and Kenilworth (Limpus 2008). Fecundity is low with a single clutch laid by females each ranging from 12 to 25 eggs (Flakus 2000).
Movement patterns	During the nonbreeding season, the movements of both male and female Mary River turtles are very localised (200-600 m) (). During the breeding season, females can swim up to 2km to find a suitable sand bank on which to lay their eggs (Flakus 2000).
Habitat	The Mary River turtle uses cloacal respiration, which restricts it to flowing, well-oxygenated sections of streams. Its habitat consists of riffles (particularly productive parts of a river that are shallow with fast-flowing, aerated water) and shallow stretches alternating with deeper, flowing pools. It generally does not occur in impoundments due to reduced oxygen levels. Adults are usually found in areas with underwater shelter, such as sparse to dense aquatic plant cover, submerged logs and rock crevices. They bask on logs and rocks. Juveniles occur in rocky areas with sand or gravel on the riverbed, based on limited data (DEWHA 2008).
Diet	As a juvenile, the Mary River turtle mainly eats insect larvae and freshwater sponges which are generally found in shallow rocky areas. As the Mary River turtle matures, its diet shifts to a more herbivorous one comprising mainly water plants (Flakus 2000).
Key threats	Predation of the eggs by feral dogs, foxes and goannas is a big problem for the Mary River turtle. Dams and weir altering water quality, flow transportation of sediment (Flakus 2002).

White-throated snapping turtle
(*Elseya albagula*)

Photo: Chris Pietsch

Legislative listing	Listed as **Critically Endangered** under the EPBC Act (1999) and **Endangered** under the Nature Conservation Act (1992).
Species distribution	Endemic to the Fitzroy, Burnett and Mary River catchments.
Distribution in the Mary River catchment	Has been recorded from the Mary River near Kenilworth and further downstream near Gunalda. Also known from Yabba and Tinana Creeks. Mary River Barrage, Imbil Weir, Borumba Dam and Tallegal (Limpus 2008, ALA 2020).
Life history	The white-throated snapping turtle takes around 15-20 years to reach maturity (Limpus et al. 2011). The white-throated snapping turtle breed between autumn and winter, while hatching occurs during spring to summer (Hamann et al. 2007). The species may not breed during periods of low food availability. There two known breeding banks for Mary River turtle along the Mary River proper (the first near Tiaro and the second between Traveston and Kenilworth), as well as several known breeding banks on Yabba Creek (Limpus 2008). Fecundity is low with a single clutch laid by females averaging 14 eggs (Limpus 2008).
Movement patterns	The species has relatively small home ranges, commonly utilising stream lengths of less than 1 km, however, isolated long distance movements of up to 10 km have been recorded (DE 2014).
Habitat	The white-throated snapping turtle is recognised as a habitat specialist. Within the river system the white-throated snapping turtle prefers clear, flowing, well-oxygenated waters. This preference appears to be associated with their physiological adaption to extract oxygen from water via cloacal respiration (Mathie & Franklin 2006; Clark et al. 2008). White-throated snapping turtles do occur in non-flowing waters, but typically at much reduced densities. The species prefers waterways with permanent flowing water, with undercut banks, large woody debris, deep pools (6 m deep) and shallow riffle zones (Hamann et al. 2007). The white-throated snapping turtle also has been recorded in streams with a sand-gravel substrate and overhanging riparian vegetation (Hamann et al. 2007). The species utilises highly productive riffle zones during the wet season to feed and build energy reserves for reproduction (Hamann et al. 2007).
Diet	The white-throated snapping turtle is a benthic foraging species. It is primarily herbivorous, feeding on fruit and buds of riparian vegetation that fall on the water, leaves and stems of terrestrial plants, tree roots, filamentous algae , and instream macrophytes. The species changes its diet from being largely carnivorous (feeding on benthic invertebrates) when young, to largely herbivorous as it gets older (DEE 2017).
Key threats	Loss of eggs is related to predation and trampling of the banks by cattle. Feral pigs, foxes, dogs, goannas and water rats can disturb the nests and destroy many clutches of eggs. Habitat modification through the installation of barrages and weirs has reduced the availability of riffle habitat through flow regulation (DE 2014).

Platypus (*Ornithorhynchus anatinus*)		
	Photo: Mark Sanders	
Legislative listing	Platypus is a **Special Least Concern** species under the Nature Conservation Act (1992) but is not threatened at National or State levels.	
Species distribution	Eastern Australia from the border of South Australia and Victoria through to the wet tropics north of Cairns in Queensland. They are also found throughout Tasmania.	
Distribution in the Mary River catchment	Platypus have been recorded throughout the Mary River catchment from the upper reaches of all major tributaries through to Maryborough (ALA 2020).	
Life history	Typically breed in spring, with breeding occurring earlier in norther regions of the species' distribution compared to southern regions (Grant 2007). 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 2007).	
Habitat	Platypus are a semi-aquatic mammal that feed only in the water. They find their prey by searching along shallow riffles, gleaning items from submerged logs and branches, digging under banks, and diving repeatedly to the bottom of pools. They are found over a wide variety of streams and impounded waters (Grant 2007).	
Diet	They are carnivorous, feeding on worms, insect larvae, freshwater shrimps, and yabbies' (Grant 2007).	
Key threats	Reduction in habitat quality limiting the availability of nutritious food. Variability in stream flow (both droughts and floods). Reduced water quality, particularly in urban environments. Litter getting tangled around diving platypus. Dams and weirs. Pumps, pipes and culverts. Urban development. Dangerous nets and traps. Inappropriate angling practices. Predators and disease. (Grant 2007).	

Appendix B – Site reconnaissance photographs

Site 1 – Cooloolabin Dam 21/11/2019	Co-ordinates - UTM 56 J E 488246 N 7062855
	

General comments
A large body of water which meets the requirements for releasing fish that have been stocked into Lake Macdonald for recreational purposes that are not EVNT species (i.e. Australian bass, golden perch, southern saratoga).

Site 2 – Six Mile Creek (east branch) 21/11/2019	Co-ordinates - UTM 56 J E 490171 N 7080092
 Upstream	 Downstream

General comments
Two mid-sized pools present. Potentially capacity to relocate a small number of aquatic fauna. Would require high flow to allow movement out of the reach for further relocation of aquatic fauna. Short drive from Lake Macdonald and good access.

Site 3 – Six Mile Creek 21/11/2019	Co-ordinates - UTM 56 J E 489157 N 7086491
 Upstream	 Downstream

General comments
A large pool, relatively steep banks and deep water. No boat launch and difficult to sample effectively. Likely to be able to take a small number of aquatic fauna.

Site 4 – Six Mile Creek 21/11/2019	Co-ordinates - UTM 56 J E 484959 N 7086511

Upstream

Downstream

General comments

A series of smaller pools which have potential capacity to relocate a small number of aquatic fauna. No large pools noted immediately adjacent to the reach so potentially less room for aquatic fauna to move into adjacent habitat. May be able to take a small number of aquatic fauna.

Site 5 – Six Mile Creek 21/11/2019	Co-ordinates - UTM 56 J E 478420 N 7089063

Upstream

Downstream

General comments

Several mid-sized pools throughout the reach. Potential capacity to relocate a small number of aquatic fauna. Would require high flow to allow movement out of the reach for further relocation of aquatic fauna.

Site 6 – Dingo Creek 21/11/2019	Co-ordinates - UTM 56 J E 477795 N 7090114

Upstream

Downstream

General comments

Dry site, unlikely to hold water for more than a short period of time after rainfall.

Site 7 – Six Mile Creek 21/11/2019	Co-ordinates - UTM 56J E 475960 N 7092575
 Upstream	 Downstream

General comments
An apparently deep pool at the site and at least one more adjacent to the reach. Reasonable habitat but some difficulties with site access due to steep banks. May be able to take a small number of aquatic fauna.

Site 8 – Six Mile Creek 21/11/2019	Co-ordinates - UTM 56 J E 473905 N 7095985
 Upstream	 Downstream

General comments
Several large and apparently deep pools with potential capacity to relocate several aquatic fauna individuals. Good parking but relatively steep banks and deep water. No boat launch.

Site 9 – Woondum Creek 21/11/2019	Co-ordinates - UTM 56 J E 476900 N 7095458
 Upstream	 Downstream

General comments
Largely dry. Pool below the causeway likely a result of scoring from the causeway.

Site 10 – Sandy Creek 21/11/2019	Co-ordinates - UTM 56J E 477010 N 7094516
 Upstream	 Downstream

General comments
Largely dry. A small pool below the bridge likely a result of scoring from the bridge.

Site 11 – Traveston Creek 21/11/2019	Co-ordinates - UTM 56 J E 472061 N 7088401
 Upstream	 Downstream

General comments
Water quality poor; low dissolved oxygen, high turbidity and conductivity.

Site 12 – Mary River 21/11/2019	Co-ordinates - UTM 56 J E 470262 N 7087513
 Upstream	 Downstream

General comments
Good site access and safe launch. Popular spot for local people to swim and take dogs for swims. Concern the high public usage might encourage angling for released Mary River Cod from observers.

Site 13 – Mary River 21/11/2019

Co-ordinates - UTM 56J
E 471772 N 7086344


Upstream


Downstream

General comments
Inaccessible without private property access.

Site 14 – Kandanga Creek 21/11/2019

Co-ordinates - UTM 56 J
E 469082 N 7082218


Upstream


Downstream

General comments
Largely inaccessible due to heavy weed infestation of the riparian zone and private property.

Site 15 – Kandanga Creek 21/11/2019

Co-ordinates - UTM 56 J
E 470348 N 7084295


Upstream


Downstream

General comments
Large pools upstream and downstream. Poor parking and site access.

Site 16 – Coonan-Gibber Creek 21/11/2019

Co-ordinates - UTM 56J
E 472773 N 7075973


Upstream


Downstream

General comments
Largely dry. A small shallow pool immediately above the road bridge.

Site 17 – Mary River 21/11/2019

Co-ordinates - UTM 56 J
E 475087 N 7077293

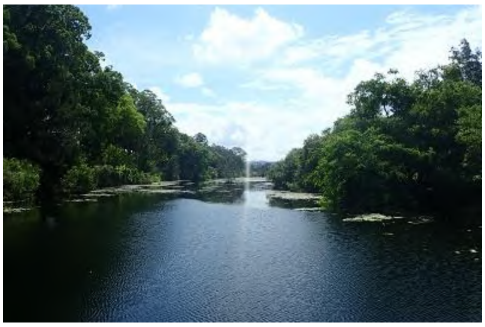

Upstream


Downstream

General comments
A large pool at this site. A reasonable footpath provides reasonable point access but the banks are high and the water deep for most of this reach. No boat launching in public access areas. Likely to be able to difficult to sample well under current constraints for capacity or monitoring post relocation.

Site 18 – Yabba Creek 21/11/2019

Co-ordinates - UTM 56 J
E 468073 N 7073451


Upstream


Downstream

General comments
Excellent site for all criteria.

<table>
<tr><td>Site 19 – Belli Creek
21/11/2019</td><td><u>Co-ordinates - UTM 56J</u>
E 477931 N 7070724</td></tr>
<tr><td>
Upstream</td><td>
Downstream</td></tr>
<tr><td colspan="2"><u>General comments</u>
Not flowing some remnant pools present. Potential capacity to relocate a small number of aquatic fauna individuals under better flow conditions.</td></tr>
<tr><td>Site 20 – Belli Creek
21/11/2019</td><td><u>Co-ordinates - UTM 56 J</u>
E 481121 N 7067673</td></tr>
<tr><td>
Upstream</td><td>
Downstream</td></tr>
<tr><td colspan="2"><u>General comments</u>
Not flowing, some small remnant pools present with poor water quality. Poor access and unsafe access.</td></tr>
<tr><td>Site 21 – Six Mile Creek
4/12/2019</td><td><u>Co-ordinates - UTM 56 J</u>
E 480968 N 7087762</td></tr>
<tr><td>
Upstream</td><td>
Downstream</td></tr>
<tr><td colspan="2"><u>General comments</u>
Several small to mid-sized pools throughout the reach. Potentially capacity to relocate a small number of aquatic fauna under flow conditions. Would require high flow to allow movement out of the reach for further relocation of aquatic fauna. Short drive good and good access.</td></tr>
</table>

Site 22 – Amamoor Creek 4/12/2019	**Co-ordinates - UTM 56J** **E 468572 N 7088012**
 Upstream	 Downstream
General comments Poor parking for a car with a trailer. Poor access from the road to the creek.	

Site 23 – Amamoor Creek 4/12/2019	**Co-ordinates - UTM 56J** **E 467778 N 7086604**
Unable to obtain useful photograph	Unable to obtain useful photograph
General comments No public access.	

Site 24 – Amamoor Creek 4/12/2019	**Co-ordinates - UTM 56 J** **E 467321 N 7086336**
 Upstream	 Downstream
General comments Not flowing, some small remnant pools present with poor water quality. Good parking and reasonable access. Potential capacity to relocate a small number of aquatic fauna individuals under better flow conditions.	

Site 25 – Amamoor Creek
4/12/2019

Co-ordinates - UTM 56 J
E 466202 N 7085823

Upstream

Downstream

General comments
Good point access but private property making access for aquatic ecosystem assessment difficult. Potential capacity to relocate a small number of aquatic fauna individuals under better flow conditions.

Site 26 – Amamoor Creek
4/12/2019

Co-ordinates - UTM 56J
E 465197 N 7085152

Upstream

Downstream

General comments
Not flowing some remnant pools present. Potential capacity to relocate several aquatic fauna individuals under better flow conditions.

Site 27 – Kandanga Creek
4/12/2019

Co-ordinates - UTM 56 J
E 467746 N 7081573

Upstream

Downstream

General comments
Not flowing, some small remnant pools present with poor water quality. Poor access largely excludes this site.

<table>
<tr><td>Site 28 – Kandanga Creek Weir
4/12/2019</td><td><u>Co-ordinates - UTM 56J</u>
E 467372 N 7081138</td></tr>
<tr><td>
Upstream</td><td>
Downstream</td></tr>
<tr><td colspan="2"><u>General comments</u>
A large pool formed by the Kandanga Weir.</td></tr>
<tr><td>Site 29 – Kandanga Creek
4/12/2019</td><td><u>Co-ordinates - UTM 56J</u>
E 466818 N 7080555</td></tr>
<tr><td>
Upstream</td><td>
Downstream</td></tr>
<tr><td colspan="2"><u>General comments</u>
Some small remnant pools. Unlikely to have any larger pools even under better flow conditions.</td></tr>
<tr><td>Site 30 – Kandanga Creek
4/12/2019</td><td><u>Co-ordinates - UTM 56 J</u>
E 464458 N 7081131</td></tr>
<tr><td>
Upstream</td><td>
Downstream</td></tr>
<tr><td colspan="2"><u>General comments</u>
Site largely dry.</td></tr>
</table>

Site 31 – Yabba Creek 4/12/2019	**Co-ordinates - UTM 56 J** E 462860 N 7069961
 Upstream	 Downstream

General comments
Excellent site for all criteria.

Site 32 – Mary River 4/12/2019	**Co-ordinates - UTM 56J** E 473589 N 7059185
 Upstream	 Downstream

General comments
Poor access to site due to private property. Larger pools absent.

Site 33 – Mary River 4/12/2019	**Co-ordinates - UTM 56 J** E 475676 N 7063772
 Upstream	 Downstream

General comments
Not flowing, some small remnant pools present. Potential capacity to relocate a small number of aquatic fauna individuals under better flow conditions. Good parking but the road is heavily used by trucks going to and from the stone quarry, often driving very fast. Access on and off the road considered a potential hazard.

Site 34 – Belli Creek
4/12/2019

Co-ordinates - UTM 56 J
E 482278 N 7065872


Upstream


Downstream

General comments
Small to mid-sized pools but a relatively small creek with poor aquatic fauna relocation potential.

Site 35 – Belli Creek
4/12/2019

Co-ordinates - UTM 56J
E 486382 N 7069060


Upstream


Downstream

General comments
Small to mid-sized pools but a relatively small creek with poor aquatic fauna relocation potential.

Site 36 – Mary River
4/12/2019

Co-ordinates - UTM 56J
E 474590 N 7067494

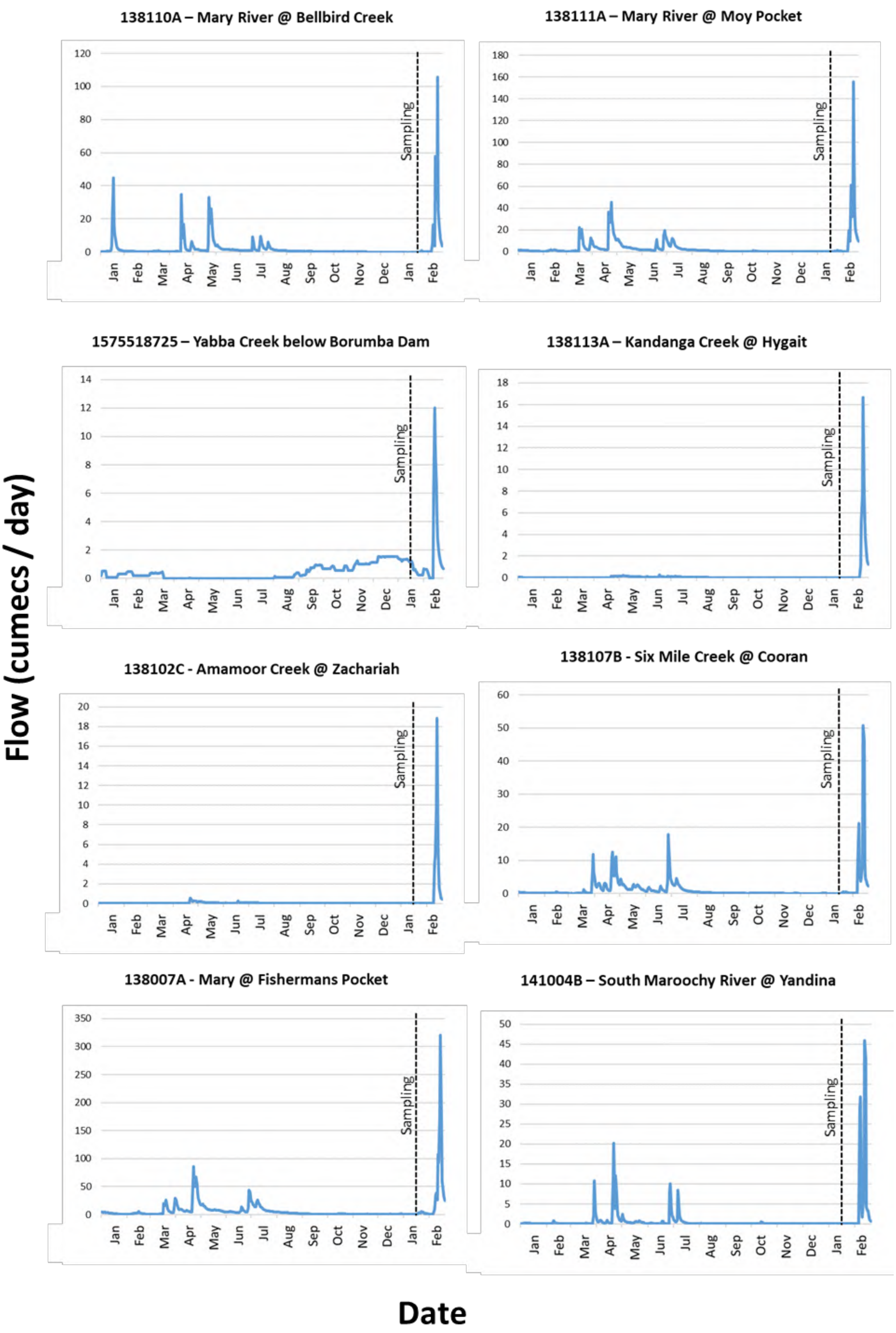

Upstream


Downstream

General comments
Some mid-sized pools adjacent but at the site the channel is largely infilled. Potential capacity to relocate a small number of aquatic fauna individuals under better flow conditions.

<table>
<tr><td>Site 37 – Mary River
4/12/2019</td><td><u>Co-ordinates - UTM 56J</u>
E 476475 N 7061738</td></tr>
<tr><td>
Upstream</td><td>
Downstream</td></tr>
<tr><td colspan="2"><u>General comments</u>
Excellent site for all criteria. Access to relocation site through private property but the landowner is amenable to allowing access.</td></tr>
<tr><td>Site 38 – Six Mile Creek
4/12/2019</td><td><u>Co-ordinates - UTM 56J</u>
E 482533 N 7087217</td></tr>
<tr><td>
Upstream</td><td>
Downstream</td></tr>
<tr><td colspan="2"><u>General comments</u>
A large pool at the site and some mid-sized pools adjacent. Poor access to the water.</td></tr>
</table>

Appendix C – Flow graphs preceding sampling


138110A – Mary River @ Bellbird Creek
138111A – Mary River @ Moy Pocket
1575518725 – Yabba Creek below Borumba Dam
138113A – Kandanga Creek @ Hygait
138102C - Amamoor Creek @ Zachariah
138107B - Six Mile Creek @ Cooran
138007A - Mary @ Fishermans Pocket
141004B – South Maroochy River @ Yandina
Sampling
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb
Flow (cumecs / day)
Date

Appendix D – Fish and turtle sampling effort

Method; BPE – backpack electrofisher, BTE – boat electrofisher, UBT – unbaited box trap, SN – seine net, DN – dip net. Brackets represent number of sampling units.

Site number	Method	Time start	Time end	Conductivity (µS/cm)	Effort time (minutes)	Electrofishing on-time (seconds)	Volts	% duty cycle	Frequency (Hz)
1	BTE	853	930	79	37	1200	500	40	120
	BTE	950	1031		41	1200	500	40	120
	BTE	1054	1145		49	1200	500	40	120
	UBT (10)	815	1202		227	-	-	-	-
	TN (4)	828	1155		207	-	-	-	-
2	BPE	713	729	791	16	377	200	40	40
	UBT (5)	655	740		45	-	-	-	-
3	BPE	848	910	189	22	447	250	40	40
	UBT (5)	830	915		45	-	-	-	-
	TN (2)	1703	904		841	-	-	-	-
4	BPE	1015	1039	238	24	471	250	40	40
	UBT (5)	959	1044		45	-	-	-	-
5	BPE	1239	1307	247	28	528	250	40	40
	UBT (5)	1232	1322		50	-	-	-	-
7	TN (2)	1721	921	301	840	-	-	-	-
8	BPE	904	937	337	33	854	250	40	40
	UBT (5)	859	944		45	-	-	-	-
12	BTE	850	936	269	46	1200	500	90	120
	BPE	1000	1032		32	756	250	40	40
	UBT (10)	940	1125		105	-	-	-	-
18	BTE	1456	1341	274	45	1200	500	60	120
	UBT (10)	1205	1345		100	-	-	-	-
21	BPE	1141	1202	244	21	408	250	40	40
	UBT (5)	1131	1215		44	-	-	-	-
31	BTE	1212	1256	248	44	1200	500	90	120
	BPE	1405	1425		20	377	250	40	40
	UBT (10)	1326	1436		70	-	-	-	-
37	BTE	933	1012	293	39	826	500	60	120
	UBT (10)	915	1022		67	-	-	-	-

Appendix E – Travel distances and times to sites

Site	Time/distance one way (Google maps)	Estimated time factor with trailer	Notes on access
1	32min / 35km	< 1.5	Steep and winding road from Yandina to the lake. Locked gate just before the ramp controlled by Seqwater.
2	6min / 6km	1.2	Good parking access off the side of Elm St.
3	16min / 18km	1.2	Reasonable parking on the side of the road at the bridge crossing. Take care of passing traffic.
4	15min / 17km	1.2	Good parking access off the side of Pomona Kin Kin Rd.
5	24min / 25km	1.2	Good parking bay just before the bridge crossing on Howe Rd.
7	28min / 37km	1.2	Good parking bay just before the bridge crossing on Tandur Rd. Difficult footing to water's edge.
8	33min / 42km	1.2	Good parking bay just next to the bridge crossing on Woondum Rd. Moderately difficult access to water's edge.
12	24min / 31min	1.2	Best release site is just off Meddleton Rd at UTM 56J E 470296 N 7087358. The release sites is at UTM 56J E 470264 N 7087507, release downstream of the riffle section.
17	23min / 28km	1.2	Good parking and point access on the eastern side of the Tuchekoi Rd bridge.
18	33min / 40km	1.2	Excellent parking and point access on the eastern side of the Kandanga Imbil Rd bridge.
21	22min / 22km	1.2	Good parking access off the side of Old Noosa Rd next to the bridge crossing.
24	27min / 36min	1.2	Good parking access off the side of Amamoor Creek Rd next to the bridge crossing.
25	28min / 37km	1.2	Reasonable parking on the side of the road at the bridge crossing. Take care of passing traffic.
28	28min / 38km	1.2	Excellent parking off main street. Point access a short distance.
31	39min / 47km	1.3	Good parking access off the side of Derrier Rd next to the bridge crossing.
33	29min / 36km	1.2	Good parking access but large trucks driving to and from quarry. Often driving fast and heavily loaded.
36	36min / 43km	1.3	Good parking access off the side of Walker Rd next to the bridge crossing.
37	28min / 35km	1.2	Access is on private property off Eumundi Kenilworth Rd. UTM 56J E 476832 N 7062006. Release site is 500 metres from the gate.

Appendix F – Site profiles

Site 1 - 15/01/2020 Cooloolabin Dam	Co-ordinates - UTM 56 J E 488246 N 7062855
	

Key information		Riparian vegetation		Substrate composition	
Full capacity	8,183 ML	Riparian veg height (max)	35 m	Bedrock	-
Catchment area	8.1 km^2		<50m	Boulder (>256 mm)	2 %
Max depth	16 m	Riparian width	10 %	Cobble (64-256 mm)	2 %
		Bare ground	20 %	Pebble (4-64 mm)	-
		Grass	10 %	Gravel (2-4 mm)	-
		Shrubs	10 %	Sand (2-4 mm)	-
		Trees < 10 m	80 %	Silt/Clay (<0.05 mm)	96 %
		Trees > 10 m	2 %		
		Canopy cover			

Mesohabitat composition		Instream wood		Other microhabitat	
Riffle	-	Detritus (leaves etc)	little	Periphyton	little
Run	-	Sticks (<2cm diam)	some	Filamentous algae	little
Rocky pool	-	Branches (<15cm diam)	some	Bank overhang veg	little
Sandy pool	100 %	Logs (>15cm diam)	some	Trailing bank veg	little
Dry				Bank undercuts	-

Macrophyte species		Macroinvertebrates		Fish	
Floating	-		M	Total abundance	1,185
Floating attached	2	Taxa diversity	17	Species richness	9
Submerged	5	Abundance	90	Native species	7
Emergent	6	Macrocrustaceans	Y		

General comments

A large body of water with a low abundance of large bodied fish and similar aquatic macrophyte assemblages to Lake Macdonald. Capacity to take a large number of fish.

Site 2 - 17/01/2020 **Six Mile Creek**	**<u>Co-ordinates - UTM 56 J</u>** **E 490171 N 7080092**
	

Channel characteristics		**Riparian vegetation**		**Substrate composition**	
Reach length	80 m	Riparian veg height (max)	20 m	Bedrock	-
Bankfull bank height	3.0 m	Riparian width (left bank)	50 m	Boulder (>256 mm)	-
Bankfull stream width	15 m	Riparian width (right bank)	5 m	Cobble (64-256 mm)	-
Mean water depth	80 cm	Bare ground	5 %	Pebble (4-64 mm)	-
Max water depth	120 cm	Grass	60 %	Gravel (2-4 mm)	-
Mean wetted width	5 m	Shrubs	15 %	Sand (2-4 mm)	80 %
Max wetted width	8 m	Trees < 10 m	60 %	Silt/Clay (<0.05 mm)	20 %
		Trees > 10 m	10 %		
		Canopy cover	80 %		
Mesohabitat composition		**Instream wood**		**Other microhabitat**	
Riffle	20 %	Detritus (leaves etc)	Mod	Periphyton	Some
Run	-	Sticks (<2cm diam)	Some	Filamentous algae	Some
Rocky pool	-	Branches (<15cm diam)	Little	Bank overhang veg	Some
Sandy pool	80 %	Logs (>15cm diam)	Little	Trailing bank veg	Some
Dry	-			Bank undercuts	Some
Macrophyte species		**Macroinvertebrates**		**Fish**	
Floating	-		<u>C</u>	Total abundance	144
Floating attached	-	Taxa diversity	20	Species richness	6
Submerged	1	Abundance	103	Native species	5
Emergent	4	Macrocrustaceans	Y		

General comments

Close to Lake Macdonald. Small to intermediate sized pools that may be suitable for a small number of saw-shelled and broad-shelled turtles.

Site 3 - 17/01/2020 Six Mile Creek	Co-ordinates - UTM 56 J E 489157 N 7086491

Channel characteristics		Riparian vegetation		Substrate composition	
Reach length	100 m	Riparian veg height (max)	30m	Bedrock	-
Bankfull bank height	4 m	Riparian width (left bank)	50m	Boulder (>256 mm)	-
Bankfull stream width	27 m	Riparian width (right bank)	50m	Cobble (64-256 mm)	-
Mean water depth	200 cm	Bare ground	10%	Pebble (4-64 mm)	-
Max water depth	ND	Grass	5%	Gravel (2-4 mm)	-
Mean wetted width	12 m	Shrubs	20%	Sand (2-4 mm)	40 %
Max wetted width	15 m	Trees < 10 m	10%	Silt/Clay (<0.05 mm)	60 %
		Trees > 10 m	90%		
		Canopy cover	90%		

Mesohabitat composition		Instream wood		Other microhabitat	
Riffle	-	Detritus (leaves etc)	Mod	Periphyton	Little
Run	10 %	Sticks (<2cm diam)	Mod	Filamentous algae	Little
Rocky pool	-	Branches (<15cm)	Mod	Bank overhang veg	Some
Sandy pool	90 %	Logs (>15cm diam)	Some	Trailing bank veg	Some
Dry	-			Bank undercuts	Moderate

Macrophyte species		Macroinvertebrates		Fish	
Floating	-		C	Total abundance	73
Floating attached	-	Taxa diversity	21	Species richness	6
Submerged	-	Abundance	128	Native species	6
Emergent	3	Macrocrustaceans	Y		

General comments

Site 4 - 17/01/2020 Six Mile Creek	Co-ordinates - UTM 56 J E 484959 N 7086511
	

Channel characteristics

Reach length	100 m
Bankfull bank height	5 m
Bankfull stream width	20 m
Mean water depth	80 cm
Max water depth	150 cm
Mean wetted width	6 m
Max wetted width	9 m

Riparian vegetation

Riparian veg height (max)	25m
Riparian width (left bank)	50m
Riparian width (right bank)	50m
Bare ground	5%
Grass	20%
Shrubs	15%
Trees < 10 m	20%
Trees > 10 m	60%
Canopy cover	80%

Substrate composition

Bedrock	-
Boulder (>256 mm)	-
Cobble (64-256 mm)	-
Pebble (4-64 mm)	-
Gravel (2-4 mm)	-
Sand (2-4 mm)	60 %
Silt/Clay (<0.05 mm)	40 %

Mesohabitat composition

Riffle	-
Run	20 %
Rocky pool	-
Sandy pool	80 %
Dry	-

Instream wood

Detritus (leaves etc)	Ext
Sticks (<2cm diam)	Ext
Branches (<15cm diam)	Ext
Logs (>15cm diam)	Some

Other microhabitat

Periphyton	Little
Filamentous algae	-
Bank overhang veg	Some
Trailing bank veg	Some
Bank undercuts	Moderate

Macrophyte species

Floating	-
Floating attached	-
Submerged	-
Emergent	1

Macroinvertebrates

	C
Taxa diversity	19
Abundance	90
Macrocrustaceans	Y

Fish

Total abundance	78
Species richness	5
Native species	4

General comments

Site 5 - 17/01/2020 Six Mile Creek	Co-ordinates - UTM 56 J E 478420 N 7089063

Channel characteristics		Riparian vegetation		Substrate composition	
Reach length	100 m	Riparian veg height (max)	m	Bedrock	%
Bankfull bank height	m	Riparian width (left bank)	m	Boulder (>256 mm)	%
Bankfull stream width	m	Riparian width (right bank)	m	Cobble (64-256 mm)	%
Mean water depth	cm	Bare ground	%	Pebble (4-64 mm)	%
Max water depth	cm	Grass	%	Gravel (2-4 mm)	%
Mean wetted width	m	Shrubs	%	Sand (2-4 mm)	%
Max wetted width	m	Trees < 10 m	%	Silt/Clay (<0.05 mm)	%
		Trees > 10 m	%		
		Canopy cover	%		

Mesohabitat composition		Instream wood		Other microhabitat	
Riffle	-	Detritus (leaves etc)		Periphyton	
Run	40 %	Sticks (<2cm diam)		Filamentous algae	
Rocky pool	-	Branches (<15cm diam)		Bank overhang veg	
Sandy pool	60 %	Logs (>15cm diam)		Trailing bank veg	
Dry	-			Bank undercuts	

Macrophyte species		Macroinvertebrates		Fish	
Floating	-		C	Total abundance	45
Floating attached	-	Taxa diversity	19	Species richness	7
Submerged	-	Abundance	90	Native species	7
Emergent	1	Macrocrustaceans	Y		

General comments

Site 7 - 17/01/2020 Six Mile Creek	Co-ordinates - UTM 56J E 475960 N 7092575

Channel characteristics		Riparian vegetation		Substrate composition	
Reach length	80 m	Riparian veg height (max)	m	Bedrock	%
Bankfull bank height	m	Riparian width (left bank)	m	Boulder (>256 mm)	%
Bankfull stream width	m	Riparian width (right bank)	m	Cobble (64-256 mm)	%
Mean water depth	cm	Bare ground	%	Pebble (4-64 mm)	%
Max water depth	cm	Grass	%	Gravel (2-4 mm)	%
Mean wetted width	m	Shrubs	%	Sand (2-4 mm)	%
Max wetted width	m	Trees < 10 m	%	Silt/Clay (<0.05 mm)	%
		Trees > 10 m	%		
		Canopy cover	%		

Mesohabitat composition		Instream wood	Other microhabitat
Riffle	-	Detritus (leaves etc)	Periphyton
Run	5 %	Sticks (<2cm diam)	Filamentous algae
Rocky pool	-	Branches (<15cm diam)	Bank overhang veg
Sandy pool	95 %	Logs (>15cm diam)	Trailing bank veg
Dry	-		Bank undercuts

Macrophyte species		Macroinvertebrates		Fish	
Floating	-	Taxa diversity	-	Total abundance	-
Floating attached	-	Abundance	-	Species richness	-
Submerged	-	Macrocrustaceans	-	Native species	-
Emergent	1				

General comments

Steep boulder banks and deep water from edge. Point access under the road bridge. No macroinvertebrate or fish sampling. Cathedral traps left overnight for turtles, none caught. May be suitable for a small number of saw-shelled and broad-shelled turtles.

Site 8 - 17/01/2020 **Six Mile Creek**	**Co-ordinates - UTM 56 J** **E 473905 N 7095985**
	

Channel characteristics		**Riparian vegetation**		**Substrate composition**	
Reach length	100 m	Riparian veg height (max)	m	Bedrock	%
Bankfull bank height	m	Riparian width (left bank)	m	Boulder (>256 mm)	%
Bankfull stream width	m	Riparian width (right bank)	m	Cobble (64-256 mm)	%
Mean water depth	cm	Bare ground	%	Pebble (4-64 mm)	%
Max water depth	cm	Grass	%	Gravel (2-4 mm)	%
Mean wetted width	m	Shrubs	%	Sand (2-4 mm)	%
Max wetted width	m	Trees < 10 m	%	Silt/Clay (<0.05 mm)	%
		Trees > 10 m	%		
		Canopy cover	%		
Mesohabitat composition		**Instream wood**		**Other microhabitat**	
Riffle	-	Detritus (leaves etc)		Periphyton	
Run	10 %	Sticks (<2cm diam)		Filamentous algae	
Rocky pool	-	Branches (<15cm diam)		Bank overhang veg	
Sandy pool	90 %	Logs (>15cm diam)		Trailing bank veg	
Dry	-			Bank undercuts	
Macrophyte species		**Macroinvertebrates**		**Fish**	
Floating	-		C	Total abundance	84
Floating attached	-	Taxa diversity	20	Species richness	5
Submerged	-	Abundance	109	Native species	5
Emergent	2	Macrocrustaceans	Y		

General comments

Site 12 - 13/01/2020 Mary River	Co-ordinates - UTM 56 J E 470262 N 7087513
	

Channel characteristics		Riparian vegetation		Substrate composition	
Reach length	250 m	Riparian veg height	m	Bedrock	%
Bankfull bank height	m	Riparian width (left bank)	m	Boulder (>256 mm)	%
Bankfull stream width	m	Riparian width (right bank)	m	Cobble (64-256 mm)	%
Mean water depth	cm	Bare ground	%	Pebble (4-64 mm)	%
Max water depth	cm	Grass	%	Gravel (2-4 mm)	%
Mean wetted width	m	Shrubs	%	Sand (2-4 mm)	%
Max wetted width	m	Trees < 10 m	%	Silt/Clay (<0.05 mm)	%
		Trees > 10 m	%		
		Canopy cover	%		

Mesohabitat composition		Instream wood	Other microhabitat
Riffle	10 %	Detritus (leaves etc)	Periphyton
Run	15 %	Sticks (<2cm diam)	Filamentous algae
Rocky pool	-	Branches (<15cm diam)	Bank overhang veg
Sandy pool	75 %	Logs (>15cm diam)	Trailing bank veg
Dry	-		Bank undercuts

Macrophyte species		Macroinvertebrates	M	E	Fish	
Floating	3		M	E	Total abundance	705
Floating attached	2	Taxa diversity	18	21	Species richness	18
Submerged	3	Abundance	82	86	Native species	13
Emergent	10	Macrocrustaceans	Y	Y		

General comments

Site 17 - 14/01/2020 Mary River	Co-ordinates - UTM 56 J E 475087 N 7077293
	

Channel characteristics		Riparian vegetation		Substrate composition	
Reach length	m	Riparian veg height (max)	m	Bedrock	%
Bankfull bank height	m	Riparian width (left bank)	m	Boulder (>256 mm)	%
Bankfull stream width	m	Riparian width (right bank)	m	Cobble (64-256 mm)	%
Mean water depth	cm	Bare ground	%	Pebble (4-64 mm)	%
Max water depth	cm	Grass	%	Gravel (2-4 mm)	%
Mean wetted width	m	Shrubs	%	Sand (2-4 mm)	%
Max wetted width	m	Trees < 10 m	%	Silt/Clay (<0.05 mm)	%
		Trees > 10 m	%		
		Canopy cover	%		

Mesohabitat composition		Instream wood	Other microhabitat
Riffle	-	Detritus (leaves etc)	Periphyton
Run	-	Sticks (<2cm diam)	Filamentous algae
Rocky pool	-	Branches (<15cm diam)	Bank overhang veg
Sandy pool	100 %	Logs (>15cm diam)	Trailing bank veg
Dry	-		Bank undercuts

Macrophyte species		Macroinvertebrates		Fish	
Floating	3	Taxa diversity	-	Total abundance	-
Floating attached	-	Abundance	-	Species richness	-
Submerged	5	Macrocrustaceans	-	Native species	-
Emergent	1				

General comments

Single point of bank access and steep banks with deep water for the rest of the reach. Unsafe to sample from the bank and no suitable boat launches available. Deep large pool. While sampling not easily conducted likely to have similar assemblages of macroinvertebrates and fish as the other large pools on the Mary River (sites 12, 37). Hence some capacity for relocation of aquatic fauna from Lake Macdonald.

Site 18 - 14/01/2020 Yabba Creek	Co-ordinates - UTM 56 J E 468073 N 7073451
	

Channel characteristics		Riparian vegetation		Substrate composition	
Reach length	m	Riparian veg height (max)	m	Bedrock	%
Bankfull bank	m	Riparian width (left bank)	m	Boulder (>256 mm)	%
height	m	Riparian width (right bank)	m	Cobble (64-256 mm)	%
Bankfull	cm	Bare ground	%	Pebble (4-64 mm)	%
stream width	cm	Grass	%	Gravel (2-4 mm)	%
Mean water	m	Shrubs	%	Sand (2-4 mm)	%
depth	m	Trees < 10 m	%	Silt/Clay (<0.05 mm)	%
Max water		Trees > 10 m	%		
depth		Canopy cover	%		
Mean wetted					
width					
Max wetted					
width					

Mesohabitat composition		Instream wood	Other microhabitat
Riffle	-	Detritus (leaves etc)	Periphyton
Run	-	Sticks (<2cm diam)	Filamentous algae
Rocky pool	-	Branches (<15cm diam)	Bank overhang veg
Sandy pool	100%	Logs (>15cm diam)	Trailing bank veg
Dry	-		Bank undercuts

Macrophyte species		Macroinvertebrates			Fish	
Floating	-		M	E	Total abundance	1,083
Floating	3	Taxa diversity	22	31	Species richness	15
attached	3	Abundance	26	257	Native species	12
Submerged	4	Macrocrustaceans	1	Y		
Emergent			Y			

General comments

Site 21 - 17/01/2020 Six Mile Creek	Co-ordinates - UTM 56 J E 480968 N 7087762

Channel characteristics		Riparian vegetation		Substrate composition	
Reach length	m	Riparian veg height (max)	m	Bedrock	%
Bankfull bank height	m	Riparian width (left bank)	m	Boulder (>256 mm)	%
Bankfull stream width	m	Riparian width (right bank)	m	Cobble (64-256 mm)	%
Mean water depth	cm	Bare ground	%	Pebble (4-64 mm)	%
Max water depth	cm	Grass	%	Gravel (2-4 mm)	%
Mean wetted width	m	Shrubs	%	Sand (2-4 mm)	%
Max wetted width	m	Trees < 10 m	%	Silt/Clay (<0.05 mm)	%
		Trees > 10 m	%		
		Canopy cover	%		

Mesohabitat composition		Instream wood	Other microhabitat
Riffle	-	Detritus (leaves etc)	Periphyton
Run	20 %	Sticks (<2cm diam)	Filamentous algae
Rocky pool	-	Branches (<15cm diam)	Bank overhang veg
Sandy pool	80 %	Logs (>15cm diam)	Trailing bank veg
Dry	-		Bank undercuts

Macrophyte species		Macroinvertebrates		Fish	
Floating	-		C	Total abundance	89
Floating attached	-	Taxa diversity	15	Species richness	7
Submerged	-	Abundance	56	Native species	7
Emergent	2	Macrocrustaceans	Y		

General comments

Site 24 - 14/01/2020 Amamoor Creek	Co-ordinates - UTM 56 J E 467321 N 7086336
	

Channel characteristics		Riparian vegetation		Substrate composition	
Reach length	m	Riparian veg height (max)	m	Bedrock	%
Bankfull bank height	m	Riparian width (left bank)	m	Boulder (>256 mm)	%
Bankfull stream width	m	Riparian width (right bank)	m	Cobble (64-256 mm)	%
Mean water depth	cm	Bare ground	%	Pebble (4-64 mm)	%
Max water depth	cm	Grass	%	Gravel (2-4 mm)	%
Mean wetted width	m	Shrubs	%	Sand (2-4 mm)	%
Max wetted width	m	Trees < 10 m	%	Silt/Clay (<0.05 mm)	%
		Trees > 10 m	%		
		Canopy cover	%		

Mesohabitat composition		Instream wood	Other microhabitat
Riffle	-	Detritus (leaves etc)	Periphyton
Run	-	Sticks (<2cm diam)	Filamentous algae
Rocky pool	-	Branches (<15cm diam)	Bank overhang veg
Sandy pool	80 %	Logs (>15cm diam)	Trailing bank veg
Dry	20 %		Bank undercuts

Macrophyte species		Macroinvertebrates		Fish	
Floating	2	Taxa diversity	-	Total abundance	-
Floating attached	1	Abundance	-	Species richness	-
Submerged	1	Macrocrustaceans	-	Native species	-
Emergent	3				

General comments

No macroinvertebrate or fish sampling undertaken due to water quality and high turbidity suggesting any sampling could adversely impact on existing conditions and health of aquatic biota. Suggest sampling under better conditions prior to any potential relocation.

Site 25 - 14/01/2020 Amamoor Creek	Co-ordinates - UTM 56 J E 466202 N 7085823
	

Channel characteristics		Riparian vegetation		Substrate composition	
Reach length	m	Riparian veg height (max)	m	Bedrock	%
Bankfull bank height	m	Riparian width (left bank)	m	Boulder (>256 mm)	%
Bankfull stream width	m	Riparian width (right bank)	m	Cobble (64-256 mm)	%
Mean water depth	cm	Bare ground	%	Pebble (4-64 mm)	%
Max water depth	cm	Grass	%	Gravel (2-4 mm)	%
Mean wetted width	m	Shrubs	%	Sand (2-4 mm)	%
Max wetted width	m	Trees < 10 m	%	Silt/Clay (<0.05 mm)	%
		Trees > 10 m	%		
		Canopy cover	%		

Mesohabitat composition		Instream wood	Other microhabitat
Riffle	-	Detritus (leaves etc)	Periphyton
Run	-	Sticks (<2cm diam)	Filamentous algae
Rocky pool	-	Branches (<15cm diam)	Bank overhang veg
Sandy pool	70 %	Logs (>15cm diam)	Trailing bank veg
Dry	30 %		Bank undercuts

Macrophyte species		Macroinvertebrates		Fish	
Floating	3	Taxa diversity	-	Total abundance	-
Floating attached	1	Abundance	-	Species richness	-
Submerged	1	Macrocrustaceans	-	Native species	-
Emergent	4				

General comments

No macroinvertebrate or fish sampling undertaken due to water quality and high coverage of floating macrophytes suggesting any sampling could adversely impact on existing conditions and health of aquatic biota. Suggest sampling under better conditions prior to any potential relocation.

Site 28 - 13/01/2020 Kandanga Creek Weir	Co-ordinates - UTM 56J E 467372 N 7081138
	

Channel characteristics		Riparian vegetation		Substrate composition	
Reach length	m	Riparian veg height (max)	m	Bedrock	%
Bankfull bank height	m	Riparian width (left bank)	m	Boulder (>256 mm)	%
Bankfull stream width	m	Riparian width (right bank)	m	Cobble (64-256 mm)	%
Mean water depth	cm	Bare ground	%	Pebble (4-64 mm)	%
Max water depth	cm	Grass	%	Gravel (2-4 mm)	%
Mean wetted width	m	Shrubs	%	Sand (2-4 mm)	%
Max wetted width	m	Trees < 10 m	%	Silt/Clay (<0.05 mm)	%
		Trees > 10 m	%		
		Canopy cover	%		

Mesohabitat composition		Instream wood	Other microhabitat
Riffle	-	Detritus (leaves etc)	Periphyton
Run	-	Sticks (<2cm diam)	Filamentous algae
Rocky pool	-	Branches (<15cm diam)	Bank overhang veg
Sandy pool	100 %	Logs (>15cm diam)	Trailing bank veg
Dry	-		Bank undercuts

Macrophyte species		Macroinvertebrates		Fish	
Floating	2	Taxa diversity	-	Total abundance	-
Floating attached	-	Abundance	-	Species richness	-
Submerged	2	Macrocrustaceans	-	Native species	-
Emergent	2				

General comments

No macroinvertebrate or fish sampling undertaken due to water quality and high turbidity suggesting any sampling could adversely impact on existing conditions and health of aquatic biota. Australian smelt noted as gasping at the water surface with some mortalities also noted. Suggest sampling under better conditions prior to any potential relocation.

Site 31 - 13/01/2020 Yabba Creek	Co-ordinates - UTM 56 J E 462860 N 7069961
	

Channel characteristics		Riparian vegetation		Substrate composition	
Reach length	m	Riparian veg height (max)	m	Bedrock	%
Bankfull bank height	m	Riparian width (left bank)	m	Boulder (>256 mm)	%
Bankfull stream width	m	Riparian width (right bank)	m	Cobble (64-256 mm)	%
Mean water depth	cm	Bare ground	%	Pebble (4-64 mm)	%
Max water depth	cm	Grass	%	Gravel (2-4 mm)	%
Mean wetted width	m	Shrubs	%	Sand (2-4 mm)	%
Max wetted width	m	Trees < 10 m	%	Silt/Clay (<0.05 mm)	%
		Trees > 10 m	%		
		Canopy cover	%		

Mesohabitat composition		Instream wood	Other microhabitat
Riffle	5 %	Detritus (leaves etc)	Periphyton
Run	5 %	Sticks (<2cm diam)	Filamentous algae
Rocky pool	-	Branches (<15cm diam)	Bank overhang veg
Sandy pool	90 %	Logs (>15cm diam)	Trailing bank veg
Dry	-		Bank undercuts

Macrophyte species		Macroinvertebrates			Fish	
Floating	-		M	E	Total abundance	491
Floating attached	2	Taxa diversity	20	31	Species richness	18
Submerged	5	Abundance	92	171	Native species	15
Emergent	6	Macrocrustaceans	Y	Y		

General comments

Site 33 - 16/01/2020 Mary River	Co-ordinates - UTM 56 J E 475676 N 7063772
	

Channel characteristics		Riparian vegetation		Substrate composition	
Reach length	m	Riparian veg height (max)	m	Bedrock	%
Bankfull bank height	m	Riparian width (left bank)	m	Boulder (>256 mm)	%
Bankfull stream width	m	Riparian width (right bank)	m	Cobble (64-256 mm)	%
Mean water depth	cm	Bare ground	%	Pebble (4-64 mm)	%
Max water depth	cm	Grass	%	Gravel (2-4 mm)	%
Mean wetted width	m	Shrubs	%	Sand (2-4 mm)	%
Max wetted width	m	Trees < 10 m	%	Silt/Clay (<0.05 mm)	%
		Trees > 10 m	%		
		Canopy cover	%		

Mesohabitat composition		Instream wood	Other microhabitat
Riffle	-	Detritus (leaves etc)	Periphyton
Run	20 %	Sticks (<2cm diam)	Filamentous algae
Rocky pool	-	Branches (<15cm diam)	Bank overhang veg
Sandy pool	80 %	Logs (>15cm diam)	Trailing bank veg
Dry	-		Bank undercuts

Macrophyte species		Macroinvertebrates		Fish	
Floating	-	Taxa diversity	-	Total abundance	-
Floating attached	1	Abundance	-	Species richness	-
Submerged	2	Macrocrustaceans	-	Native species	-
Emergent	7				

General comments

Site 36 - 17/01/2020 **Mary River**	**Co-ordinates - UTM 56J** **E 474590 N 7067494**
	

Channel characteristics		Riparian vegetation		Substrate composition	
Reach length	m	Riparian veg height (max)	m	Bedrock	%
Bankfull bank height	m	Riparian width (left bank)	m	Boulder (>256 mm)	%
Bankfull stream width	m	Riparian width (right bank)	m	Cobble (64-256 mm)	%
Mean water depth	cm	Bare ground	%	Pebble (4-64 mm)	%
Max water depth	cm	Grass	%	Gravel (2-4 mm)	%
Mean wetted width	m	Shrubs	%	Sand (2-4 mm)	%
Max wetted width	m	Trees < 10 m	%	Silt/Clay (<0.05 mm)	%
		Trees > 10 m	%		
		Canopy cover	%		
Mesohabitat composition		**Instream wood**		**Other microhabitat**	
Riffle	-	Detritus (leaves etc)		Periphyton	
Run	10 %	Sticks (<2cm diam)		Filamentous algae	
Rocky pool	-	Branches (<15cm diam)		Bank overhang veg	
Sandy pool	80 %	Logs (>15cm diam)		Trailing bank veg	
Dry	10 %			Bank undercuts	
Macrophyte species		**Macroinvertebrates**		**Fish**	
Floating	-	Taxa diversity	-	Total abundance	-
Floating attached	-	Abundance	-	Species richness	-
Submerged	-	Macrocrustaceans	-	Native species	-
Emergent	2				

General comments

Site 37 - 16/01/2020 Mary River	Co-ordinates - UTM 56J E 476475 N 7061738

Channel characteristics		Riparian vegetation		Substrate composition	
Reach length	200 m	Riparian veg height	15m	Bedrock	-
Bankfull bank height	12 m	Riparian width (left bank)	5m	Boulder (>256 mm)	-
Bankfull stream width	50 m	Riparian width (right bank)	5m	Cobble (64-256 mm)	10 %
Mean water depth	20 cm	Bare ground	10%	Pebble (4-64 mm)	70 %
Max water depth	ND	Grass	80%	Gravel (2-4 mm)	10 %
Mean wetted width	5 m	Shrubs	5%	Sand (2-4 mm)	20 %
Max wetted width	7 m	Trees < 10 m	5%	Silt/Clay (<0.05 mm)	-
		Trees > 10 m	5%		
		Canopy cover	5%		

Mesohabitat composition		Instream wood		Other microhabitat	
Riffle	-	Detritus (leaves etc)	Some	Periphyton	Little
Run	-	Sticks (<2cm diam)	Little	Filamentous algae	Little
Rocky pool	-	Branches (<15cm diam)	Some	Bank overhang veg	Little
Sandy pool	100 %	Logs (>15cm diam)	Some	Trailing bank veg	Little
Dry	-			Bank undercuts	Some

Macrophyte species		Macroinvertebrates			Fish	
Floating	1		B	E	Total abundance	856
Floating attached	1	Taxa diversity	12	16	Species richness	14
Submerged	3	Abundance	58	65	Native species	9
Emergent	4	Macrocrustaceans	Y	Y		

General comments

Appendix G – Aquatic macrophyte raw data

Growth form	Common name	Scientific name	1	2	3	4	5	7	8	12	17	18	21	24	25	28	31	33	36	37
Free floating	Azolla	*Azolla pinnata*								<1	<1			15	10	<1		15		
	Water hyacinth	*Eichornia crassipes*								<1										
	Duck weed	*Spirodela punctata*									<1			5	5	<1				
	Salvinia	*Salvinia molesta*								<1	<1				90					
	Water lettuce	*Pistia stratiotes*																		1
Floating attached	Water primrose	*Ludwigia peploides*								<1		<1						2		<1
	Cape blue waterlily	*Nymphaea caerulea*	5									5								
	Snowflake lily	*Nymphoides indica*	5							<1		10		10	1		<1			
Submerged	Blyxa	*Blyxa aubertii*	<1																	
	Cabomba	*Cabomba caroliniana*	10																	
	Hornwort	*Ceratophyllum demersum*										20								
	Stonewort	*Chara* spp.	5	5																
	Leafy elodea	*Egeria densa*														20	15			
	Hydrilla, water thyme	*Hydrilla verticillata*	5								2	15								
	Milfoil	*Myriophylum* spp.								2	2						5	2		1
	Curly pondweed	*Potomageton crispus*								15	10				15	5	20			5
	Pondweed	*Potamogeton octandrus*	5								<1									
	Ribbonweed	*Vallisneria nana*								10	2	2		10			5	2		1
Emergent	Jointed twigrush	*Baumea articulata*	<1																	
	Dirty dora	*Cyperus difformis*								<1										1
	Sedge sp.	*Cyperus erogrostis*								2								1		
	Sedge sp.	*Cyperus exaltatus*			1					2								1		
	Umbrella sedge	*Cyperus involucratus*										2		15	20		<1			
	Sedge sp.	*Cyperus polystachus*	<1							2						<1				
	Common rush	*Juncus spp.*	<1	2						2								5		
	Grey sedge	*Lepironia articulata*	90																	
	Spiny mattrush	*Lomandra longifolia*		10	15	40	15	20	35		1	5	20	2			5	1	5	
	Primrose sp.	*Ludwigia c.f octovalvis /peruviana*		1						1							2			1
	Water couch	*Paspalum distichum*								2										
	White smartweed	*Persicaria attenuata*	<1							<1							2	5	1	2
	Prince's feather	*Persicaria c.f orientalis*							2	3						<1				20
	Spotted Knotweed	*Persicaria strigosa*			5								1							
	Sagittaria	*Sagittaria graminea-platyphylla*		5																
	Star clubrush	*Schoenoplectus mucronatus*	<1																	
	River clubrush	*Schoenoplectus validus*								5		2			5		5	5		
	Cumbungi	*Typha cf. orientalis*													1					
	Paragrass	*Urochloa mutica*										10		25	15			10		20

Appendix H – Aquatic macroinvertebrate raw data

Site	1	2	3	4	6	8	12	12	18	18	31	31	21	37	37
Habitat	Macrophyte	Composite	Composite	Composite	Composite	Composite	Macrophyte	Edge	Macrophyte	Edge	Macrophyte	Edge	Composite	Bed	Edge
Microcrustacea															
Cladocera	P	P	P	P	P	P	P		P	P			P	P	P
Copepoda	P	P	P	P	P	P	P		P	P	P	P	P		
Ostracoda	P	P	P	P	P	P	P	P	P	P	P	P			P
Hydrozoa															
Hydridae			5		1								1		
Turbellaria															
Dalyelliidae						1									
Dugesiidae		1							3	3					
Temnocephalidae		2	1	1			1			2		1			
Nematoda			1			1			4	5			1		
Gastropoda								1							
Ancylidae		6				5				2					
Lymnaeidae									7	4		2			3
Physidae							6	7			4			3	
Planorbidae			1					1	8	13	1	3		1	
Tateidae								1				4			
Thiaridae							10	7	6		1				
Bivalvia											1				
Cyreniidae											1				
Hirudinea															
Erpobdellidae										1					
Glossiphoniidae	4									1					
Hirudinidae	2														
Oligochaeta		9	7	3	2	5	1	7	100	47	4	17	6	3	3
Polychaeta															
Araneae															
Acarina	19	7	11	8	3	2	5	3	26	37	3	2	4	10	1
Isopoda															
Corallanidae											1				2
Decapoda							1								
Atyidae	9	6	8	8	3	4	3	4	9	5	3	6	4	5	12
Palaemonidae	1					1	3	4		1		2	3	1	
Parastacidae		1	1	1		2							1		
Coleoptera															
Dytiscidae	7	7	6	2	9	6	1	5		5	7	6	1		
Elmidae											5				
Gyrinidae												1			
Hydrochidae			3												
Hydrophilidae	1			7	2			1		3	4	5		2	1
Noteridae	2														
Scirtidae															1

Site	1	2	3	4	6	8	12	12	18	18	31	31	21	37	37
Habitat	Macrophyte	Composite	Composite	Composite	Composite	Composite	Macrophyte	Edge	Macrophyte	Edge	Macrophyte	Edge	Composite	Bed	Edge
Diptera															
Ceratopogonidae	1		1	1	1	1			8	18				1	
s-f Chironominae		12	35	25	33	54	14	7	17	17	7	17	14	17	19
s-f Orthocladiinae									3		2	12			
s-f Tanypodinae	7						5	2	11	25	5	3		2	
Culicidae							1		1						
Stratiomyidae		1								1					
Tipulidae													1		
Ephemeroptera															
Baetidae	1	7	2			2	15	11	17	14	2	8			1
Caenidae				1			1	1	4	1	2	4	1	1	1
Leptophlebiidae		1	10	2	3	5					17	1	9		
Hemiptera															
Belostomatidae	4	2								3					1
Corixidae				1					1						
Gerridae						4				2		1			1
Hebridae								1	2	1		1			
Hydrometridae		2	4							1					
Mesoveliidae		2			1		1	1				1			4
Micronectidae	2					1		7				9		12	6
Naucoridae									8	7					
Notonectidae				3	4	1						2			
Pleidae							2			2		1			
Veliidae		3	4	3		5				3		1			2
Megaloptera															
Sialidae				3	1										
Odonata															
S.O. Zygoptera															
Coenagrionidae	26	15					9	8	17	9		6			7
Isostictidae		3	4	2									5		
S.O. Epiproctiphora												1			
Cordulephyidae			1												
Corduliidae	1	2				1									
Gomphidae				1											
Libellulidae	2		8	1		4	3	1		4		4			
Trichoptera										1	1	2			
Calamoceratidae			1							1		11			
Ecnomidae									3		19		2		
Helicopsychidae												5			
Hydroptilidae									1			2			
Leptoceridae	1	14	14	17	8	4		6	5	18	2	25	3		
Odontoceridae												5			

Appendix I

Lake Macdonald (Six Mile Creek) Dam Improvement Project – Biomass Survey

LAKE MACDONALD DAM UPGRADE - FISH BIOMASS SURVEY

Document Control Summary	
Report Title:	Lake Macdonald Dam Upgrade - Fish Biomass Surveys
Report Status:	Final
Version:	V1.0
Prepared By:	Aaron Dunlop, Stefan Sawynok
Project Team:	Stefan Sawynok, Aaron Dunlop, James Reid
Client:	seqwater
Client Contact	Mark Seddon
Issue Date:	28 October 2019

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The wall of the Lake Macdonald impoundment (near Cooroy) requires upgrading and seqwater is seeking a better understanding of the aquatic fauna inhabiting the dam. Lake Macdonald has been stocked with recreationally valued fish species (Australian bass, golden perch, silver perch, saratoga and Mary River cod) intermittently, since 1980. Seqwater are considering a fauna salvage operation to remove and relocate the fish prior to any upgrade works. Primarily, fish biomass and abundance are of interest however, an understanding of turtles and any other aquatic fauna are also of interest to seqwater.

The primary aim of the project was to systematically survey Lake Macdonald to estimate the number of fish and other fauna inhabiting the lake (biomass). The results would inform how the biomass was distributed throughout the lake and the estimate would be used to guide the strategies and effort required to relocate large bodied fish (>200mm in length) and other fauna. The survey included all areas of Lake Macdonald, accessible by boat or kayak.

The pre-survey was completed from July 10 to 11, 2019 while the main survey was completed over seven days between July 22 to August 6, 2019. Lake Macdonald was divided into 10 survey zones. This allowed for up to three zones to be surveyed in a single day and the majority of the open waters of the lake to be surveyed over two days (e.g. zones 1-6). Three surveys in each zone over subsequent days allowed for the comparison of fish counts between surveys and an indication of the distribution throughout the lake. It also allowed for the detection of any large-scale movement between zones during the course of the survey. The access and open water in upper reaches zones (zones 7-9) was more constrained by the presence of dense aquatic plant beds in shallower (approximately 2m) waters so a single survey was allowed for in these zones.

Fish biomass and distribution data was collected with the BioSonics DT-X split beam echo sounder and generated using the Visual Acquisition software package (BioSonics Inc. 2017). During all surveys, data collection parameters are always set to allow the greatest number of echoes and therefore tracks to be accepted by the Visual Acquisition software, termed ‘raw data’. Post-survey echogram re-analysed involves increasing the number of echoes that an object needs to return to be accepted. For this assessment, the raw data was re-analysed three (3) times:

- once to focus on fish <200mm;
- once to focus on fish >200mm; and
- once to focus on structure.

A total of 405 fish <200mm was counted in the pre-survey trial in Zone 1. A total of 221 fish >200mm was counted in the pre-survey trial in Zone 1. The results of the down-looking trial confirmed that the mostly shallow water depths (<5m) and limited / narrow effective surveyed water resulted in small counts of fish in all size classes, compared to the side-looking transducer configuration. Totals of 13,973, 13,032 and 3,706 fish <200mm were counted in the a, b and c sub-surveys of Survey 1. Ranges of 7,914 to 4,432, 7,472 to 4,147 and 3,173 to 1,639 fish >200mm were counted in the a, b and c surveys of Survey 1. Totals of 13,269, 10,596 and 6,785 fish <200mm were counted in the a, b and c sub-surveys of Survey 2. Ranges of 7,290 to 4,249, 6,710 to 3,691and 4,789 to 2,783 fish >200mm were counted in the a, b and c surveys of Survey 2. Totals of 19,259, 19,639 and 9,380 fish <200mm were counted in the a, b and c sub-surveys of Survey 3. Ranges of 7,721 to 4,417, 8,310 to 4,835 and 4,886 to 2,828 fish >200mm were counted in the a, b and c surveys of Survey 3. Fish <200mm: a total of 46 fish was counted in Survey 4. A range of 40-30 fish was counted in Survey 4.

The most abundant large bodied fish species in Lake Macdonald were Australian bass (*Percalates novemaculeata*). A total of 48 Australian bass were caught ranging in size from 220mm to 450mm. A single eel-tailed catfish (*Tandanus tandanus*) was caught in zone 2 (approximately 400mm) and numerous longfin eel (*Anguilla reinhardtii*) were either caught or observed free-swimming during the surveys in zones 3, 4 and 5 (580mm to >1m). The most abundant smaller bodied fish species in Lake Macdonald is likely to be bony bream (*Nematalosa erebi*). A single platypus was observed on August 6, approximately 100m downstream of the Cooroy-Noosa Rd road bridge that crosses Six Mile Creek. Turtles were observed in zones 4, 6b and 9 during the survey however, are likely to inhabit many areas of the lake.

The biomass surveys were successful in detecting fish in a range of size classes and habitats in all zones that were surveyed. Survey zones 1 to 3 were the most common areas to hold large numbers of fish with some shift in the biomass observed on occasion. The upper limit of the bulk of the biomass was the lower reaches of zone 4 and smaller numbers of fish were located further upstream, into zones 5 and 6a.

Based on the completed biomass surveys, any future salvage efforts should focus on zones 1 to 3, where the reservoir is deeper, and the bulk of the biomass was repeatedly detected. The deeper areas of the lake will also be the last areas to hold water, and where the majority of fish will be concentrated as the water level is reduced. Where target numbers of fish are required for salvage efforts, it is recommended to use the maximum extrapolated number of fish >200mm in any survey as opposed to averages across the surveys. The extrapolated maximum number of fish in Lake Macdonald >200mm is 17,671, while the extrapolated maximum number of fish <200mm is 37,698.

Based on the findings of the survey, the following recommendations are put forward for consideration:

- Investigate opportunities to obtain signals for turtles and eels and discuss further analysis options to tease the potential numbers out of the current datasets.
- Investigate opportunities to further breakdown the data at Lake Macdonald based on number of species/clusters of similar signals. Recent analysis and modelling completed by Infofish on other projects suggests that species clustering (diversity) can be determined.

INTRODUCTION

The wall of the Lake Macdonald impoundment (near Cooroy) requires upgrading and seqwater is seeking a better understanding of the aquatic fauna inhabiting the dam. Lake Macdonald has been stocked with recreationally valued fish species (Australian bass, golden perch, silver perch, saratoga and Mary River cod) intermittently, since 1980. Seqwater are considering a fauna salvage operation to remove and relocate the fish prior to any upgrade works. Primarily, fish biomass and abundance are of interest however, an understanding of turtles and any other aquatic fauna are also of interest to seqwater.

PROJECT AIMS AND EXTENT

The primary aim of the project was to systematically survey Lake Macdonald to estimate the number of fish and other fauna inhabiting the lake (biomass). The results would inform how the biomass was distributed throughout the lake and the estimate would be used to guide the strategies and effort required to relocate large bodied fish (>200mm in length) and other fauna. The survey included all areas of Lake Macdonald, accessible by boat or kayak.

METHODS

SURVEY TIMING

The pre-survey was completed from July 10 to 11, 2019 while the main survey was completed over seven days between July 22 to August 6, 2019. The weather during the survey period was mostly sunny to cloudy with moderate winds developing towards the end of the main survey period. Lake Macdonald was above full capacity and spilling during the survey.

SURVEY PLANNING AND DESIGN

A number of questions were raised during the planning stages of the survey, which were:

- Were fish likely to be mobile or remain relatively still during the surveys?
- How would the fish be distributed throughout the lake and what habitats would they be associating with?
- If in open water, what part of the water column would the bulk of the biomass be occupying?
- Would the fish counts be similar between the same survey zones on different days?
- Would the fish be schooled up in a particular location?
- Would a shift in the biomass be observed over the course of subsequent days?

To answer these questions, the survey was designed with the following in mind:

- Keeping zones to a size that was surveyable in approximately two hours, resulting in three zones completed in a single day.
- Repeated surveys (nominally 3) in each zone to compare the stability of the fish counts / biomass between zones and surveys.
- The inclusion of two days of pre-survey to determine the most effective transducer configuration and distances for survey, as well as to collect machine learning training data for local fish and aquatic habitat types present.

As a result, Lake Macdonald was divided into 10 survey zones (Figure 1). This allowed for up to three zones to be surveyed in a single day and the majority of the open waters of the lake to be surveyed over two days (e.g. zones 1-6). Zones 1-6 were surveyed 3 times each on alternating days, for a total of six days e.g. zones 1-3 surveyed on day 1 then zones 4-6 surveyed on day 2, zones 1-3 surveyed again on day 3 and so on. Three surveys in each zone over subsequent days allowed for the comparison of fish counts between surveys and an indication of the distribution throughout the lake. It also allowed for the detection of any large-scale movement between zones during the course of the survey. The access and open water in upper reaches zones (zones 7-9) was more constrained by the presence of dense aquatic plant beds in shallower (approximately 2m) waters so a single survey was allowed for in these zones.

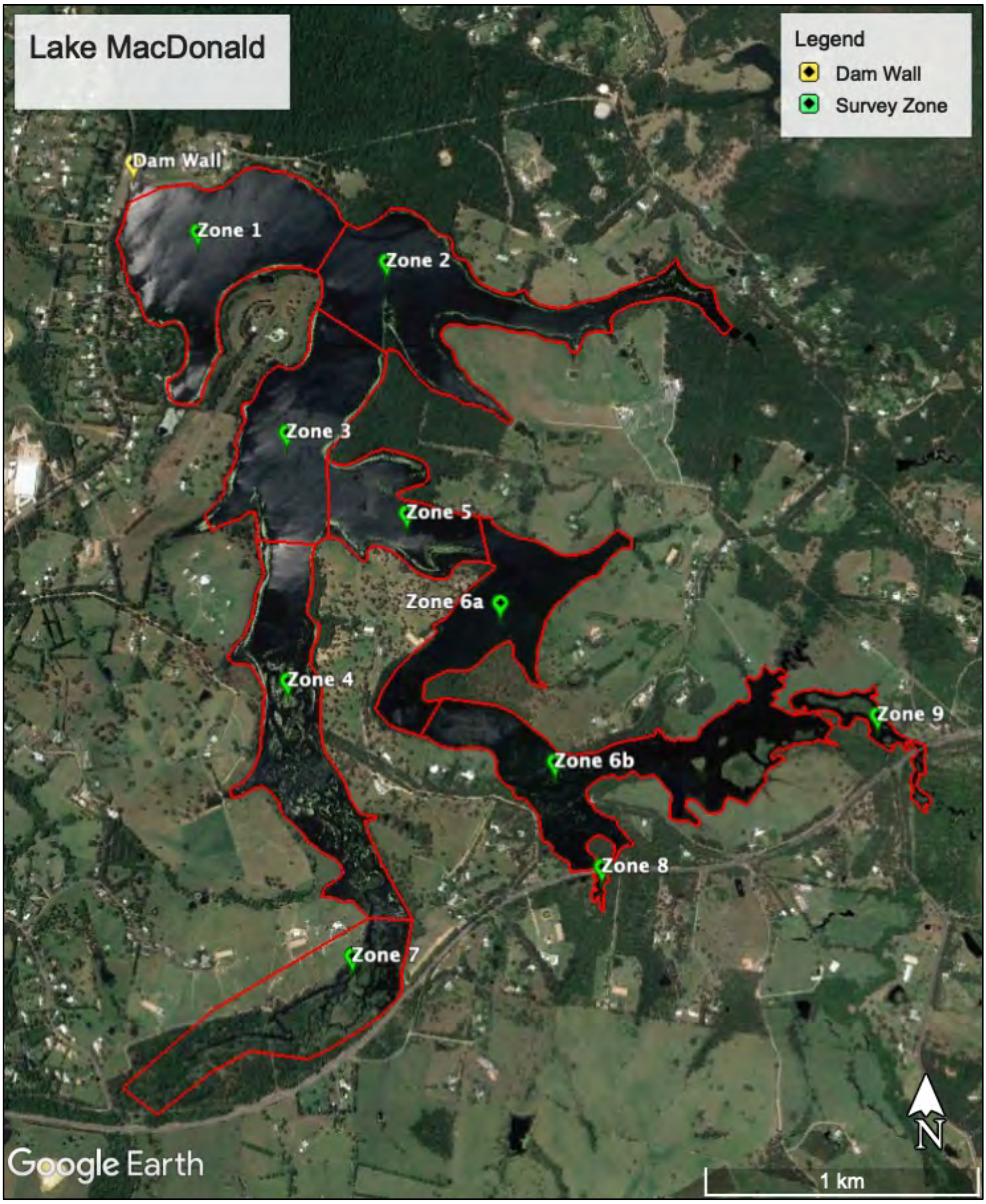


Figure 1. Lake Macdonald extent and survey zones.

PRE-SURVEY AND ECHO SOUNDER CONFIGURATION

The pre-survey was completed over two days, from July 10 to 11, and allowed a range of transducer angles (-3, -6 and -9, and -90 degrees down from horizontal), survey vessel distances from the bank (40m, 60m and 100m) and the distances between transects (50m and 100m) to be tested. The transducer angle and distances used in any survey are typically dependent on the bathymetry of a water body and the slope of the banks e.g. gentle or steep.

The shape of the ping produced by the echo sounder transducer is a 6.7^{O} cone. The greater the distance from the transducer (range), the wider the cone will be and the greater volume of water it will ensonify. Some examples of cone width and water volume surveyed at a number of trialed ranges is presented in Table 1.

Table 1. Calculated ping cone widths and associated water volumes surveyed at varying ranges.

Survey Range (m)	Cone Width at End Range (m)	Water Volume Surveyed (m3)
5	0.6	0.47
10	1.1	3.17
20	2.3	27.7
50	5.8	440.3
60	7.0	769.7

With the transducer in a down-looking configuration, in waters 10m deep, the maximum cone width is 1.1m and the water volume surveyed per ping is 3.17m3. The maximum depth recorded in Lake Macdonald during the survey was approximately 8m near the bubble outlet, located in the center of zone 1, with depths of 3-5m being common elsewhere in the lake. In past experiences, down-looking surveys are best suited to waters >20m deep, where the cone width is at least 2m across. To increase the coverage of water surveyed with the transducer in a down-looking configuration, many more transects would have been required which would have added time and associated costs to the survey. In shallower waters (<3m) the chance of the vessel creating a fright bias or triggering avoidance behavior by fish is increased. Surveys in Lake Macdonald using a down-looking transducer configuration were considered ineffective and inefficient.

The trials of surveying with the transducer in a side looking configuration are not as constrained by water depth and a range can be set to receive echoes that is suitable for the bathymetry of a water body. In the case of Lake Macdonald, the arrangement for the most effective coverage were transducer angled to -3^{o} below horizontal and set to ping and receive echoes at a range of 60m. Based on this transducer angle and range, transects were then spaced approximately 50m apart. Figure 2 shows the results of the transducer at -3^{o} below horizontal with a range of 60m. Echoes from the bed of the lake were being received from approximately 35m to 60m with more than half of the surveyed area being open water (0m to approximately 35m). In this configuration some fish are masked by the bottom noise however, post field review of the echograms and filtering of the data reveals where fish have been tracked and the re-analysis can be set to target them. A range of 100m could have been set but this would have resulted in more bottom echoes being received and a smaller proportion of open water being surveyed. Decreasing the transducer angle to less than -3^{o} below horizontal (e.g. -1.5^{o} below horizontal), resulted in the receipt of echoes from the water surface, especially on windier days which can create noisy data, sometimes masking the echoes received from other objects. Further to this, surveying with the transducer set to -6^{o} below horizontal resulted in the echoes from the bed being received as close as 20m from the transducer and a greater proportion of bottom noise compared to open water being surveyed. As a point of comparison, in other deeper water impoundment surveys (>20m deep) Infofish have used the same transducer angle (-3^{o}) and set to ping and receive echoes from 110m to 200m ranges.

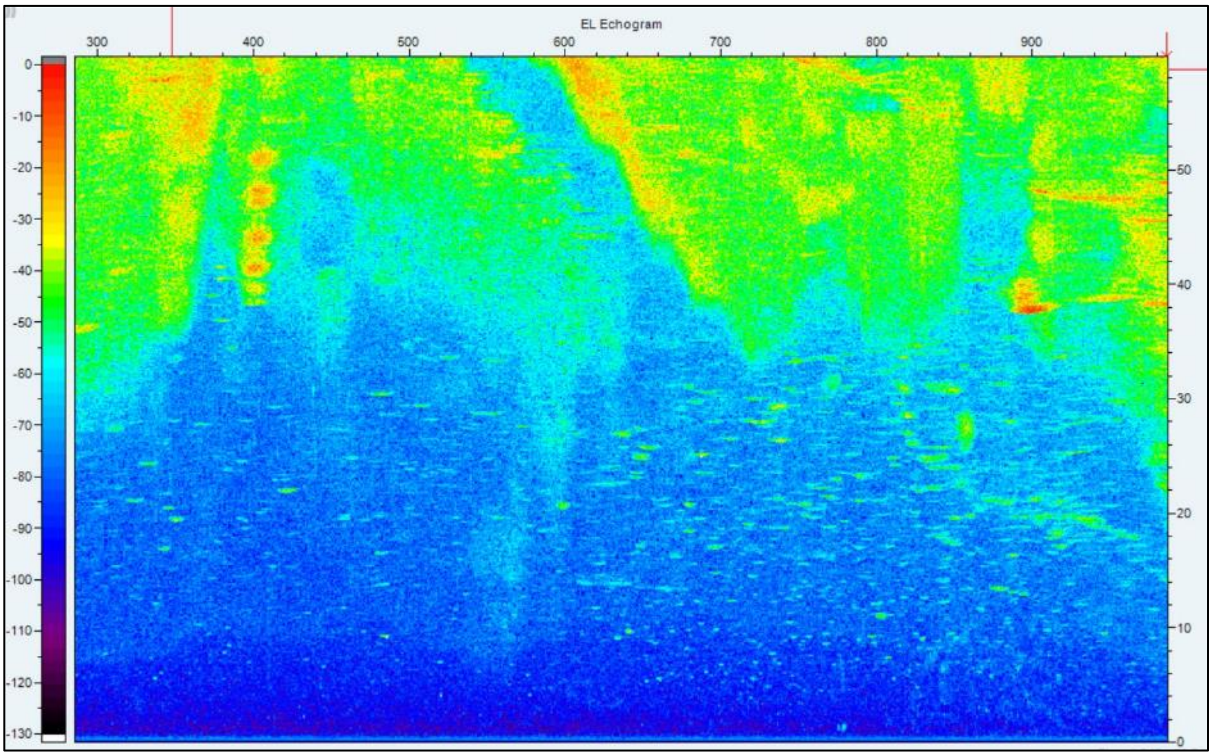


Figure 2. Example echogram (planform view) showing the proportions of open water (blue background) and 'louder' echoes (green to red) from the preferred -3° below horizontal transducer angle set to a range of 60m.

All data (fish and weed) collected during the pre-survey was used to train machine learning models for data post-processing and analysis. The distribution of fish in the water column and throughout the lake, and information on the potential habitat and presence of Mary River Cod was also assessed. Further detail on machine learning training, fish distribution and Mary River cod approaches is provided below.

Machine Learning Preparation

fish, weed and timber signals collected during the pre-survey were used to train the machine learning models used in acoustic signal data assessment. Machine learning based data processing vastly reduces the amount of time and costs and allowed for daily updates of fish counts in each zone to seqwater.

Fish Distribution and Movement

While there are limitations on how much movement can be detected, all of the zones were checked in the am and pm for fish presence/absence and to assess whether any spatial shifts in the biomass had occurred. This data was used to inform the optimal times to survey and the survey approach for each survey zone.

Mary River Cod

Mary River Cod are known to inhabit Lake Macdonald from fish stocking. They are likely to be widely distributed across the lake and associating with structure. Side imaging data was collected using recreational Lowrance and Hummingbird fish finders. Locations likely to hold Mary River Cod were identified and included into the survey.

BATHYMETRY

Bathymetry data was collected using Humminbird Solix 12 (Solix) and Lowrance HDS7 (HDS7) fish finders during fish biomass surveys. Water depth data from the fish finders was recorded and stored on micro SD card in the head units. The data was uploaded into the ReefMaster (ReefMaster 2018) software package and compiled to create the bathymetry map for the lake, post survey. Figure 3 shows a typical bathymetry mapping output from Zone 1. Bathymetry data was used in the post processing of accepted fish tracks as a point of reference for machine learning models.

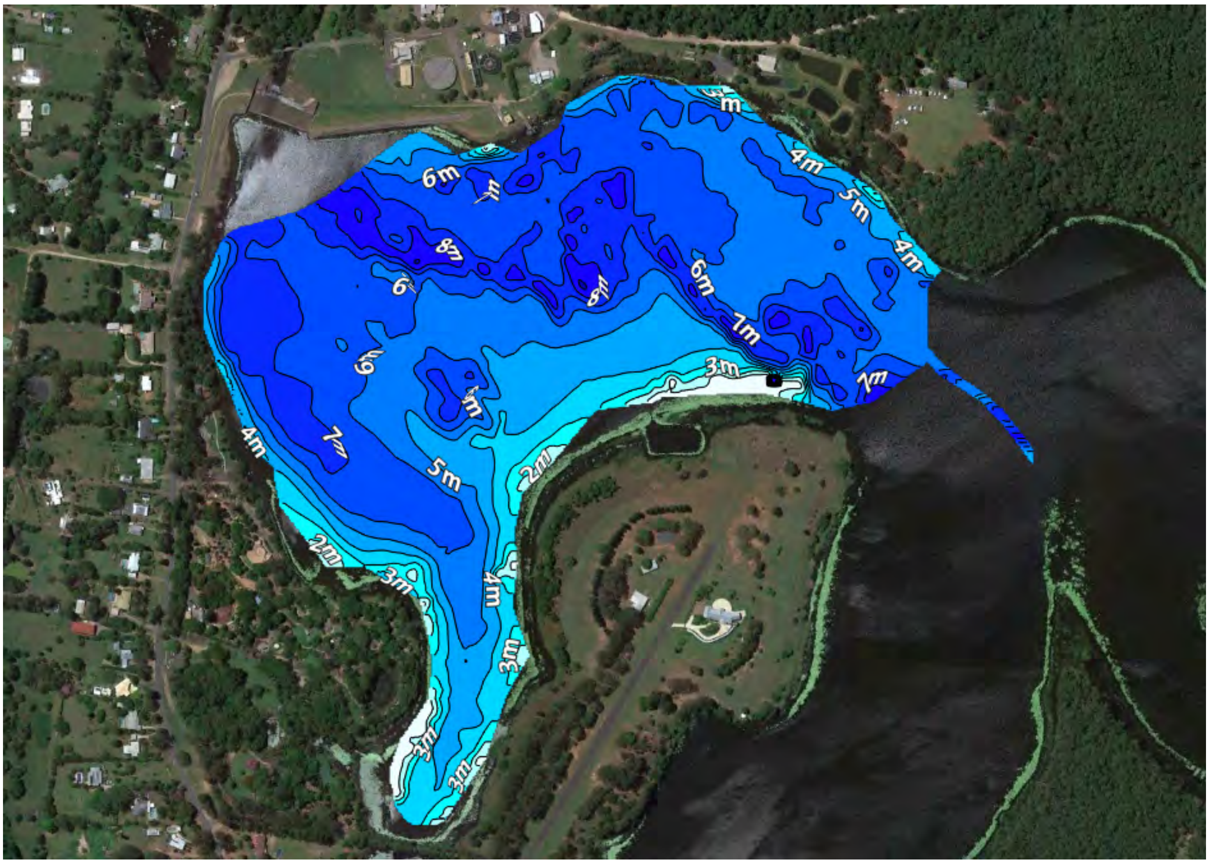


Figure 3. Example bathymetry mapping output from data collected during fish biomass surveys.

FISH BIOMASS DATA COLLECTION

Fish biomass and distribution data was collected with the BioSonics DT-X split beam echo sounder and generated using the Visual Acquisition software package (BioSonics Inc. 2017). The software enables the user to set parameters such as:

- the ping rate (pings per second) - can be set between 1 and 10 and is dependent on the aims of the survey and types of data being collected.
- the decibel threshold - the threshold below which echoes are rejected (small objects return low decibel echoes; larger objects return higher decibel echoes and hard surfaces return very high decibel echoes).
- the number of echoes an object needs to return to be classified as a 'track' – the sequential stitching together of echoes that are above the decibel threshold. The software counts only accepted tracks, and
- the maximum number of echoes an object needs to return for it to be deemed 'too many' – this setting is relaxed to allow all tracks to be counted. An object that is too big is accepted but not counted by the software.

During all surveys, data collection parameters are always set to allow the greatest number of echoes and therefore tracks to be accepted by the Visual Acquisition software, termed 'raw data' (e.g. 5 pings per second, a threshold of -60dB and at least 2 echoes received from an object to be classified as a track and counted).

In each zone, the entire edge of the lake was surveyed from approximately 60m away and the open water basins were surveyed from a series of linear transects located across the basins, approximately 50m apart. The water on each side of a linear transect was surveyed for greater coverage of each zone. Data collected in each direction, e.g. data collected when boat travelled along east to west transects and vice versa, in each zone was divided into 'a' and 'b' sub-surveys to allow for comparisons in each survey zone and to assess the stability of fish counts per zone. The edge surveys are referred to as 'c' surveys. Figure 4 shows the typical survey transect pattern used in all zones with data collected in linear light and dark blue transects comprising the sub-surveys.

During surveys one and two, numerous fish were observed occupying the upper banks and channels of the submerged Six Mile Creek. For greater penetration and fish detections in the submerged creek beds, the cross-transects were realigned to cut across the channels (and the transect directions travelled in surveys one and two) at right angles. Figure 13, a) – c) (Appendix A) shows the shoreline and cross-transect alignments for all zones in each survey.

Surveys were not able to be completed in parts of zone 6b and the whole of zones 7 and 8 due to the dense submerged and floating aquatic plant beds present in these zones. The survey was stopped numerous times in the upper reaches of zone 4 (which bordered zone 7) to clear entangled aquatic plants from the transducer. An inspection of zones 7 and 8 confirmed the increase in aquatic plant coverage, density and shallowing water depths in these zones. Aquatic plants coverage and density was similar in parts of zone 6b also, making navigation through these zones problematic. Zone nine was able to be surveyed by kayak however, the dense and narrow (2-4m) passages through aquatic plant beds resulted in minimal coverage and the collection of poor-quality data. The limited open waters in Zone 9 resulted in edge (c) sub-surveys being completed only. No fish were detected in Zone 9 and although it has been included in the tables and graphs, will not be reported on. Data from all zones with dense and extensive aquatic plants was considered poor and of low value and was therefore removed from the survey.

Figure 4. Typical survey transect pattern used in each zone recorded in the internal gps unit in the head unit of the DT-X.

FISH SPECIES VALIDATION AND GENERAL OBSERVATIONS

Fish species validation was completed using the line and lure survey method. The locations of where fish were aggregating during the biomass surveys (on screen in the BioSonics Visual Acquisition software package (BioSonics Inc. 2017) were noted and revisited at the end of each day. Fish were targeted with a range of lure types (surface, mid-water / diving and weighted). Fish that were visually observed swimming near to or below the water surface during any survey were counted, identified and the length estimated. The total survey effort for line and lure surveys was 7 hours (2 x field staff sampling for 3 x 1-hour blocks and 1 x 0.5 hours over four days).

DATA ANALYSIS

ECHOGRAM REVIEW AND RE-ANALYSIS

The stages of the echogram review process is displayed in Figure 5 and shows;

a) The raw echogram;
b) The number of accepted raw tracks (in green) as collected during survey;
c) The manual reduction of 'noisy' bottom echoes and how a fish track appears in a cross-section view of the echo sounder beam, sitting above the softer bottom noise (inset); and
d) A re-analysed echogram where the noisy signals have been rejected and the objects that returned at least 4 echoes have been accepted as a fish, or other object of interest.

Once the re-analysed echogram has been reviewed and the results are deemed acceptable the metadata for each echogram is exported from Visual Acquisition. The primary aim of review and re-analysis is to provide the post processor with a cleaner dataset. Other objects (wood, rocks, anthropogenic structures, etc.) will also meet the re-analysis echo criteria however, deciphering and classifying those included objects is where the machine learning based post processor is relied upon. It should be noted that in some instances, structure maps which single out harder objects are generated and included in the post processing to provide further points of reference, which improve the machine learning classifications, especially around larger fish.

Echogram re-analysed involves increasing the number of echoes that an object needs to return to be accepted. For this assessment, the raw data was re-analysed three (3) times:

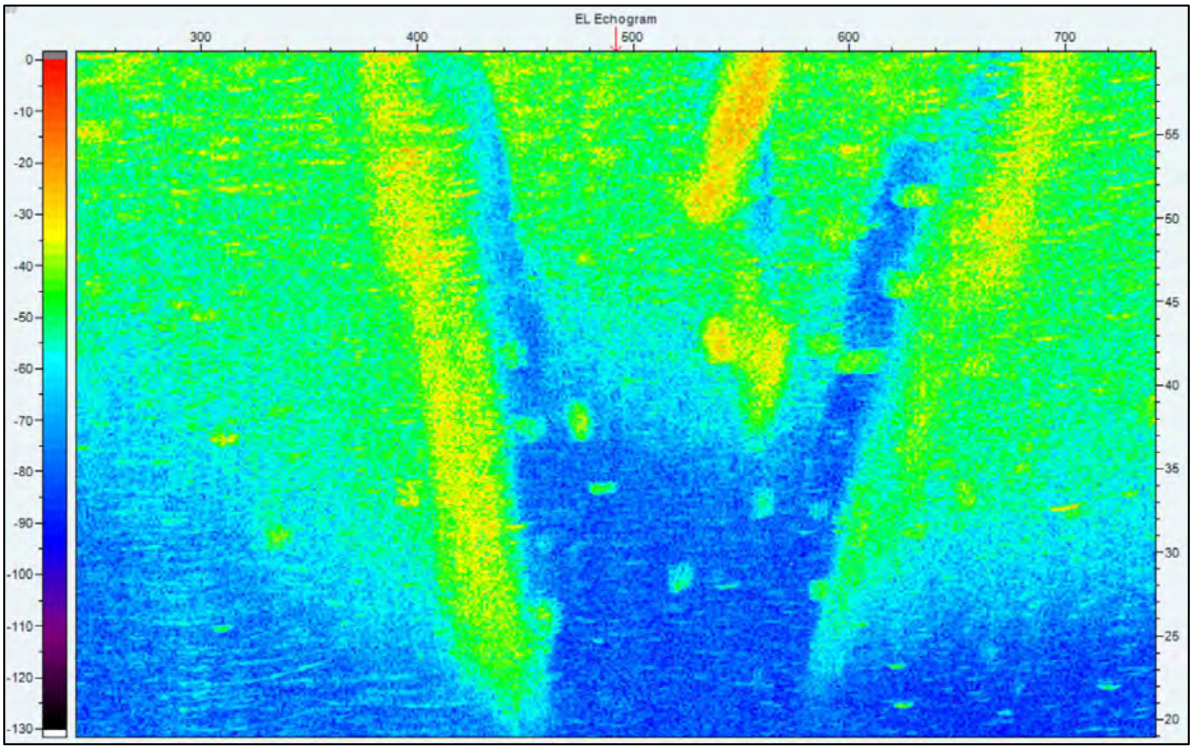
- once to focus on fish <200mm;
- once to focus on fish >200mm; and
- once to focus on structure.

The purpose of re-analysing for fish <200mm was to provide an estimate of the biomass of smaller fish in the lake, which are not typically detected during larger fish analyses. It should also be noted that reducing the number of echoes that an object needs to return to allow more smaller fish to be accepted will introduce more 'noisy signals' into the data. In this instance the machine learning models are relied upon more heavily to tease out the smaller fish tracks from the noise. However, it should be expected that there is a greater degree of error in the estimates for smaller fish. Re-analysis for smaller fish was completed using 5 pings per second, a threshold of -60dB and at least 3 echoes (maximum) received from an object to be classified as a track and counted. As such, no range has been reported for fish <200mm. The maximum number is reported only.

The purpose of re-analysing for fish >200mm was to provide an estimate of fish that will realistically be targeted for salvage. This process removes many of the smaller objects and 'noisy' signals (e.g. bottom noise, boat wash, surface water chop, etc.) that can be collected. It should be noted that pings and echoes are not a direct indicator of size as a small fish swimming in the same direction as the vessel, when surveying, can spend longer in the ensonified water and will continue to return echoes while it remains there. Generally, a smaller fish will return fewer echoes than a larger fish. The re-analysis for the range of fish >200mm was completed using 5 pings per second, a threshold of -60dB, at least 4 (upper limit) and 5 echoes (lower limit) received from an object to be classified as a track and counted. An upper and lower limit (range) of fish >200mm is reported.

The structure analysis provides location data on object that return high decibel echoes. This analysis is combined with the fish >200mm analysis to assist in querying and differentiating the larger objects (>800mm) which return louder echoes from structure, which also returns louder echoes. The structure re-analysis is completed using 5 pings per second, a threshold of -10 to -15dB, and at least 1 echo received from an object to be classified as structure and counted. Where these objects are classified, they are removed from the large fish (>800mm) dataset.

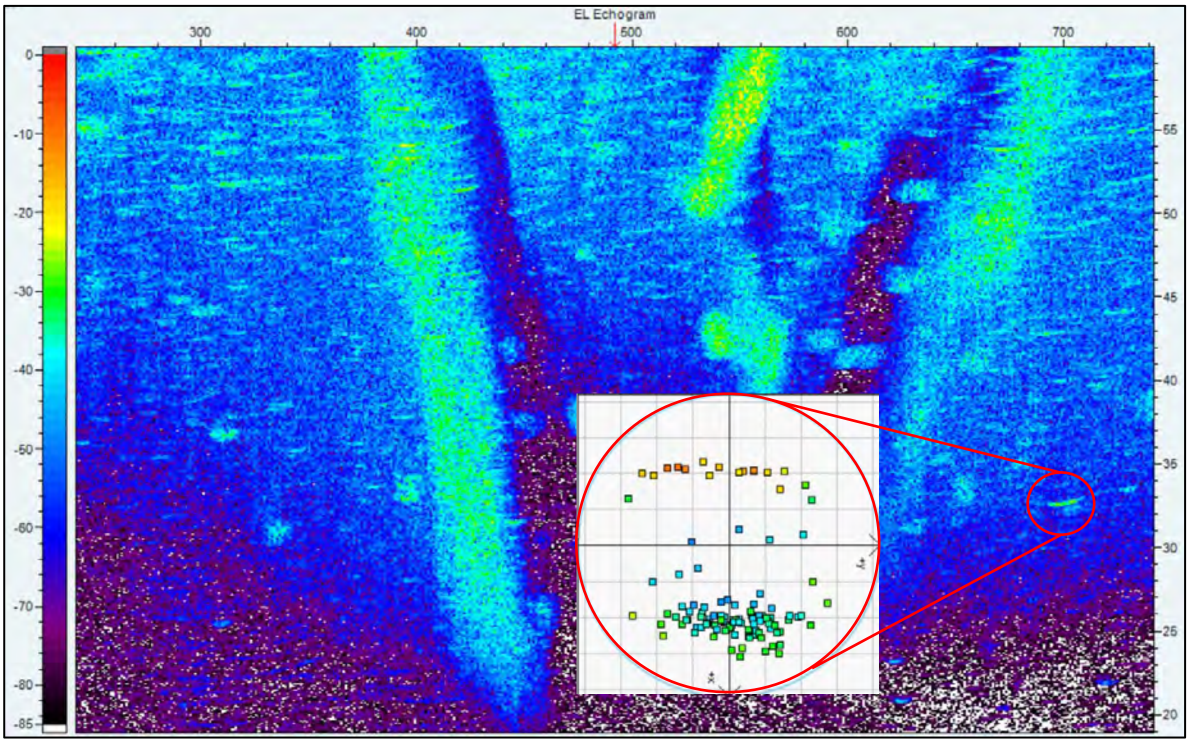
All data is presented as it was collected, providing ranges of fish >200mm for each survey and the maximum counts of smaller fish (<200mm) in each survey.



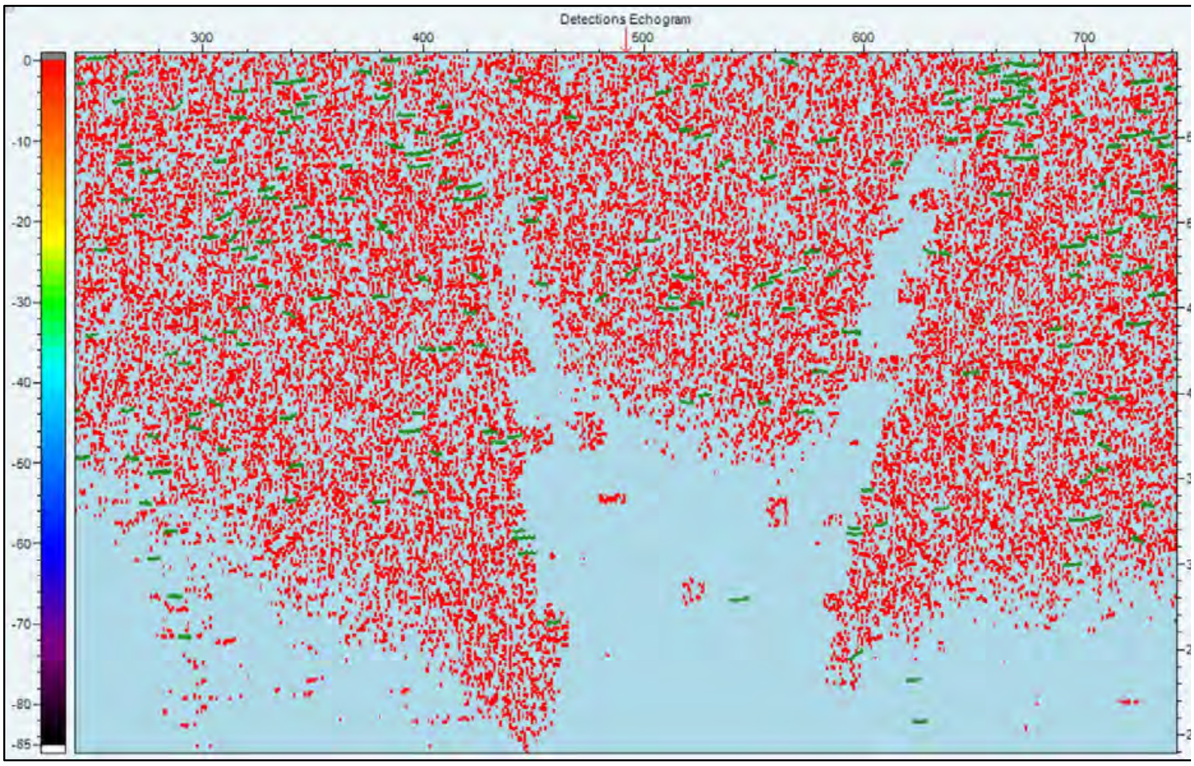
a)


60
55
50
45
40
35
30
25
20

b)


EL Echogram
300
400
500
600
700
0
-10
-20
-30
-40
-50
-60
-70
-80
-85
55
50
45
40
35
30
25
20

c)



d)

Figure 5. Example of a raw data echogram (plan view - all). Plot (a) raw accepted and counted tracks in green, plot (b) filtered bottom noise revealing fish tracks above the bottom, plot (c) an example of how this can be displayed for review (c, inset) and plot (d) post reviewed and re-analysed data to extract fish tracks from bottom noise noting the rejection of smaller fish by red pings in the open water.

MACHINE LEARNING AND MODELLING

Machine learning based post processing and modelling involves the following:

- Data is imported in its re-analysed format and aggregated into groups of transects collected in the same habitat type (e.g. open water impoundment) or zone, in the case of Lake Macdonald. The data is then processing with the same methodology. For example, if there are 10 tracks and all in the same region with the same habitat they are processed as one block. If two habitats types (e.g. open water / impoundment and riverine) have been surveyed, they are processed separately.
- Spatial information and the parameters used to assess individual objects for identification purposes are generated.
- Identified objects are then assessed by a machine learning model, that is selected from a reference library based on the habitat type. Once assessed, objects are assigned a classification.
- Validation graphics and datasets are generated for individual transects, groups of transects, and a whole processed survey overall.
- Client usable datasets are output, including point cloud data, accepted fish tracks and summaries of detected fish and other objects of interest.

Due to the extensive cover of aquatic plants around the lake, post survey re-analysis of the collected data was completed to classify the typically noisy and inconsistent ‘tracks’ that aquatic plants return. Solid objects include wood, rock, anthropogenic structures and fish / aquatic fauna were classified also.

Once processed, classified and modeled, the fish in aquatic plants beds / stands were detectable and counted. An example of a densely vegetated reach of Lake Macdonald (collected during pre-survey) that has been processed, classified and modeled (as above) is displayed in Figure 6 a and b. The render shows the dense vegetated edge in blue (a) and 12 fish signals detected among the plant stand (orange dots), above the bottom (red dots), once the aquatic plant signals had been removed. The thick orange band of dots in each render are not fish but where the bathymetry data was purposely removed as part of the training process.

FISH BIOMASS ESTIMATES AND SIZE GRADING

The strength of the echo that an object returns, in decibels, is referred to as the mean target strength (MTS). The calculated average decibels of all echoes returned by an object is referred to as mean target strength. A relationship between fish length and mean target strength exists and it is from Love's (1969) equation that the length of an object (fish) can be calculated from its mean target strength. Love's equation is as follows:

$$Length = 10^{\left(\frac{MTS+a}{b}\right)}$$

Where MTS is the mean target strength of an object and a and b values are constants derived from the linear regression equation describing the log transformed and plotted mean target strength data.

DATA OUTPUTS

All processed data was output in point cloud and .csv format was exported from the processing system to QGIS (version 3.8, 2019) for review. Zone by zone summaries were generated and exported in .csv format for reporting. Fish biomass estimates were calculated as the number of fish / m^2 of surveyed area per survey zone and extrapolated to provide an estimate for each zone. The total for the entire lake was derived from the sum of extrapolated fish counts per survey zone. Summary data is presented in tables and graphs.

FISH DISTRIBUTION MAPPING

All fish distribution mapping is produced in QGIS (version 3.8, 2019) from the point cloud data .csv files generated by the machine learning post processing. From the .csv files, the classified objects are categorized in QGIS and displayed spatially. Where large numbers of fish are detected in a survey, heat maps are also generated to more clearly define fish biomass aggregation / distribution. Screenshots of fish distribution heatmaps are presented in Figure 14, a) to h), Appendix C.

TWO DIMENSIONAL AND VOLUMETRIC CALCULATIONS

The percentage coverage of fish from survey results was calculated per m^2 and in m^3. The coverage of fish per m^2 was derived by dividing the number of fish counted per transect by the area of water that each survey transect covered (echosounder range x transect length). Totals for each survey (a, b and c) were calculated and presented in tables and graphs. This approach was preferred as the area of surveyed water, in two-dimensions / m^2, could then be expressed as a percentage of the total area of each zone and the calculated fish / m^2 in the surveyed area could be extrapolated to provide an estimate for 100% of each zone.

Volumetric calculations (fish per m^3) were derived by dividing the number of fish counted per transect by the volume of water ensonified by a single ping ($V = 1/3x\pi(3.35^\circ \text{ x range})$) by the length of a transect. This is commonly referred to as the ‘swept volume’. This calculation is an approximation as it is difficult to factor in an undulating bathymetry along the survey transect. If the volume of water in each zone was known, then the volume of water surveyed could be expressed as a percentage of the total volume of each zone and the fish / m^3 of surveyed area could be extrapolated to provide an estimate for 100% of each zone. In lieu of any volume data, the fish / m^3 of surveyed water volume was calculated and presented.

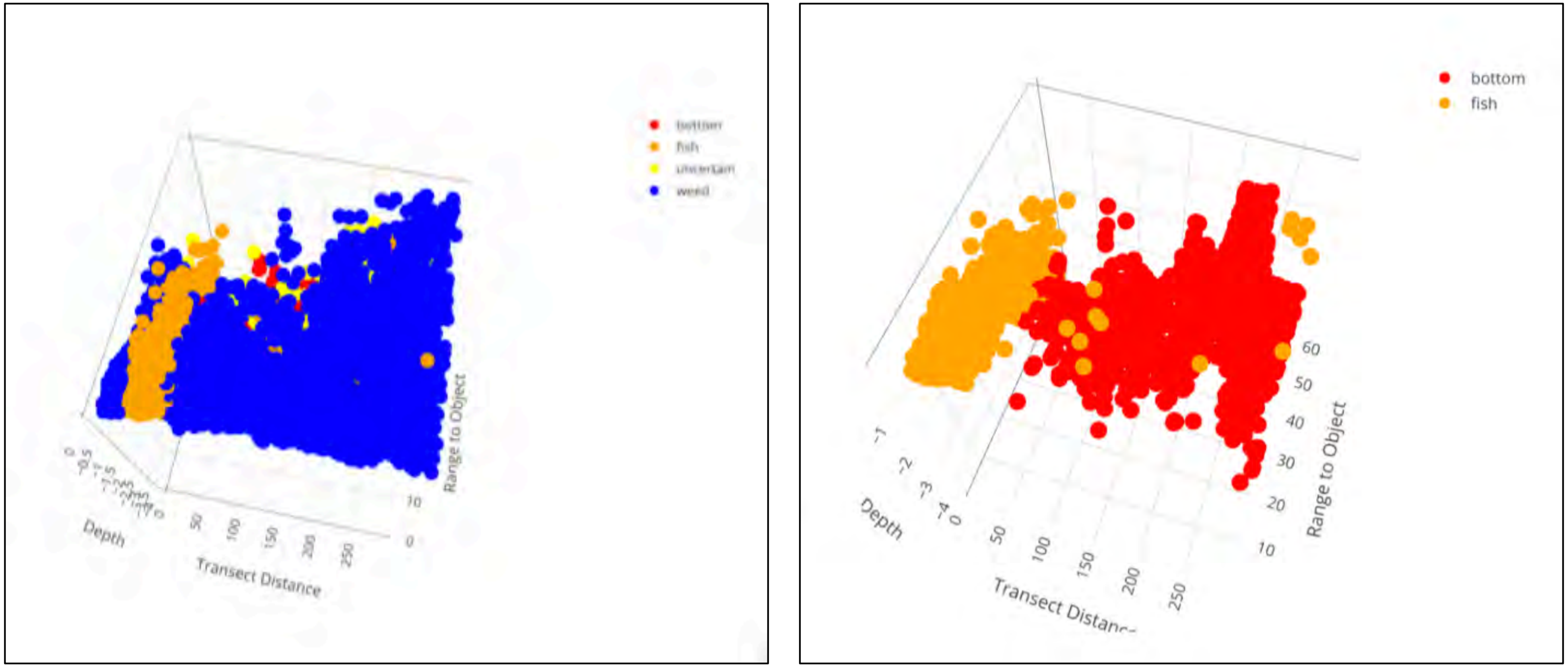
LIMITATIONS, UNDCERTAINTIES AND ERRORS

This report details the findings of three fish biomass surveys, replicated over short temporal scales over July and August 2019 (<2weeks), at Lake Macdonald, with no seasonal replication. The data was collected using high quality and tested and calibrated echo sounder / sonar technology. Fish counts were based on what was deemed an appropriate ping acceptance setting to remove as much noisy data as possible, without losing too many fish signals. The post processing and machine learning models confirmed that most signals used to derive actual and extrapolated biomass ranges for this study were indeed fish. All extrapolated data and variance are presented in Appendix D.

Fish length data was calculated using standard accepted equations developed for a range of species, in lieu of no specific length from target strength equations for the species inhabiting Lake Macdonald (e.g. Australian bass, Mary River cod, golden perch, bony bream, etc.). Further to this, fish caught during line and lure validation surveys, targeting areas where fish aggregated during biomass surveys, were in line dominant size classes, calculated from target strength data. We are currently collecting validated fish target strength data for a range of Australian species in QLD and NSW and developing a reference library. See Table 18, Appendix E for the summary statistics and variance on fish length calculations across surveys.

Error in the observed fish locations during the surveys is expected to be minimal given the high accuracy of present-day gps units. It is expected that any error in observed fish locations will not have significant effect on the quality of the data collected for this project.

The density of aquatic plants (particularly *Cabomba Caroliniana*) prevented access to some planned survey areas and limited the effectiveness of some collected data. The total area likely impacted is minimal in size and depth compared to the total area that was successfully surveyed. It is likely that some fish were missed in the densely vegetated areas. However, field observations suggest these numbers are minimal, and not likely to be in orders of magnitude when compared to the remaining dataset.



a) b)

Figure 6. Modelled aquatic plant data in blue (a) and removed (b), revealing 12 fish in the plant bed.

RESULTS

SURVEYED AREA PER SURVEY ZONE

The calculated surface areas for each survey zone and the area surveyed in each zone (m^2) are presented in Table 2. The surveyed area in each zone calculated as a percentage of the total of each survey zone is presented in Table 7, Appendix D, and displayed graphically in Figure 7, a) to c). The area calculations show some differences between a and b surveys in each zone and where the areas surveyed were more comparable. Worth noting is the coverage of the edge (c) surveys in each zone, where in the narrower zones the edge survey covered more area compared to the wider zones, as expected. It should also be noted that the narrower zones were typically shallower, and the presence and extent of aquatic plant beds was greater. The calculated percentages of surveyed area per zone were used with fish counts to derive extrapolated biomass estimates for each survey zone.

Volumetric calculations of the water surveyed (m^3) are presented in

Table 3. The greatest volume of water surveyed occurred in Zone 1, which is not unexpected considering it is the widest and deepest of all the zones. Water volumes are mostly comparable between a and b sub-surveys and typically decrease from downstream to upstream zones, as the lake narrows and gets shallower. The number of fish / m^3 for the surveyed water volume was calculated and is presented in the Summary Statistics and Biomass Estimates section. Extrapolated volumetric (fish/m^3) calculations were not completed.

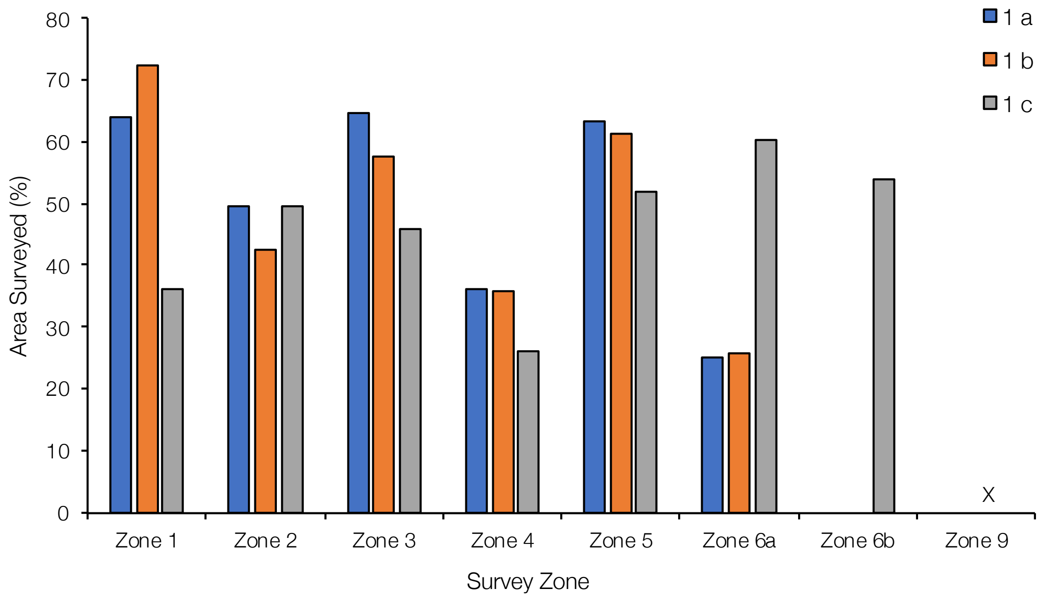
As zones 7 and 8 were too densely vegetated and not surveyed, they have not been presented in any table or graph.

Table 2. Total survey zone surface areas and the areas surveyed (m^2).

Zone	1	2	3	4	5	6a	6b	9
Surface Area (m2)	430,095	412,892	325,100	346,328	182,070	241,803	339,035	51,085
Surveyed Area (m2)								
1a	274,976	204,450	210,249	125,567	115,021	60,652	-	-
1b	311,416	176161	186,721	123,557	111,647	61,897	-	-
1c	155,667	204,740	149,042	90,691	94,577	145,825	-	-
2a	288,229	160,283	160,623	183,705	93,780	53,024	-	-
2b	231,866	157,801	149,178	178,131	92,481	46,559	-	-
2c	163,749	209,566	157,546	137,621	98,364	162,027	-	-
3a	297,009	180,278	201,110	106,915	79,467	87,557	-	-
3b	304,348	188,840	186,417	104,394	66,995	88,648	-	-
3c	179,887	203,409	157,981	126,341	88,048	126,880	-	-
4c	-	-	-	-	-	-	70,069	-
5c	-	-	-	-	-	-	-	19,000

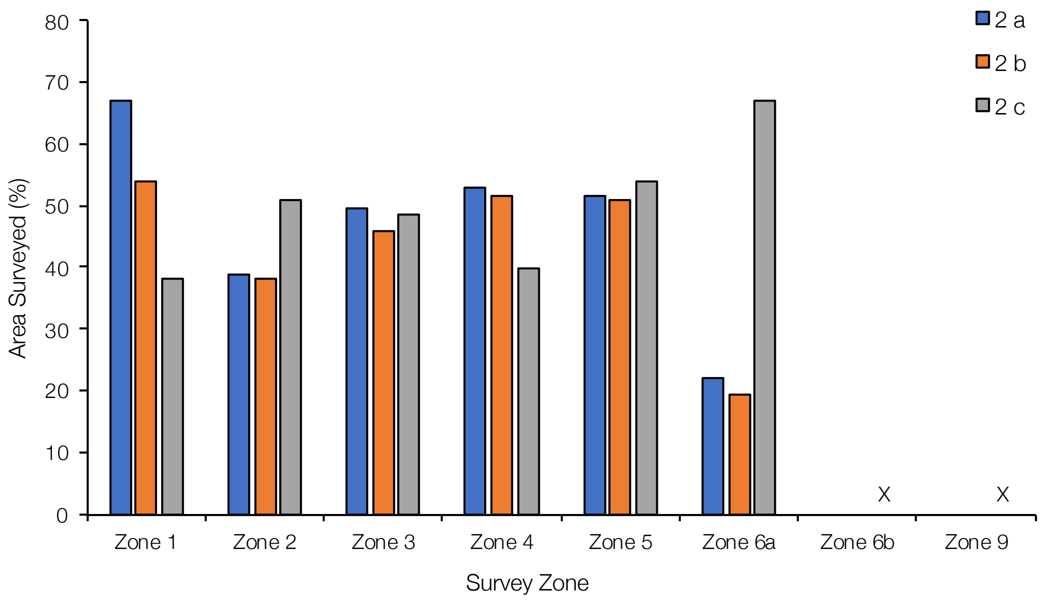
Table 3. Volumetric calculations (m^3) of water surveyed in each zone.

Zone	1	2	3	4	5	6a	6b	9
1a	980,399	727,616	748,386	296,500	409,726	143,207	-	-
1b	1,109,484	625,671	663,936	291,565	397,563	145,768	-	-
1c	552,367	725,150	527,921	213,633	334,877	458,999	-	-
2a	1,027,604	569,817	570,734	653,419	335,276	190,179	-	-
2b	827,376	561,811	529,474	633,732	329,586	166,341	-	-
2c	580,826	742,020	557,957	488,420	349,511	574,672	-	-
3a	1,060,908	644,794	720,636	275,186	285,803	287,033	-	-
3b	1,086,495	673,713	667,358	269,328	241,628	292,153	-	-
3c	638,130	721,470	559,865	373,514	312,681	450,059	-	-
4c	-	-	-	-	-	-	159,431	-
5c	-	-	-	-	-	-	-	17,899



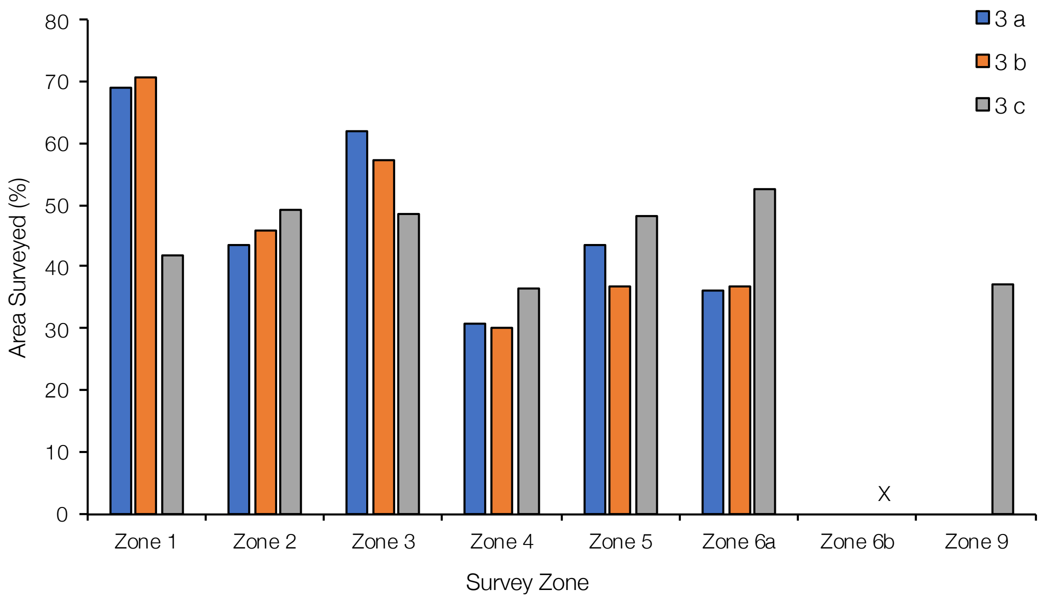
x – not surveyed

a) Survey 1



x – not surveyed

b) Survey 2



x – not surveyed

c) Survey 3

Figure 7. Area surveyed (m^2) in each survey and sub-survey.

FISH COUNTS, SIZE GRADING AND DISTRIBUTION

Pre-Survey

Fish <200mm: a total of 405 fish <200mm was counted in the pre-survey trial in Zone 1 (Table 5, Appendix B). The greatest proportion of fish were those in the 100-200mm size class followed by fish in the 50-100mm size class. Fish distribution heat mapping shows two aggregations (hot spots) in zone 1 (Figure 14, a) – Appendix C).

Fish >200mm: a total of 221 fish >200mm was counted in the pre-survey trial in Zone 1 (Table 6, Appendix B). The greatest proportion of fish were those in the 200-400mm size class followed by fish in the 400-800mm size class. These proportions are similar to those in the side-looking surveys completed in Zone 1 however, more water was surveyed in the side-looking surveys and actual counts were higher. Fish distribution heat mapping shows two aggregations (hot spots) in zone 1 (Figure 14, b) – Appendix C).

The results of the down-looking trial confirmed that the mostly shallow water depths (<5m) and limited / narrow effective surveyed water resulted in small counts of fish in all size classes, compared to the side-looking transducer configuration. The confidence around any estimate is more reliable with numbers derived from actual counts rather than extrapolated counts from a limited survey, which is why the side-looking method was preferred.

Survey 1

Fish <200mm: totals of 13,973, 13,032 and 3,706 fish were counted in the a, b and c sub-surveys of Survey 1 in Lake Macdonald (Figure 8) (Table 5, Appendix B). The greatest proportion of fish were those in the 100-200mm size class followed by fish in the 50-100mm size class in all sub-surveys. The counts were comparable between the edge (c) survey and the cross-zone a and b sub-surveys. Fish distribution heat mapping shows fish <200mm were common in zones 1-3 and the lower reaches of zone 4, with fewer occurring in zones 5 and 6a. The densest aggregation occurred in zones 1, while smaller aggregations occurred in zones 3 and 4 (Figure 14, c) - Appendix C).

Fish >200mm: ranges of 7,914 to 4,432, 7,472 to 4,147 and 3,173 to 1,639 were counted in the a, b and c surveys of Survey 1 (Figure 9) (Table 6, Appendix B). The ranges in the a and b surveys were similar while the range in the edge (c) survey was lower. This is not unexpected considering the comparatively smaller area that is surveyed in edge surveys. Fish in the 200-400mm size class contributed the greatest proportion to the ranges in the a and b sub-surveys, followed by fish in the 400-800mm size class. The ranges of fish in the 200-400mm and 400-800mm size classes in the c survey, were similar and the result suggest fish in the 200-400mm size class were located in open waters, or away from the edges, during Survey 1. An upper limit of 315 fish >800mm contributed the smallest proportion to the a, b and c sub-surveys. Fish distribution heat mapping shows fish >200mm distributed across zones 1-3 and the lower reaches of zone 4, with the densest aggregation occurring in the lower reaches of zone 4, and a less dense aggregation occurring on the lower reaches of zone 3 (Figure 14, d) - Appendix C).

Survey 2

Fish <200mm: totals of 13,269, 10,596 and 6,785 fish <200mm were counted in the a, b and c sub-surveys of Survey 2 in Lake Macdonald (Figure 8) (Table 5, Appendix B). The greatest proportion of fish were those in the 100-200mm size class followed by fish in the 50-100mm size class in all sub-surveys. The counts were comparable between the edge (c) survey and the cross-zone a and b sub-surveys. Fish distribution heat mapping shows fish <200mm were common in zones 1-3 and the lower reaches of zone 4, with fewer fish distributed throughout zones 5 and 6a. The densest aggregation occurred in zone 4, while wider spread aggregations occurred in zones 1. Fewer fish were distributed throughout zones 2 and 3, compared to Survey 1 (Figure 14, e) - Appendix C).

Fish >200mm: ranges of 7,290 to 4,249, 6,710 to 3,691and 4,789 to 2,783 were counted in the a, b and c surveys of Survey 2 (Figure 9) (Table 6, Appendix B). The range in the b sub-survey was lower than the range in the a sub-survey, while the range in the edge (c) sub-survey was slightly lower again. It should be noted that the range in the c sub-survey was higher than in the c sub-survey of Survey 1. The ranges suggest that the biomass was less prevalent in the open waters of Lake Macdonald during Survey 2, with greater numbers of fish counted along the edges of the lake. Fish in the 200-400mm size class contributed the greatest proportion to the ranges in all sub-surveys, followed by fish in the 400-800mm size class. Fish >800mm contributed the smallest proportion (384, upper limit) to all sub-surveys and the greatest range of fish >800mm was counted in the edge (c) sub-survey. Fish distribution heat mapping shows fish >200mm distributed across zones 1-5 with the densest aggregation occurring in the lower reaches of zone 4 (coinciding with the aggregation of fish <200mm in this survey) and across the main basin of zone 2 (Figure 14, f) - Appendix C).

Survey 3

Fish <200mm: totals of 19,259, 19,639 and 9,380 fish <200mm were counted in the a, b and c sub-surveys of Survey 3 in Lake Macdonald (Figure 8) (Table 5, Appendix B). The greatest proportion of fish were those in the 100-200mm size class followed by fish in the 50-100mm size class, as in previous surveys. Many more smaller fish were counted in Survey 3 in the a and b sub-surveys however, the count in the edge (c) sub-survey was similar to the counts in Surveys 1 and 2. The reasons behind such an increase in smaller fish may be a result of less schooling behavior / looser aggregations in the open waters. More individual smaller fish were observed in echograms in the open water and on the fish finders during the survey (Figure 10, a to c). When fish are schooling tightly, the spatial separation between the fish in a school is less and harder for the echo sounder to penetrate and identify single targets. In some cases, only one or two targets will be accepted as fish, when there are clearly many more in the school that the software cannot separate out and count. This is a limitation of the technology when dealing with tightly schooled fish. In Surveys 1 and 2, the smaller fish may have been undercounted as result of tighter schooling. There was one week between Surveys 2 and 3 and the weather was consistent for the duration of the survey.

Another factor contributing to the greater number may also be the change in transect direction. The change was made to target more of the larger fish observed along or within the submerged creek channel, in Surveys 1 and 2 and the results suggest this was achieved. In doing so however, the detection and counting of smaller fish may also have been more effective. The areas and volumes of water surveyed in Survey 3 were comparable to the areas and volumes surveyed in Surveys 1 and 2. Fish distribution heat mapping also shows a greater number of fish <200mm distributed throughout all zones in the lake with the largest aggregation located in the main basin of zones 1 and 2 (Figure 14, g) - Appendix C).

Fish >200mm: ranges of 7,721 to 4,417, 8,310 to 4,835 and 4,886 to 2,828 were counted in the a, b and c surveys of Survey 3 (Figure 9) (Table 6, Appendix B). The range in the b sub-survey was higher than the range in the a sub-survey, while the range in the edge (c) sub-survey was lower. The range in the c sub-survey was higher than in the c sub-survey of Survey 1 and similar to the range in the c sub-survey in Survey 2. The ranges suggest that slightly greater biomass of fish >200mm was counted in the open waters of Lake Macdonald during Survey 3. Fish in the 200-400mm size class contributed the greatest proportion to the ranges in all sub-surveys, followed by fish in the 400-800mm size class. Fish >800mm contributed the smallest proportion (279 fish) to all sub-surveys and the lowest upper estimates of any survey were counted in Survey 3. Fish distribution heat mapping shows fish >200mm distributed across zones 1-4 with the densest aggregation occurring in the main basin of zone 2 (coinciding with the aggregation of fish <200mm in this survey). A lesser aggregation occurred in the main basin of zone 1 (Figure 14, h) - Appendix C).

Survey 4

Fish <200mm: a total of 46 fish was counted in Survey 4 (Figure 8). Fish in the 50-100mm size class contributed the greatest proportion to the total count. Survey 4 was completed in zone 6b of the lake, which was problematic to survey effectively due to the dense aquatic plant beds.

Fish>200mm: a range of 40-30 fish was counted in the edge (c) surveys (Figure 9). As with all other surveys of fish >200mm, fish in the 200-400mm size class contributed the greatest proportion to the range, followed by fish in the 400-800mm size class. It should be noted that a maximum of three fish >800mm were counted in zone 6b. The presence of large eels in zone 6b were confirmed visually during the biomass surveys, as was the presence of saratoga however, the presence of cod cannot be ruled out in this zone.

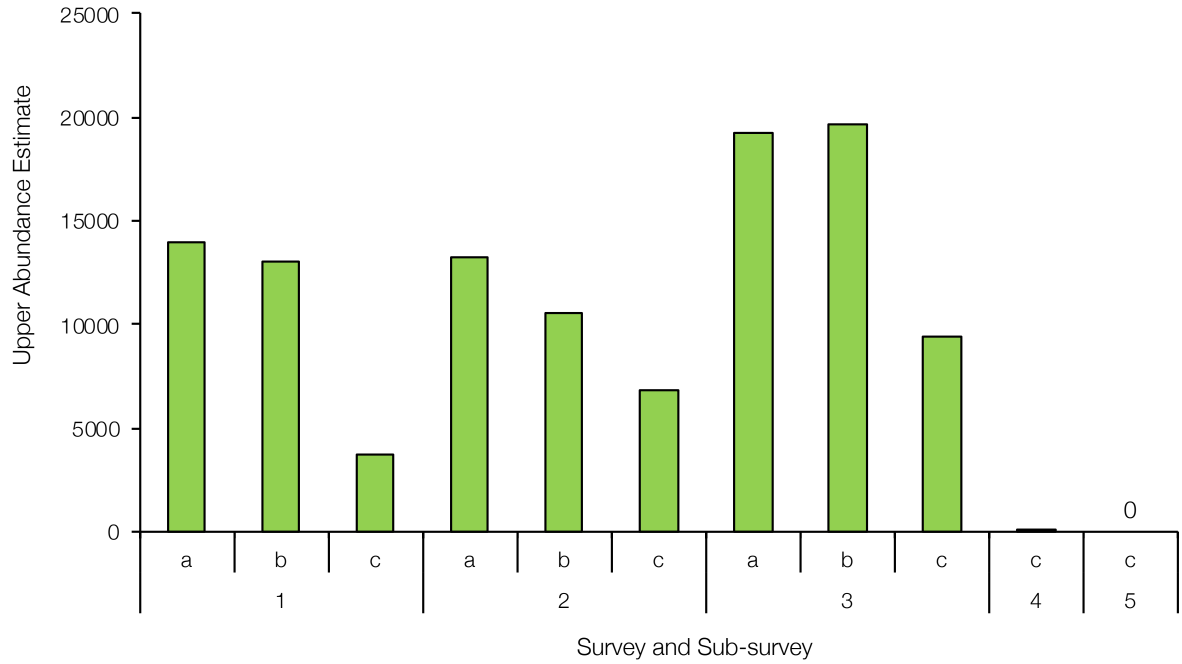


Figure 8. Total counts of fish <200mm in each survey.

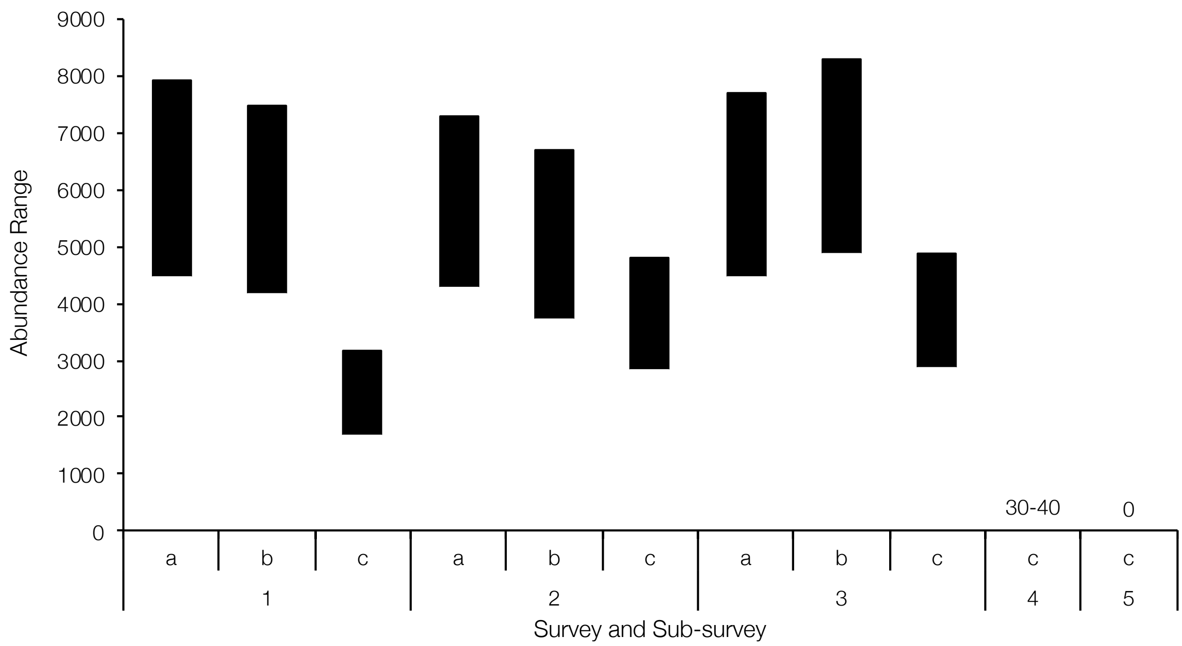
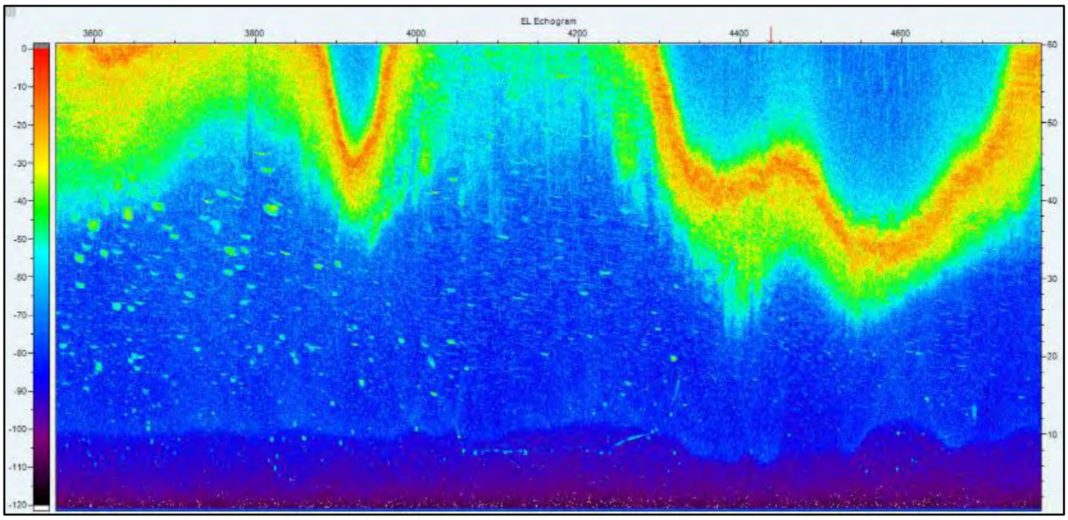
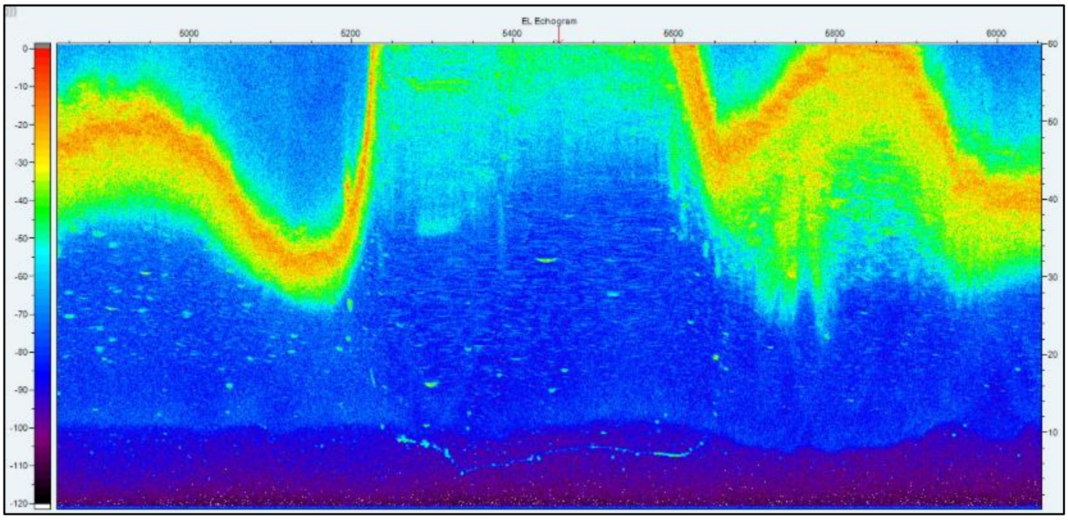


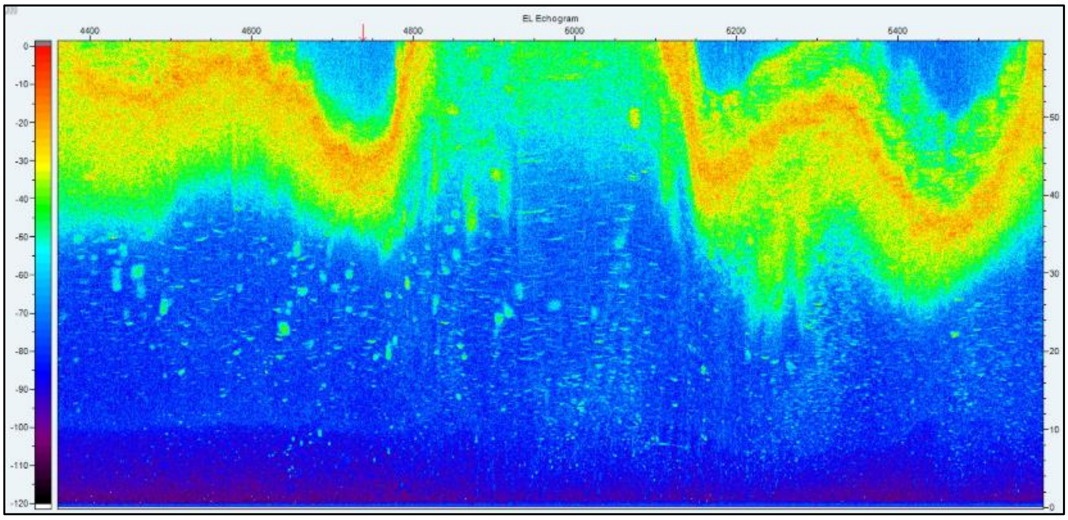
Figure 9. Ranges of counted fish, derived from a minimum of 4 echoes (upper limit) and a maximum of 5 echoes (lower limit), of all fish >200mm in each survey.



a)



b)



c)

Figure 10. Example of the increase in smaller fish / individual targets observed between Survey 1 (a), Survey 2 (b) and Survey 3 (c), represented by green dots against the lower blue portion (open water) of each echogram.

FISH SPECIES VALIDATION AND OBSERVATIONS

The most abundant large bodied fish species in Lake Macdonald were Australian bass (*Percalates novemaculeata*). A total of 48 Australian bass were caught ranging in size from 220mm to 450mm. Species validation was completed by line and lure surveys and confirmed the presence of Australian bass throughout zones 1 to 4 and 6a. A single eel-tailed catfish (*Tandanus tandanus*) was caught in zone 2 (approximately 400mm) and numerous longfin eel (*Anguilla reinhardtii*) were either caught or observed free-swimming during the surveys in zones 3, 4 and 5 (580mm to >1m). The total survey effort for line and lure surveys was 7 hours (2 x field staff sampling for 3 x 1-hour blocks and 1 x 0.5 hours over four days).

Seven southern saratoga (*Scleropages leichardti*) were observed at the water surface in zones 1, 6a, 6b and 9 (approximately 300-800mm). No golden perch (*Macquaria ambigua*) were caught during the validation surveys however, local fishermen have reported catching them on occasion around the boundary of zones 6a and 6b (R. Manning 2019, pers. comm., 24 July). No Mary River cod were caught during the fish validation surveys however, numerous large fish were detected throughout the lake and a proportion of these are likely to be Mary River cod.

The most abundant smaller bodied fish species in Lake Macdonald is likely to be bony bream (*Nematalosa erebi*). Large dense schools of small to medium fish were observed on fish finders and captured on the DT-X in all surveys and survey zones. Numerous previous fish validation surveys completed by Infofish Australia in shallower waters (<2m deep) using cast nets, confirmed that fish schooling in open waters in impoundment environments are dominated by bony bream. Also observed on the fish finders were larger fish sitting around the schools which were targeted during the line and lure surveys. The line and lure results also suggested that the schooling fish were bony bream with a single individual (approximately 120mm) observed protruding from the mouth of a line caught Australian bass.

A single platypus was observed on August 6, approximately 100m downstream of the Cooroy-Noosa Rd road bridge that crosses Six Mile Creek, immediately west of the turn off for Sivyers Rd. Potential burrow entrances were observed along the steep right bank (facing upstream) on the bend at the upper end of zone 6a. Turtles were observed in zones 4, 6b and 9 during the survey however, are likely to inhabit many areas of the lake.

SUMMARY STATISTICS AND BIOMASS ESTIMATES

The maximum number of fish <200mm extrapolated in any survey was 34,977, in Survey 3b, with the lowest being 9,494 in Survey 1c (Figure 11). The maximums in the a and b sub-surveys in Survey 3 were similar. The extrapolated 135 fish in Survey 4c (zone 6b) should be considered unreliable as the data collection in zone 6b was limited and impeded by the dense aquatic plant beds. In general, the maximum counts varied between sub-surveys however, the results of Survey 3 are considered reliable, as the counts reflect the observations of greater numbers of individual fish on the echo sounder and fish finders, noted during the survey. Maximum counts, fish densities and extrapolated counts for fish <200mm in each zone across surveys is presented in Table 8 to Table 10, Appendix D.

The maximum number of fish >200mm extrapolated in any survey was 15,201, in Survey 3b (Figure 12). The upper limits in all other a and b sub-surveys were comparable with the lowest being 13,620. The lower limits of the a and b surveys ranged from 8,862 to 7,549 fish. The extrapolated fish counts per zone in all a and b sub-surveys are comparable and considered reliable. The ranges c sub-surveys were lower again however, this is not unexpected considering their focus on the lake and zone margins. The c sub-surveys provide a point of comparison between the edge and open water surveys however, the a and b sub-surveys are considered the most reliable, as they cover each zone from edge to edge and the open waters in between. Fish count ranges (upper and lower limits), fish densities and extrapolated ranges for fish >200mm in each zone across surveys is presented in Table 11 to Table 16, Appendix D.

The extrapolation is representative of the zones that were surveyed only and does not extend to those that were not surveyed. Please refer to the discussion for commentary on the implications and assumptions made on the zones that were not surveyed. Extrapolations (including variance) for all size classes in each survey, for each zone are provided in Table 17, Appendix D.

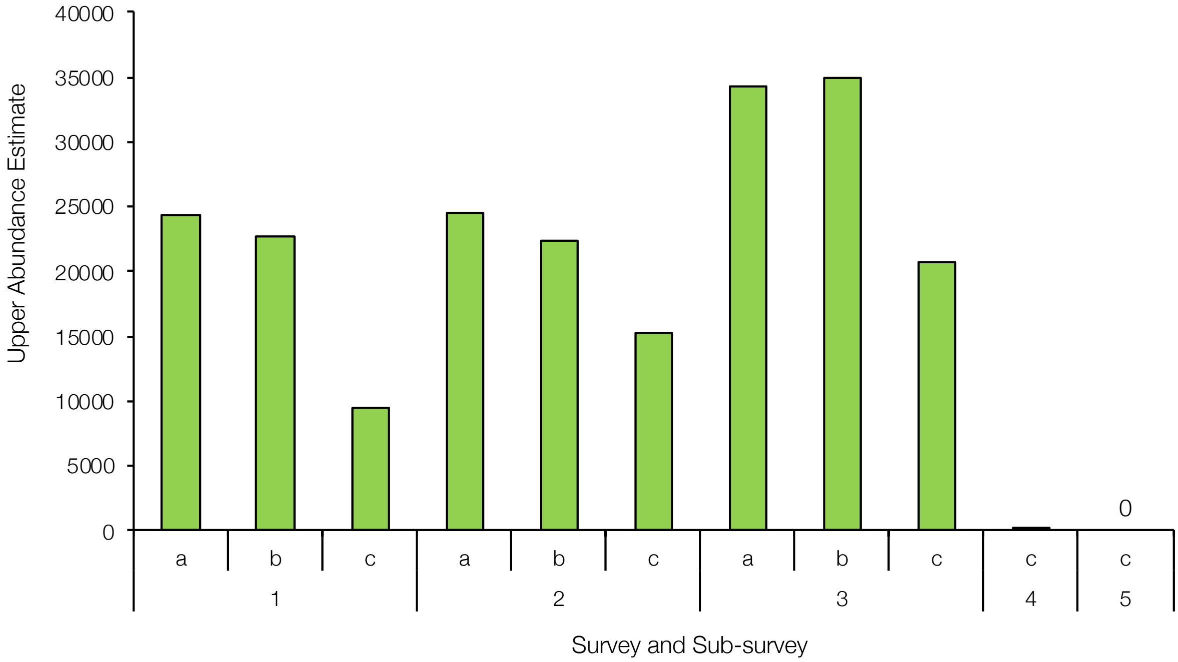


Figure 11. Extrapolated ranges of fish <200mm in each survey and sub-survey.

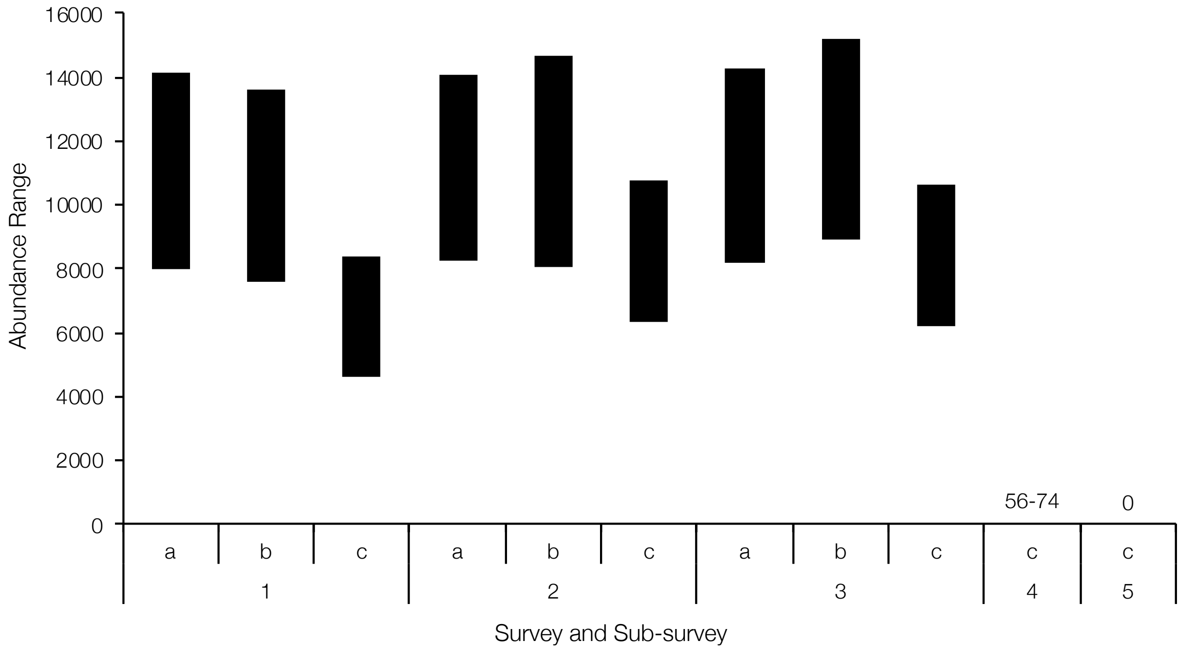


Figure 12. Extrapolated ranges of all fish >200mm in each survey and sub-survey.

DISCUSSION AND CONCLUSIONS

The biomass surveys were successful in detecting fish in a range of size classes and habitats in all zones that were surveyed. Survey zones 1 to 3 were the most common areas to hold large numbers of fish with some shift in the biomass observed on occasion. The upper limit of the bulk of the biomass was the lower reaches of zone 4 and smaller numbers of fish were located further upstream, into zones 5 and 6a. It is likely that fish would move even further into zone 6b on occasion however the numbers would be limited and low compared to the numbers of fish detected in the zones 1 to 4. A key driver of the distribution of larger bodied, predatory fish in impoundment environments is food resources. In Lake Macdonald, the bulk of smaller fish were consistency located in zones 1 to 4, as depicted in the heat maps. As a result, some heat mapping shows the densities of larger fish increasing in, or near to, these locations also. A number of larger fish were detected and counted during the surveys. Lake Macdonald has been stocked with Mary River cod historically and a proportion of these fish are likely to inhabit the lake at present however, the exact numbers cannot be teased out from the level of analysis completed to date. The larger fish are likely to be a combination of Mary River cod, saratoga, eels and possibly lungfish however, further specific analysis and speciation models should be developed to more confidently answer such questions.

The data analyses were focused on the detection of fish >200mm initially however, the data was re-analysed to include counts of fish <200mm, as requested. It should be noted that to allow more smaller fish to be detected (reducing the number of echoes that an object needs to return to be counted) will introduce more ‘noisy’ signals into the data. In this instance the machine learning models are relied upon more heavily to tease out and classify the smaller fish tracks from the noise however, it should be expected that there is a degree of error in the estimates of smaller fish.

Where surveys in the upper reach zones (6b, 7 and 8) were constrained or not completed due to dense aquatic plant beds and shallow water depths, some basic assumptions can be made. These zones are likely to be more suited to and utilized by smaller bodied fish species that inhabit the lake (e.g. gudgeons, juvenile bony bream, etc.). Larger bodied fish are likely to occur in these areas in a transitory nature, as observed during the surveys in the densely vegetated zone 4. Very few fish of any size were observed moving through the junction of zones 6a and 6b on the fish finders, during any survey. During line and lure surveys at the junction of zones 6a and 6b, only a single Australian bass was caught after 1 hour of survey effort. Even zone 5, which joins the upper end of zone 3, had very few larger bodied fish detected during the surveys, comparatively. Larger bodied fish were more common in zones 3 and the lower reaches of zone 4. Based on the results of the biomass surveys, line and lure surveys and observations made on the echo sounder and fish finders during the biomass surveys, it is unlikely that these zones are being occupied by large numbers of larger bodied fish, compared to zones 1-4, and are unlikely to increase the overall fish count ranges drastically, if they could be surveyed effectively.

The fish assemblage in the lake is likely to be dominated by Australian bass, based on line and lure surveys. The size ranges of Australian bass caught during the validation surveys (220mm to 450mm) are consistent with the greatest proportions of the size classes detected in the biomass surveys, being 200-400mm and 400-800mm. Smaller fish are likely to be dominated by bony bream, based on field observations and similarities observed between this survey and previous Infofish surveys, where echo sounder and fish finder imagery, and subsequent cast net validation has confirmed the presence, mobile schooling behavior and extent of bony bream. Lower numbers of other species known to inhabit the lake were observed during the biomass surveys or caught during the line and lure validation surveys and are likely to contribute comparatively small percentages to the total assemblage. It is assumed that most fish inhabiting the upper reaches are likely to move downstream as the water level drops however, salvage teams could consider inspecting any upper reaches pools that form for the presence of larger fish.

The presence of platypus was confirmed with a single platypus observed in zone 9 and potential burrow entrances observed at the upper end of zone 6a. The upper reaches of zone 9 are also potential platypus habitat, given the steeper sandy / clayey nature of the banks, the presence of *Lomandra longifolia* lining most of the banks. The presence of turtles was confirmed, and large number are likely to inhabit the lake. Previous Infofish Australia experience in fauna salvage efforts in QLD and NSW have indicated that turtles (and eels, when the conditions suit) will leave a body of water once it becomes unsuitable for habitation and seek more suitable habitat elsewhere.

The presence and extent of aquatic plants in Lake Macdonald and the ability of the DT-X to detect fish in these plants was of concern to seqwater. It is true that dense weeds are a challenge for any type of sonar device and extracting and analyzing fish data in aquatic plants using the default BioSonics Visual Acquisition software has limitations and is labour intensive. Once the metadata for each was transect extracted from Visual Acquisition and run through the post processor, fish located in aquatic plants were able to be identified and counted. The physical structure of the cabomba beds (thin leaved and feathery) resulted in considerable penetration of the echo sounder through them, to the point that the harder lake bottom beneath them was being detected. Fish, being considerably more solid than cabomba were returning cleaner and more consistent echoes from within the aquatic plant beds. Inspection and analysis of the pre-survey aquatic plant bed focused data provided a machine learning training set which guided post-processing of the main survey data. The result being that post-processing was tweaked to separate fish from aquatic plants. Further to this, previous experience in dam environments indicated that fish will hold in and move through aquatic plants that are generally less dense and in Lake Macdonald, the numbers of fish in the aquatic plants stands / beds were low compared to the numbers detected in the open waters of zones 1 to 4.

To conclude, the extrapolated maximum (fish <200m) and upper limits (fish >200mm) of the biomass range estimates are considered to be accurate. The extrapolated maximum number of fish >200mm and <200mm per zone, including standard error, and their totals are presented in Table 4. The re-analysis of data and post-processing was focused on counting objects (fish) for which the confidence level was high however, some fish may have been missed due to their orientation in the water, relative to the face of the transducer / angle at which the sound was aimed. The density extrapolations are considered most reliable in zones 1 to the lower reaches of zone 4, where the surveys were most effective and unimpeded by the density of aquatic plants. Small numbers of fish were detected and counted within aquatic plant beds and channels in Zone 6b however, no fish were counted in zone 9. In zones 6b and 9, extrapolations should be treated with caution and referred to as indicative only.

Based on the completed biomass surveys, any future salvage efforts should focus on zones 1 to 3, where the reservoir is deeper, and the bulk of the biomass was repeatedly detected. The deeper areas of the lake will also be the last areas to hold water, and where the majority of fish will be concentrated as the water level is reduced. Where target numbers of fish are required for salvage efforts, it is recommended to use the extrapolated maximum number of fish >200mm in any survey as opposed to averages across the surveys.

Table 4. Maximum extrapolated fish counts > 200mm and <200mm in any survey, their totals and standard error.

Size Class	Zone							Total
	1	2	3	4	5	6a	6b	
>200mm	4,453	4,843	4,090	3,120	728	364	74	17,671
Standard Error (+/-)	290	339	310	245	75	40	n/a	1,300
<200mm	12,968	10,762	8,849	3,463	986	875	135	37,768
Standard Error (+/-)	997	970	785	277	93	86	n/a	3,209

RECOMMENDATIONS

Based on the findings of the survey, the following recommendations are put forward for consideration:

- Investigate opportunities to obtain signals for turtles and eels and discuss further analysis options to tease the potential numbers out of the current datasets.
- Investigate opportunities to further breakdown the data at Lake Macdonald based on number of species/clusters of similar signals. Recent analysis and modelling completed by Infofish on other projects suggests that species clustering (diversity) can be determined.

REFERENCES

BioSonics Inc., 2016. Visual Habitat - Post-processing and Data Visualisation Software for BioSonics Echosounder Systems, v2.0.2.9744

BioSonics Inc., 2017. Visual Acquisition - Real Time Data Acquisition, Storage and Playback Software for BioSonics Echosounder Systems, v6.3.1.10980.

Google Earth Pro, 2019. Version 7.3.2.5776 (64-bit).

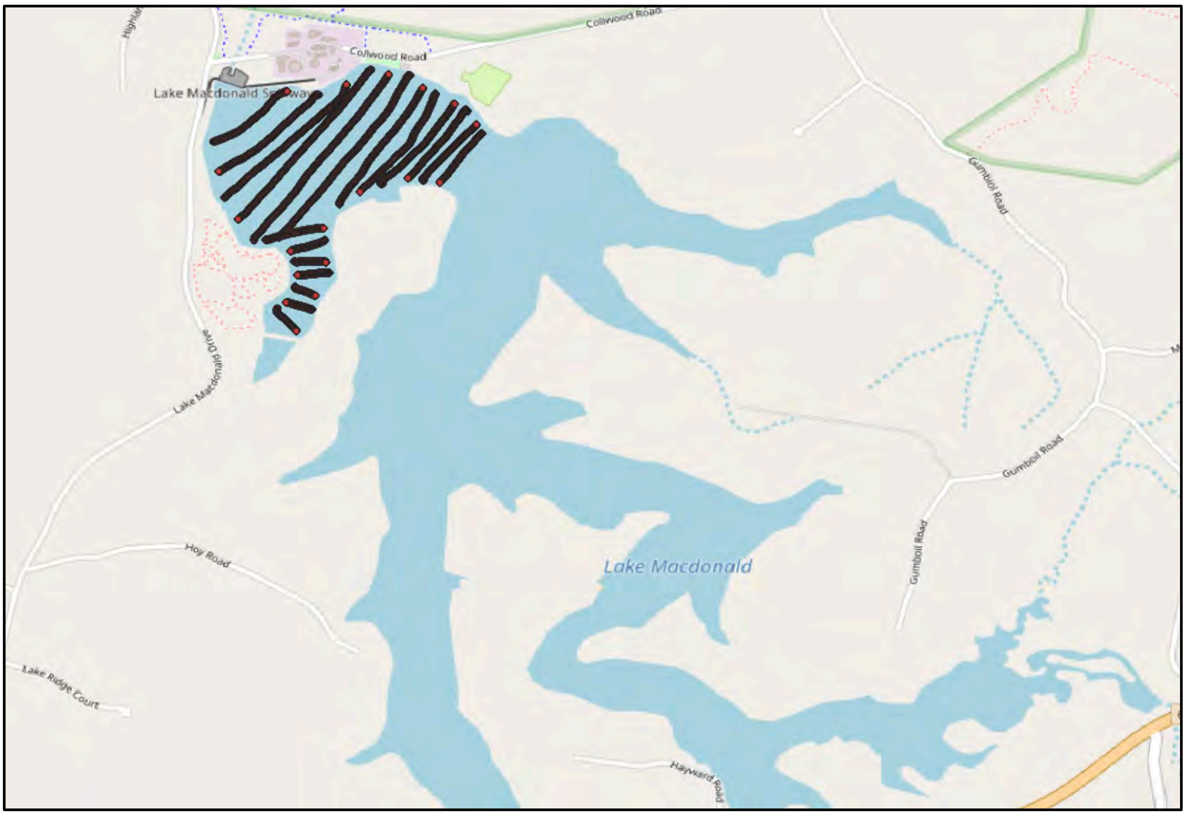
Love, R. H., 1969. An Empirical Equation for the Determination of the Maximum Side-Aspect Target Strength of an Individual Fish. Informal Report, Naval Oceanographic Office, Washington D.C.

QGIS, 2019. Version 3.8 (Zanzibar).

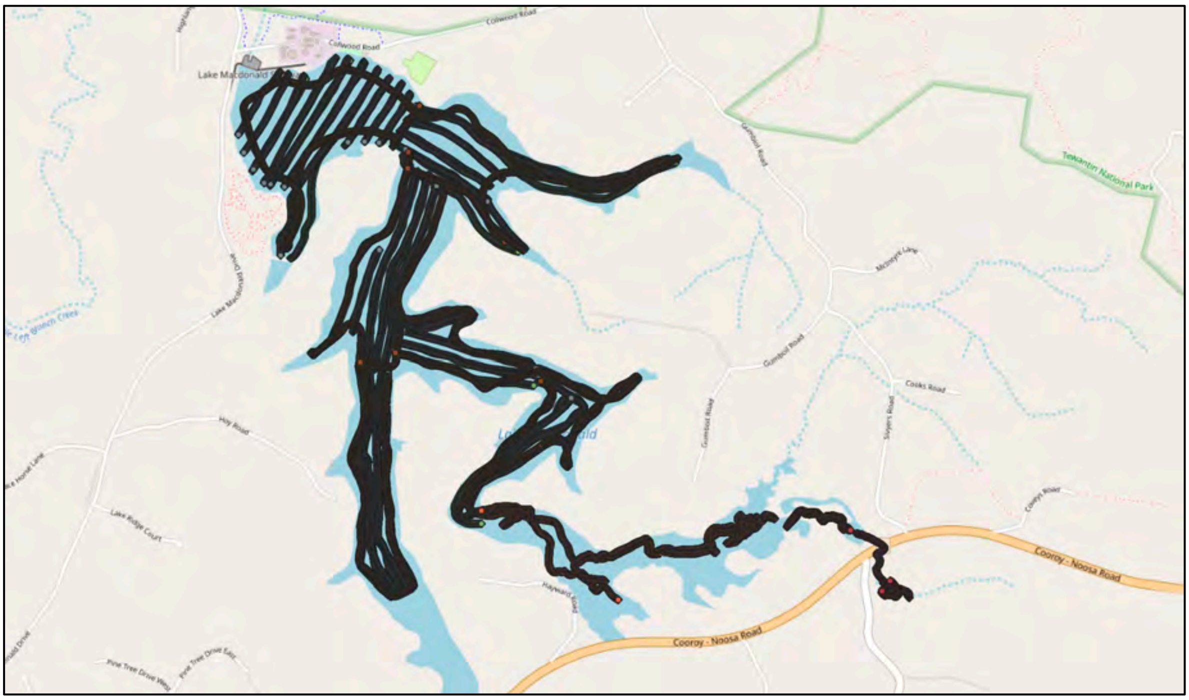
ReefMaster, 2018. ReefMaster Software Limited, V2.0

RStudio, 2018. RStudio v1.1.456.

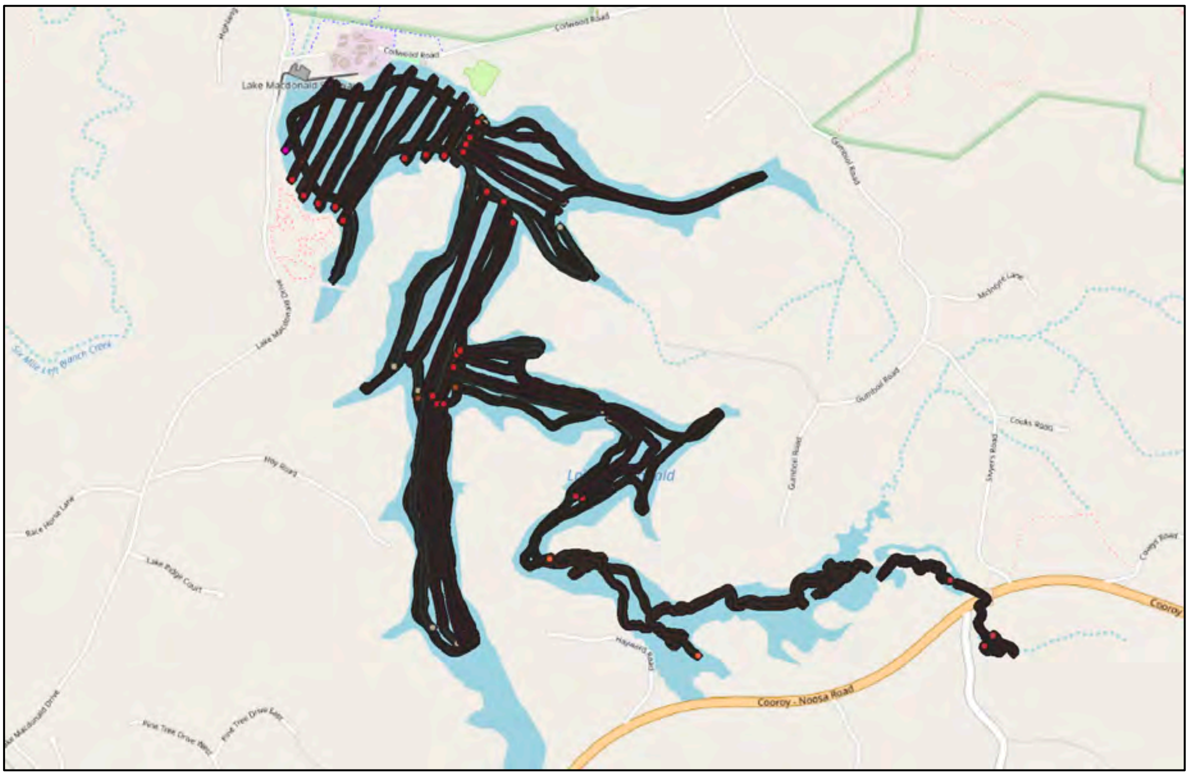
APPENDIX A – SURVEY TRANSECTS



a) Pre Survey



b) Survey 1



c) Survey 2

d) Survey 3

Figure 13. Survey transects for all zones per survey.

APPENDIX B – RAW FISH COUNTS PER SIZE CLASS

Table 5. Sub-survey and total and counts for fish <200mm across all surveys of Lake Macdonald.

Survey	Size Class (mm)			Total
	<50	50-100	100-200	
Pre-survey	8	101	296	405
1a	630	3,067	10,276	13,973
1b	469	2,730	9,833	13,032
1c	269	858	2,579	3,706
2a	491	2,884	9,894	13,269
2b	339	2,072	8,185	10,596
2c	399	1,596	4,790	6,785
3a	1,437	4,646	13,176	19,259
3b	1,492	4,618	13,529	19,639
3c	774	2,308	6,298	9,380
4c	17	28	1	46
5c	0	0	0	0

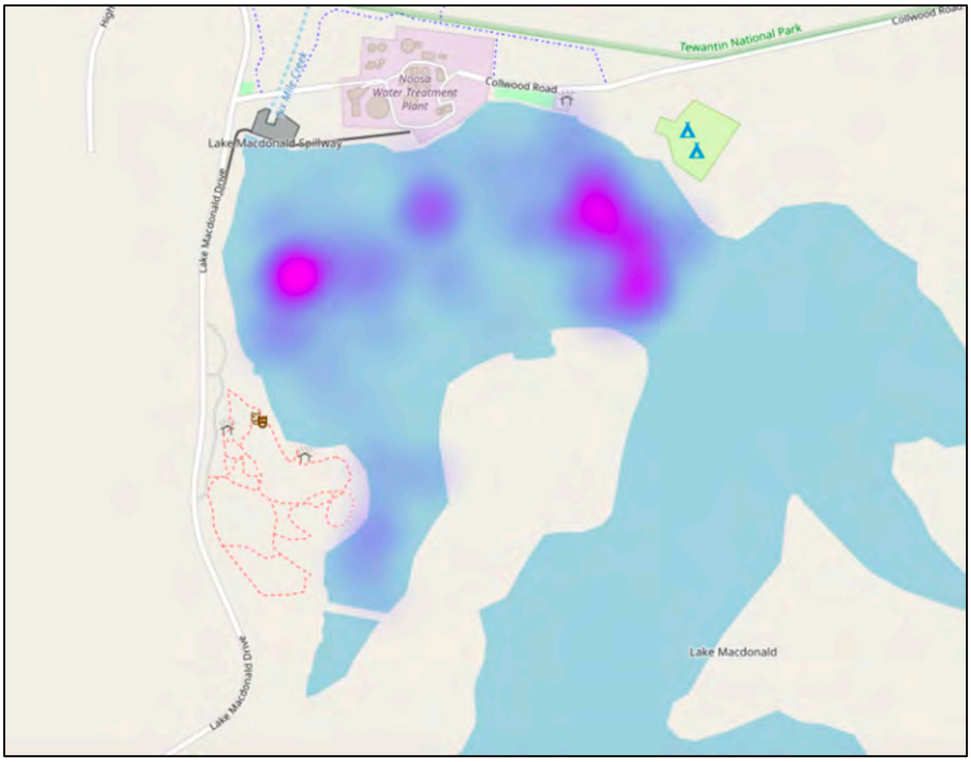
* Data collected with transducer in down-looking configuration.

Table 6. Sub-survey and total counts of fish >200mm across all surveys of Lake Macdonald.

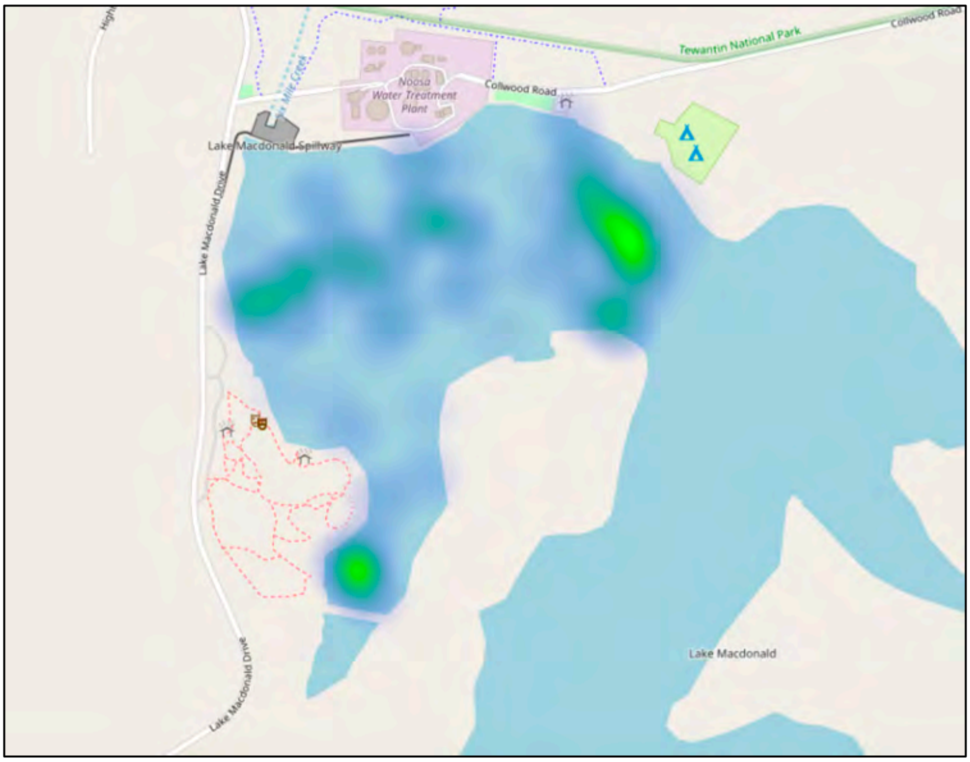
Survey	Estimate	Size Class (mm)			Total
		200-400	400-800	>800	
Pre-survey*	Maximum	153	54	14	221
1a	Upper	4,981	2,618	315	7,914
	Lower	2,666	1,547	219	4,432
1b	Upper	4,670	2,461	341	7,472
	Lower	2,517	1,438	192	4,147
1c	Upper	1,435	1,449	289	3,173
	Lower	749	741	149	1,639
2a	Upper	4,444	2,501	345	7,290
	Lower	2,522	1,494	233	4,249
2b	Upper	4,040	2,338	332	6,710
	Lower	2,205	1,286	200	3,691
2c	Upper	2,547	1,858	384	4,789
	Lower	1,522	1,071	190	2,783
3a	Upper	5,290	2,209	222	7,721
	Lower	2,928	1,320	169	4,417
3b	Upper	5,595	2,436	279	8,310
	Lower	3,191	1,462	182	4,835
3c	Upper	2,943	1,696	247	4,886
	Lower	1,742	956	130	2,828
4c	Upper	20	17	3	40
	Lower	15	13	2	30
5c	Upper	0	0	0	0
	Lower	0	0	0	0

* Data collected with transducer in down-looking configuration.

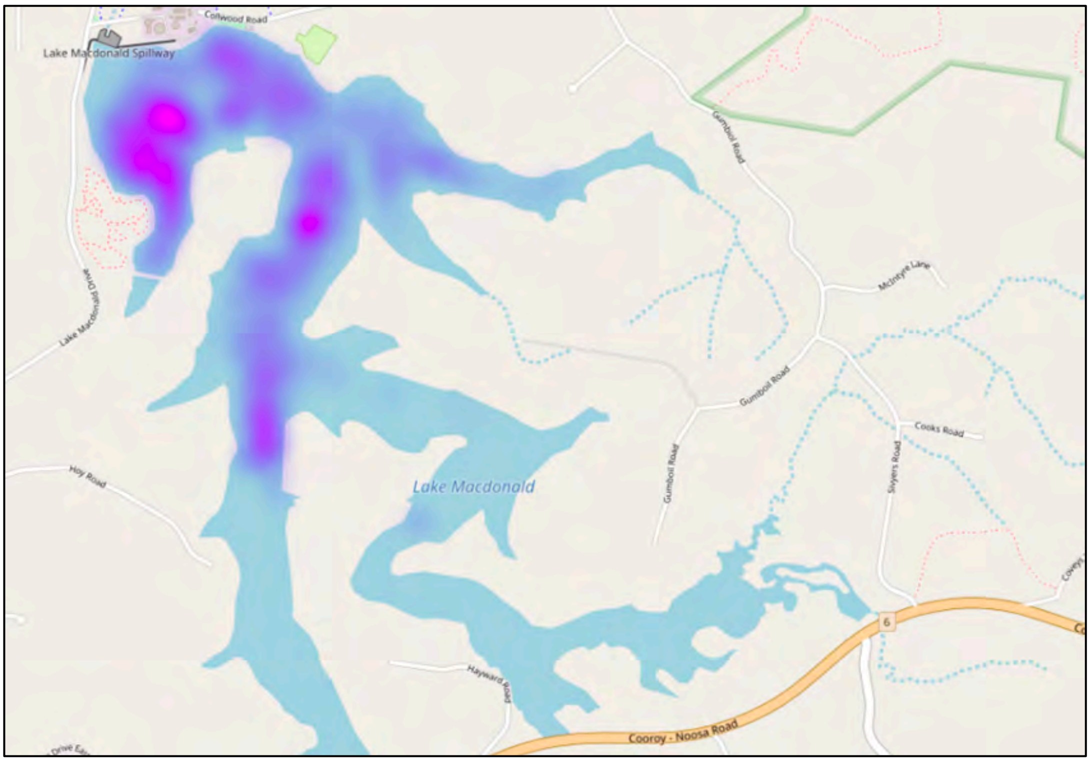
APPENDIX C – FISH DISTRIBUTION HEAT MAPS



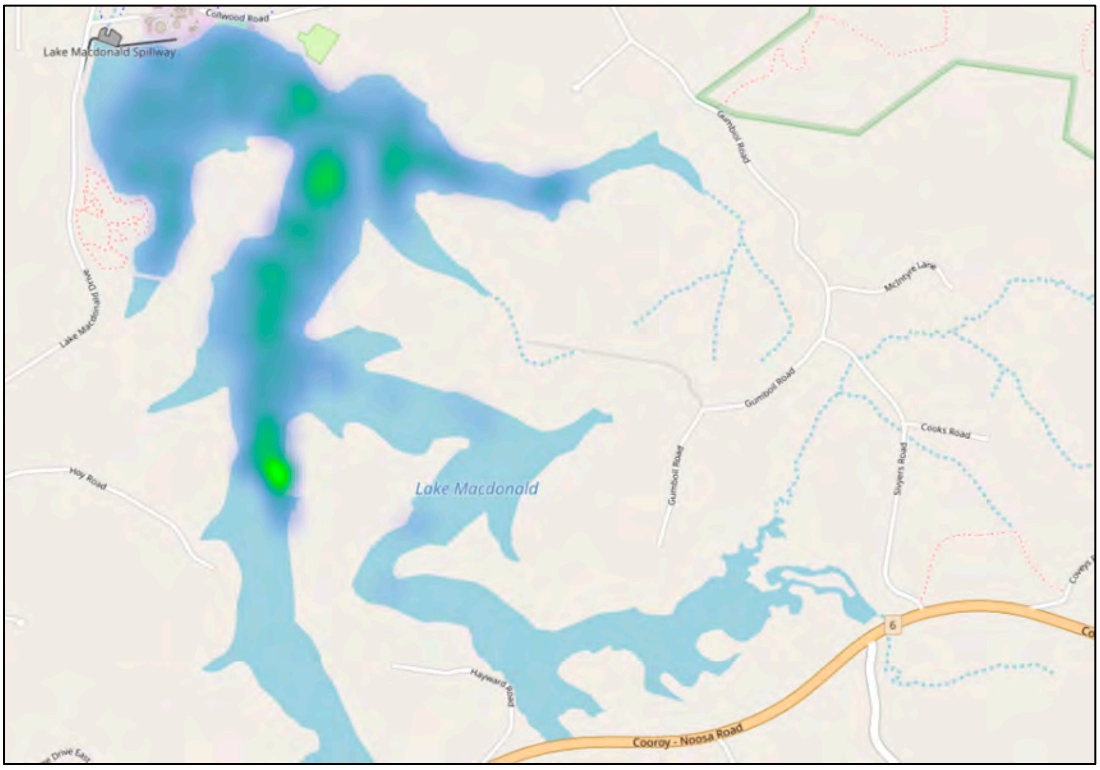
a) Pre-survey (fish <200mm)



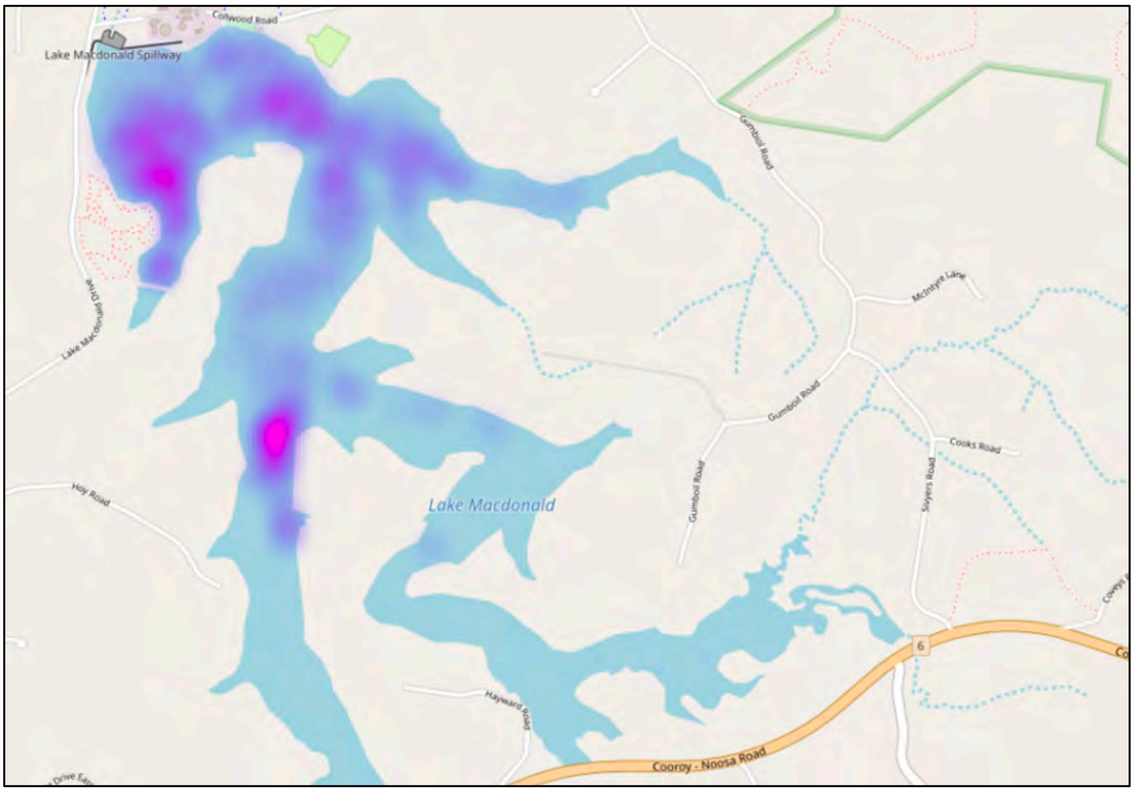
b) Pre-survey (fish <>200mm)



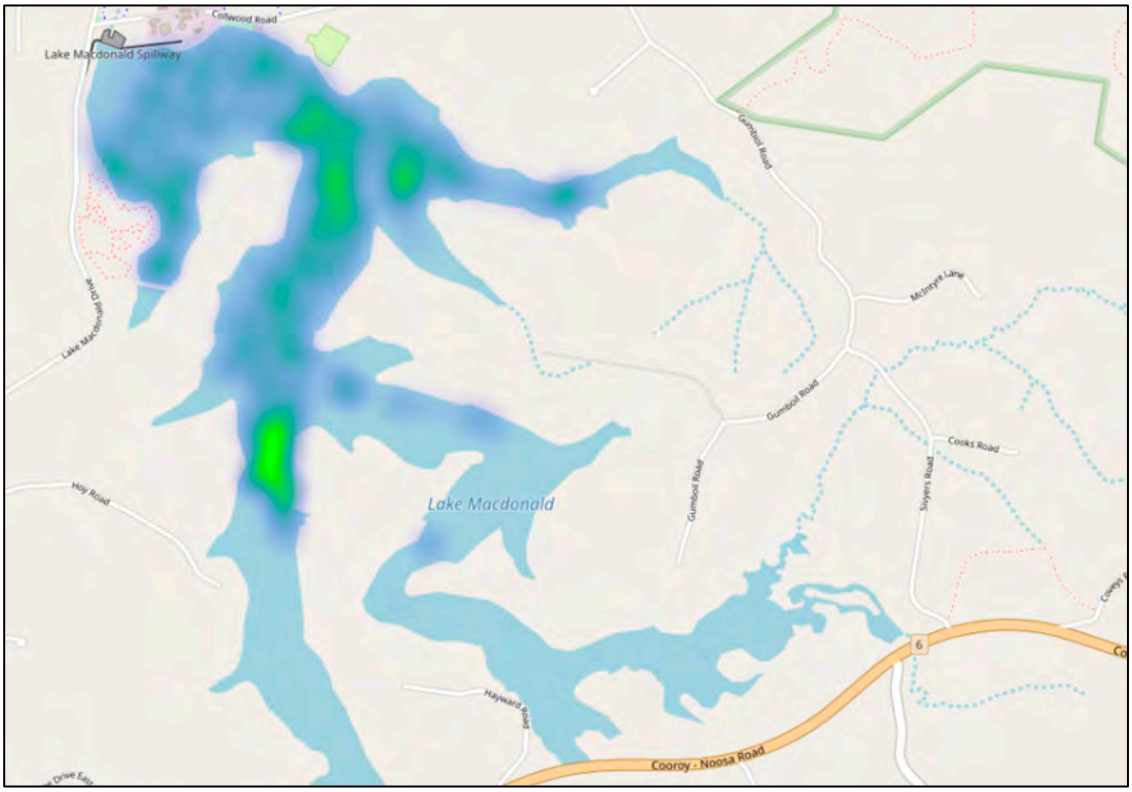
c) Survey 1 (fish <200mm)



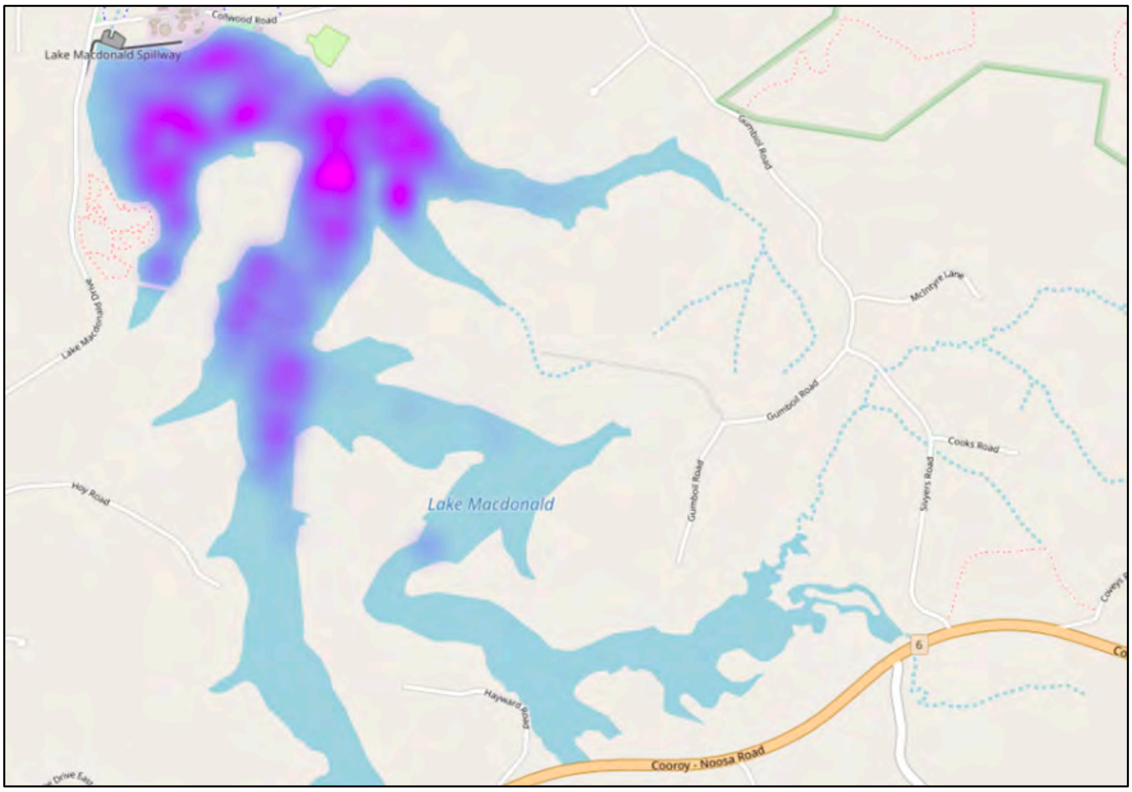
d) Survey 1 (fish >200mm)



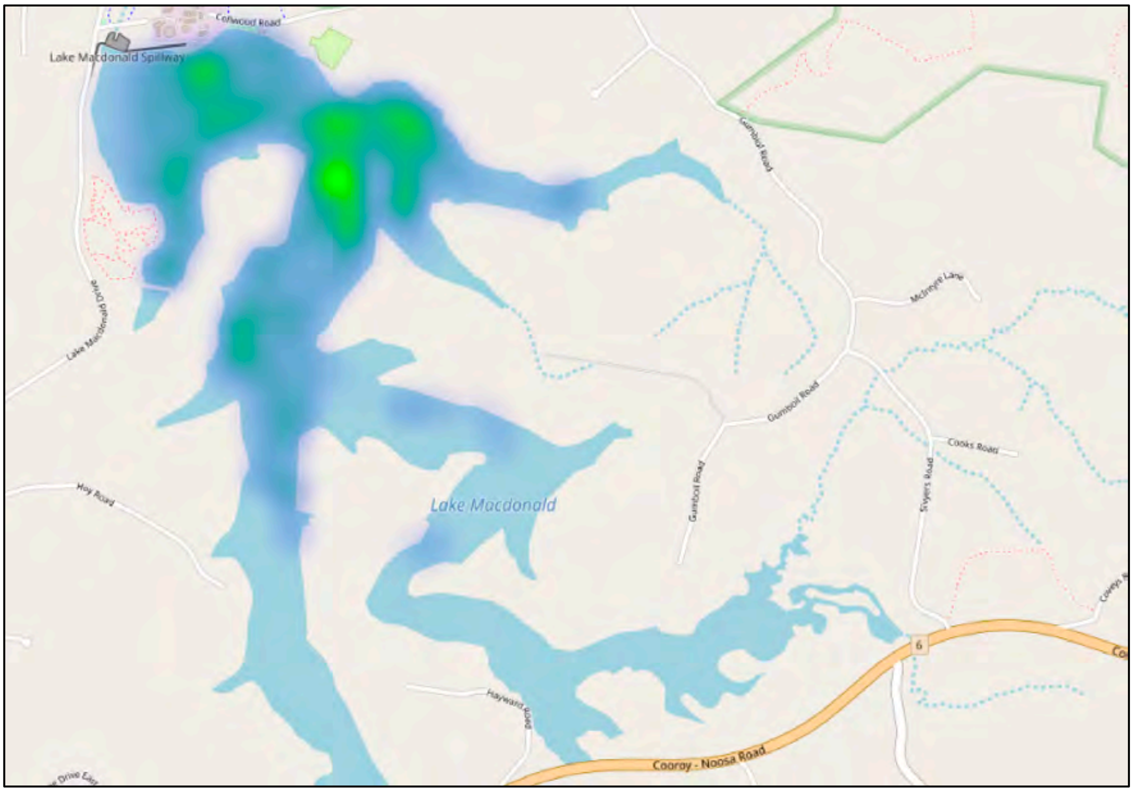
e) Survey 2 (fish <200mm)



f) Survey 2 (fish >200mm)



g) Survey 3 (fish <200mm)



h) Survey 3 (fish >200mm)

Figure 14. Distribution heat maps of fish <200mm and fish >200mm in all surveys.

APPENDIX D – AREA SURVEYED (%) AND BIOMASS EXTRAPOLATIONS

Table 7. Area surveyed in each zone expressed as a percentage of the total area of each zone.

Zone	1	2	3	4	5	6a	6b	9
Pre-survey*	5	-	-	-	-	-	-	-
1a	64	50	65	36	63	25	-	-
1b	72	43	57	36	61	26	-	-
1c	36	50	46	26	52	60	-	-
2a	67	39	49	53	52	22	-	-
2b	54	38	46	51	51	19	-	-
2c	38	51	48	40	54	67	-	-
3a	69	44	62	31	44	36	-	-
3b	71	46	57	30	37	37	-	-
3c	42	49	49	36	48	52	-	-
4c	-	-	-	-	-	-	54	-
5c	-	-	-	-	-	-	-	37

* data collected in down-looking transducer configuration

Table 8. Count of fish <200mm in each zone across surveys.

Zone	1	2	3	4	5	6a	6b	9	Total
Pre-survey*	405	-	-	-	-	-	-	-	405
1a	6,245	2,452	3,963	1,075	176	62	-	-	13,973
1b	6,603	1,868	3,449	872	67	173	-	-	13,032
1c	1,192	811	906	577	79	141	-	-	3,706
2a	6,501	2,384	2,172	1,663	508	41	-	-	13,269
2b	5,274	2,013	2,227	833	163	86	-	-	10,596
2c	2,026	1,475	1,213	1,376	128	567	-	-	6,785
3a	8,769	4,184	5,001	816	271	218	-	-	19,259
3b	8,603	4,922	5,074	634	203	203	-	-	19,639
3c	3,915	2,891	1,711	270	134	459	-	-	9,380
4c	-	-	-	-	-	-	73	-	73
5c	-	-	-	-	-	-	-	0	0

* data collected in down-looking transducer configuration

Table 9. Fish densities / m^2 for fish <200mm in each zone across surveys.

Zone	1	2	3	4	5	6a	6b	9
Pre-survey*	0.0188	-	-	-	-	-	-	-
1a	0.0227	0.0120	0.0188	0.0086	0.0015	0.0010	-	-
1b	0.0212	0.0106	0.0185	0.0071	0.0006	0.0028	-	-
1c	0.0077	0.0040	0.0061	0.0064	0.0008	0.0010	-	-
2a	0.0226	0.0149	0.0135	0.0091	0.0054	0.0008	-	-
2b	0.0227	0.0128	0.0149	0.0047	0.0018	0.0018	-	-
2c	0.0124	0.0070	0.0077	0.0100	0.0013	0.0035	-	-
3a	0.0295	0.0232	0.0249	0.0076	0.0034	0.0025	-	-
3b	0.0283	0.0261	0.0272	0.0061	0.0030	0.0023	-	-
3c	0.0218	0.0142	0.0108	0.0021	0.0015	0.0036	-	-
4c	-	-	-	-	-	-	0.0004	-
5c	-	-	-	-	-	-	-	0.0000

* data collected in down-looking transducer configuration

Table 10. Extrapolated total counts for fish <200mm in each zone across surveys.

Zone	1	2	3	4	5	6a	6b	9	Total
Pre-survey*	8,081	-	-	-	-	-	-	-	8,081
1a	9,768	4,952	6,128	2,965	279	247	-	-	24,338
1b	9,119	4,378	6,005	2,444	109	676	-	-	22,732
1c	3,293	1,636	1,976	2,203	152	234	-	-	9,494
2a	9,701	6,141	4,396	3,135	986	187	-	-	24,547
2b	9,783	5,267	4,853	1,620	321	447	-	-	22,290
2c	5,321	2,906	2,503	3,463	237	846	-	-	15,276
3a	12,698	9,583	8,084	2,643	621	602	-	-	34,231
3b	12,158	10,762	8,849	2,103	552	554	-	-	34,977
3c	9,360	5,868	3,521	740	277	875	-	-	20,642
4c	-	-	-	-	-	-	135	-	135
5c	-	-	-	-	-	-	-	0	0
Mean	9,022	5,721	5,146	2,369	393	519	135	0	18,969
Standard Deviation	2,991	2,910	2,355	832	279	259	0	0	11,811
Standard Error (+/-)	997	970	785	277	93	86	0	0	3,561

* data collected in down-looking transducer configuration

Table 11. Count of fish >200mm using 4 pings (upper limits) in each zone across surveys.

Zone	1	2	3	4	5	6a	6b	9	Total
Pre-survey*	221	-	-	-	-	-	-	-	221
1a	2,555	2,218	2,378	505	191	67	-	-	7,914
1b	2,832	1,681	2,339	491	81	48	-	-	7,472
1c	538	863	886	817	19	50	-	-	3,173
2a	2,536	1,499	1,960	916	375	4	-	-	7,290
2b	2,319	1,747	1,863	612	99	70	-	-	6,710
2c	1,355	1,294	1,115	795	68	162	-	-	4,789
3a	2,654	1,892	2,481	482	168	44	-	-	7721
3b	3,151	2,215	2,345	311	171	117	-	-	8,310
3c	1,651	1,788	1,070	171	29	177	-	-	4,886
4c	-	-	-	-	-	-	40	-	40
5c	-	-	-	-	-	-	-	0	0

* data collected in down-looking transducer configuration

Table 12. Fish densities / m^2 for fish >200mm using 4 pings (upper limit) in each zone across surveys.

Zone	1	2	3	4	5	6a	6b	9
Pre-survey*	0.0103	-	-	-	-	-	-	-
1a	0.0093	0.0108	0.0113	0.0040	0.0017	0.0011	-	-
1b	0.0091	0.0095	0.0125	0.0040	0.0007	0.0008	-	-
1c	0.0035	0.0042	0.0059	0.0090	0.0002	0.0003	-	-
2a	0.0088	0.0094	0.0122	0.0050	0.0040	0.0001	-	-
2b	0.0100	0.0111	0.0125	0.0034	0.0011	0.0015	-	-
2c	0.0083	0.0062	0.0071	0.0058	0.0007	0.0010	-	-
3a	0.0089	0.0105	0.0123	0.0045	0.0021	0.0005	-	-
3b	0.0104	0.0117	0.0126	0.0030	0.0026	0.0013	-	-
3c	0.0092	0.0088	0.0068	0.0014	0.0003	0.0014	-	-
4c	-	-	-	-	-	-	0.0002	-
5c	-	-	-	-	-	-	-	0.0000

* data collected in down-looking transducer configuration

Table 13. Extrapolated total counts for fish >200mm using 4 pings (upper limit) in each zone across surveys.

Zone	1	2	3	4	5	6a	6b	9	Total
Pre-survey*	4,410	-	-	-	-	-	-	-	4,410
1a	3,996	4,479	3,677	1,393	302	267	-	-	14,115
1b	3,911	3,940	4,072	1,376	132	188	-	-	13,620
1c	1,486	1,740	1,933	3,120	37	83	-	-	8,399
2a	3,784	3,861	3,967	1,727	728	18	-	-	14,086
2b	4,302	4,571	4,060	1,190	195	364	-	-	14,681
2c	3,559	2,549	2,301	2,001	126	242	-	-	10,778
3a	3,843	4,333	4,011	1,561	385	122	-	-	14,255
3b	4,453	4,843	4,090	1,032	465	319	-	-	15,201
3c	3,947	3,629	2,202	469	60	337	-	-	10,645
4c	-	-	-	-	-	-	74	-	74
5c	-	-	-	-	-	-	-	0	0
Mean	3,698	3,772	3,368	1,541	270	215	74	0	12,938
Standard Deviation	871	1,017	930	735	225	121	0	0	3,900
Standard Error (+/-)	290	339	310	245	75	40	0	0	1,300

* data collected in down-looking transducer configuration

Table 14. Count of fish >200mm using 5 pings (lower limits) in each zone across surveys.

Zone	1	2	3	4	5	6a	6b	9	Total
1a	1,547	1,218	1,229	292	107	39	-	-	4,432
1b	1,647	903	1,243	285	33	36	-	-	4,147
1c	282	336	431	541	13	36	-	-	1,639
2a	1,501	876	1,031	613	223	5	-	-	4,249
2b	1,360	922	965	368	40	36	-	-	3,691
2c	769	715	514	595	37	153	-	-	2,783
3a	1,678	1,072	1,277	268	79	43	-	-	4,417
3b	1,926	1,283	1,237	199	101	89	-	-	4,835
3c	956	1,054	561	110	18	129	-	-	2,828
4c	-	-	-	-	-	-	30	-	30
5c	-	-	-	-	-	-	-	0	0

Table 15. Fish densities / m^2 for fish >200mm using 5 pings (lower limit) in each zone across surveys.

Zone	1	2	3	4	5	6a	6b	9
1a	0.0056	0.0060	0.0058	0.0023	0.0009	0.0006	-	-
1b	0.0053	0.0051	0.0067	0.0023	0.0003	0.0006	-	-
1c	0.0018	0.0016	0.0029	0.0060	0.0001	0.0002	-	-
2a	0.0052	0.0055	0.0064	0.0033	0.0024	0.0001	-	-
2b	0.0059	0.0058	0.0065	0.0021	0.0004	0.0008	-	-
2c	0.0047	0.0034	0.0033	0.0043	0.0004	0.0009	-	-
3a	0.0056	0.0059	0.0063	0.0025	0.0010	0.0005	-	-
3b	0.0063	0.0068	0.0066	0.0019	0.0015	0.0010	-	-
3c	0.0053	0.0052	0.0036	0.0009	0.0002	0.0010	-	-
4c	-	-	-	-	-	-	0.0002	-
5c	-	-	-	-	-	-	-	0.0000

Table 16. Extrapolated total counts for fish >200mm using 5 pings (lower limit) in each zone across surveys.

Zone	1	2	3	4	5	6a	6b	9	Total
1a	2,420	2,460	1,900	805	169	155	-	-	7,910
1b	2,275	2,116	2,164	799	54	141	-	-	7,549
1c	779	678	940	2,066	25	60	-	-	4,548
2a	2,240	2,257	2,087	1,156	433	23	-	-	8,195
2b	2,523	2,412	2,103	715	79	187	-	-	8,019
2c	2,020	1,409	1,061	1,497	68	228	-	-	6,283
3a	2,430	2,455	2,064	868	181	119	-	-	8,117
3b	2,722	2,805	2,157	660	274	243	-	-	8,862
3c	2,286	2,139	1,154	302	37	246	-	-	6,164
4c	-	-	-	-	-	-	56	-	56
5c	-	-	-	-	-	-	-	0	0
Mean	2,188	2,081	1,737	985	147	156	56	0	7,350
Standard Deviation	564	650	522	523	135	79	0	0	2,473
Standard Error (+/-)	188	217	174	174	45	26	0	0	824

Table 17. Extrapolated fish counts for all size classes in each zone across surveys.

Survey	Size Class*						
	<50mm	50-100mm	100-200mm	200-400mm	400-800mm	>800mm	Total
Zone 1							
1a	413	2,323	7,032	2,759	1,118	119	13,764
1b	304	2,061	6,755	2,693	1,088	130	13,031
1c	246	903	2,144	652	685	149	4,780
2a	354	2,273	7,075	2,511	1,122	151	13,485
2b	319	2,165	7,299	2,923	1,213	165	14,084
2c	207	1,416	3,698	1,794	1,413	352	8,880
3a	980	3,616	8,102	2,672	1,063	109	16,541
3b	1,033	3,269	7,856	2,963	1,326	164	16,610
3c	729	2,489	6,142	2,424	1,310	213	13,308
Mean	509	2,279	6,234	2,377	1,149	172	10,408
Standard Deviation	320	830	2,001	734	212	74	6,134
Standard Error (+/-)	107	277	667	245	71	25	2045
Zone 2	<50mm	50-100mm	100-200mm	200-400mm	400-800mm	>800mm	Total
1a	127	832	3,993	2,446	1,783	250	9,431
1b	110	715	3,553	2,037	1,631	272	8,318
1c	83	325	1,228	883	704	153	3,376
2a	240	1,131	4,771	2,401	1,265	196	10,003
2b	152	835	4,281	2,674	1,646	251	9,838
2c	156	571	2,179	1,296	1,056	197	5,456
3a	763	2,068	6,752	2,778	1,418	137	13,916
3b	864	2,473	7,425	3,155	1,522	166	15,605
3c	369	1,269	4,230	2,188	1,301	140	9,498
Mean	318	1,135	4,268	2,207	1,370	196	7,767
Standard Deviation	294	708	1,955	720	335	51	5,098
Standard Error (+/-)	98	236	652	240	112	17	1,537
Zone 3	<50mm	50-100mm	100-200mm	200-400mm	400-800mm	>800mm	Total
1a	354	1,294	4,480	2,403	1,155	119	9,805
1b	277	1,196	4,532	2,586	1,348	139	10,077
1c	109	399	1,468	862	916	155	3,909

2a	87	731	3,578	2,101	1,648	219	8,363
2b	122	780	3,951	2,160	1,663	238	8,913
2c	72	392	2,039	1,205	896	200	804
3a	519	1,487	6,078	2,894	1,014	103	12,095
3b	530	1,585	6,733	2,928	1,057	105	12,938
3c	356	798	2,367	1,299	774	130	5,723
Mean	270	963	3,914	2,048	1,163	156	6,966
Standard Deviation	182	445	1,780	758	323	50	4,451
Standard Error (+/-)	61	148	593	253	108	17	1,342
Zone 4	<50mm	50-100mm	100-200mm	200-400mm	400-800mm	>800mm	Total
1a	152	742	2,071	932	414	47	4,358
1b	73	513	1,858	846	426	104	3,820
1c	195	374	1,634	1,310	1,516	294	5,323
2a	119	786	2,230	1,133	528	66	4,862
2b	64	309	1,246	690	445	54	2,809
2c	385	1052	2,026	1,223	674	103	5,463
3a	198	674	1,772	1,017	492	52	4,205
3b	90	514	1,500	743	255	33	3,135
3c	58	162	521	282	154	33	1,209
Mean	148	570	1,651	909	545	87	3,199
Standard Deviation	104	274	521	315	394	82	1,993
Standard Error (+/-)	35	91	174	105	131	27	601
Zone 5	<50mm	50-100mm	100-200mm	200-400mm	400-800mm	>800mm	Total
1a	16	74	188	142	135	25	581
1b	8	18	83	52	65	15	241
1c	19	56	77	19	13	4	189
2a	78	243	666	363	316	49	1,714
2b	20	77	224	106	77	12	516
2c	28	80	130	65	56	6	363
3a	66	174	380	222	149	14	1,006
3b	46	160	345	236	196	33	1,016
3c	79	105	93	21	29	10	337
Mean	40	110	243	136	115	18	542

Standard Deviation	28	70	194	117	96	14	519
Standard Error (+/-)	9	23	65	39	32	5	156
Zone 6a	**<50mm**	**50-100mm**	**100-200mm**	**200-400mm**	**400-800mm**	**>800mm**	**Total**
1a	36	68	144	96	151	20	514
1b	47	203	426	125	43	20	863
1c	46	99	88	22	46	15	317
2a	68	87	32	14	5	0	205
2b	52	156	239	218	125	21	810
2c	57	173	616	151	78	13	1,088
3a	44	116	442	86	33	3	724
3b	49	139	366	177	128	14	873
3c	105	274	495	204	116	17	1,212
Mean	56	146	316	121	81	14	601
Standard Deviation	20	65	200	74	51	7	422
Standard Error (+/-)	7	22	67	25	17	2	127

* Upper limit for fish >200mm re-analysed using 4 pings presented.

APPENDIX E – SUMMARY STATISTICS AND VARIANCE

Table 18. Summary statistics and variance calculated for each survey between the range upper (.4) and lower (.5) limits.

Survey	Total Fish	Average Length	Standard Deviation (Length)	Standard Error (Length)
1.5.a	6823	31	19.8	0.05
1.4.a	10662	33.2	18.5	0.04
Difference		2.2		
1.5.b	6823	30.9	19.4	0.05
1.4.b	10037	33.5	18.6	0.04
Difference		2.6		
1.5.c	2238	37.9	23.1	0.1
1.4.c	3652	43	21.5	0.08
Difference		5.1		
2.5.a	6721	31	20.1	0.05
2.4.a	11502	33.6	19.2	0.04
Difference		2.6		
2.5.b	5498	32	19.9	0.06
2.4.b	8824	34.5	19.1	0.05
Difference		2.5		
2.5.c	4202	33.2	21.9	0.07
2.4.c	5974	38.5	21.4	0.06
Difference		5.3		
3.5.a	8153	26.4	18.3	0.04
3.4.a	11502	29.8	16.9	0.04
Difference		3.4		
3.5.b	8834	26.5	18.5	0.04
3.4.b	12270	30.3	17.4	0.04
Difference		3.8		
3.5.c	4834	28.5	19.7	0.06
3.4.c	6544	34.15	19.3	0.05
Difference		5.65		

Average	32.7
1.5 Average	30.8
1.4 Average	34.5
Open Water Average	31.1
Edge Average	35.9
Upper Limit Total	17,671
Lower Limit Total	10,491

Member of the Surbana Jurong Group