



Impact Assessment Report – Supplementary
Information

Six Mile Creek Dam Safety Upgrade Project

Prepared for Seqwater
29 March 2019

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1 Introduction

1.1 Background

Six Mile Creek Dam requires an upgrade to meet modern safety standards and the performance requirements of the Queensland dam safety regulations into the future. This includes improving the spillway discharge capacity and earthquake stability while maintaining water supply security. Studies considered a range of options including decommissioning of the dam, retrofitting of strengthening works and new build options. Construction for the project will commence in August 2020.

An impact assessment report (IAR) has been prepared for the Six Mile Creek Dam (Lake Macdonald) Safety Upgrade Project (the project). The draft IAR was submitted to the Office of the Coordinator General for consideration on 29 January 2019.

Seqwater (the proponent) submitted an Initial Advice Statement to the Queensland Coordinator General on 15 September 2017 in accordance with the *State Development Public Works Organisation Act 1971* (section 27AB of SDPWO Act). On 22 December 2017, the Coordinator General declared the Project to be a 'coordinated project', for which an IAR is required, pursuant to section 26(1)(b) of SDPWO Act.

The project was referred to the Commonwealth Minister for the Environment and Energy on 18 October 2017 in accordance with the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) (Referral 2017/8078). It was listed as a 'controlled action' requiring approval under the EPBC Act and assessment by an IAR was required under the Bilateral Agreement with the Queensland Government.

1.2 Purpose

This supplementary information has been prepared in response to comments on the draft IAR which were received from the Office of the Coordinator General on 12 March 2019. This supplementary report should be read in conjunction with the IAR.

2 Responses to Comments

2.1 Draft IAR – General

COMMENT

Issue: *Project area and land parcel descriptions*

Agency: *Office of the Coordinator General*

Comment:

The lot on plan details for the project area have recently changed. The updated details are to be provided.

Response

Cadastral boundary realignment was triggered by transferring ownership of land, on which the Noosa Botanic Gardens is situated, to Noosa Shire Council. This process has been ongoing for some time and was recently signed-off and reflected in the State's cadastral database. As part of this process, Lot 118 MCH814 was reconfigured and a new Lots created on 14 March, 2019.

Despite the changes described above, the Project area has not changed. The Project area remains as shown in maps and figures presented in the draft IAR. All references in the draft IAR to Lot 118 MCH814 should be taken to mean Lot 118 SP305289.

COMMENT

Issue: *Water Resource Plans were changed to Water Plans several years ago under an amendment to the Water Act 2000.*

Agency: *Department of Natural Resources, Mine and Energy*

Comment:

Replace any reference to the 'Water Resource Plan (Mary Basin) 2006', with 'Water Plan (Mary Basin) 2006'.

Response

All references to Water Resource Plans or WRPs in the draft IAR should be taken to mean Water Plans or WPs. Any reference to the *Water Resource Plan (Mary Basin) 2006* in the draft IAR should be taken to mean *Water Plan (Mary Basin) 2006*.

CLARIFICATION

Issue: *Hours of operation*

Agency: *Office of the Coordinator General*

Comment:

There are inconsistencies between draft IAR chapters on the proposed standard hours of operation (6 am / 6.30 am / 7 am).

Response

Proposed project standard construction hours are 6:30 am to 6:30 pm on Monday to Friday and 6:30 am to 4:00 pm on Saturday. An inconsistency is noted in Chapter 2 - Project Description where Saturday work hours are described (2.4.7). The Saturday work hours should be taken as 6:30 am to 4:00 pm. Noise assessments in the draft IAR use the proposed project standard construction hours.

CLARIFICATION

Issue: Noise assessment and management

Agency: Office of the Coordinator General

Comment:

The outcomes of the air and noise assessments and the predicted impacts of noise are inconsistent with the draft EMP. For example, the performance criteria outlined in the draft EMP (Noise, B. 4.9) states:

“Noise from construction activities will aim to achieve the following at sensitive receptor locations:

- 7am to 10pm: 50 dBA LAeq, 1hr*
- 10pm to 7am: 35 dBA LAeq, 1hr*
- Sleep disturbance 10pm to 7am: 52 dBA L_{Amax}”.*

However, the noise assessment in Appendix K identifies that some construction activities (e.g. lake drawdown; sheet piling, etc) exceed these proposed values even with mitigation measures in place. This means that the activities are already in non-compliance before they start. It is not clear how the EPP (Noise) values will be achieved if the construction activities start before 7am. Proponent to confirm approach to compliance.

Response

The draft EMP remains correct – construction activities will aim to achieve the noise criteria. It should be noted that activities will vary in noise emissions within a work area, and so the modelled noise impacts are based on a worst case.

The noise assessment identifies that criteria for noise nuisance are likely to be exceeded by certain activities at the nearest sensitive receptors, around 5-10 residences. For these receptors, Seqwater is aware of the likely noise criteria exceedance and is currently working with individual residents to find solutions catering to their circumstances – such as double-glazed windows/air conditioning (to further mitigate noise at their location in addition to construction site mitigations, or alternatively options such as temporary relocation for periods of time).

Seqwater has recently commenced discussions with the nearest sensitive receptors and expect that the process will be ongoing through construction planning.

CLARIFICATION

Issue: Saddle dam

Agency: Department of Natural Resources, Mine and Energy

Comment:

Clarify the mechanics of the development i.e. the purpose of the saddle dam, where water flows now, where water will flow post development.

Response

The saddle dam is required to prevent uncontrolled discharge in an extreme flood, which would otherwise occur at the location of the saddle dam due to contours of the land. The saddle dam effectively forms an extension of the dam embankment.

Floods experienced since the dam’s construction have not reached the level at which these uncontrolled flows would occur. If the saddle dam were in place since construction of the current Six Mile Creek Dam, there would have been no change in where water flowed. It would only be in much greater flood events, should they occur in the lifetime of the dam, that the saddle dam would come into play.

It should be noted that design of the saddle dam has not yet been finalised, and where it is shown on maps in the draft IAR these should be taken as indicative.

CLARIFICATION

Issue: *Coffer dam and low flow channel*

Agency: *Department of Natural Resources, Mine and Energy*

Comment:

How will water be held back the coffer dam but still allowed to flow through the construction site; when will the bypass pump will be utilised?

Response

A coffer dam will be constructed using a metal sheet piles, driven through the upstream side of the existing dam embankment and down to rock for foundations support. The metal sheet piles can be installed with a variable crest height. Across the length of the sheet piles (following the alignment of the existing dam) the top or crest of the sheet piles will be stepped toward the centre so that water can be directed downstream in a controlled manner. The centre of the stepped sheet piles will form a low flow channel, where most lake outflows will overtop the sheet pile coffer dam and flow through a designated channel formed by flood barriers (or similar) and released downstream. The coffer dam setup will function much the same as a weir. The metal sheet piles can also be adjusted at any time by cutting/welding to move the low flow channel as construction progresses.

During construction, while the coffer dam is in place, bypass pumping (or siphoning) capacity will be in place to minimise very low flows (trickles) through the low flow channel. This may minimise the risk of water quality deterioration posed by water flowing in the vicinity of a construction site. The capacity of this bypass is expected to be in the order of 2 m³/s (depending on the arrangement proposed by contractors) and will cater only for low rates of inflow to the lake or to minimise the tailing hydrograph of a larger spilling event.

It is not feasible to prevent spilling events during construction, but the bypass arrangement is intended to address extended duration of spills that are currently experienced at Lake Macdonald.

CLARIFICATION

Issue: *Weed management*

Agency: *Noosa Shire Council*

Comment:

Hygrophila costata has been the subject of management at Lake MacDonald for many years, but has not been able to be completely eradicated. The dam lowering provides the perfect opportunity to seek complete eradication of this species.

Response

Throughout the Project, Seqwater Biosecurity and Field Rangers will continue to monitor and undertake pest management activities in and around Lake Macdonald in accordance with our operational management plans. The opportunities arising from the temporary lowering of the lake to allow further treatment and control of *hygrophilia costata* will be taken into account for planning of pest management activities during the two years of construction.

While the Seqwater Project team will work closely with operational staff to coordinate these activities, it is noted that appropriate pest management resources and funds are allocated from Seqwater's operational budget and cannot be brought into the scope of the Project capital budget.

CLARIFICATION

Issue: *Spillway design/fishway*

Agency: *Noosa Shire Council*

Comment:

With the design of a new spillway, there is opportunity to incorporate the latest scientific knowledge into the design to allow for fish passage that is currently limited.

Response

Fish passage is discussed in Chapter 7 of the draft IAR and further information is provided in the Appendix 3 and Appendix 4.

CLARIFICATION

Issue: *Historic contamination in catchment*

Agency: *Noosa Shire Council*

Comment:

The Lake MacDonald catchment has a long history of agricultural use. It would be ideal to undertake some testing of soils in the lake floor to check for any potential residues. Seq Water may be aware of persistent claims of contamination of the Noosa area by tetrachlorodibenzodioxin (TCDD) as a result of historical spraying with 2,4-D and 2,4,5-T throughout the region. Noosa Council would be keen to see some sampling for this undertaken and the results made available.

Response

As part of normal operation for drinking water supply, Seqwater does not undertake routine soil, sediment or bathymetric material monitoring. Seqwater employs use of passive samplers as the leading practice technology for very low-level detection of micropollutant chemicals in water. Through routine monitoring conducted at a six-monthly frequency (during the summer and the winter periods), Seqwater uses passive samplers that absorb, over a period of 28 days, chemicals present in the water body. This long absorption period allows the accumulation of around one hundred and fifty micropollutant chemicals from the water body to be quantified to the picogram per litre (pg/L) scale. This is an extremely sensitive method for determining micropollutant concentrations in water bodies. The detection and measured concentrations of micropollutants, climatic conditions and a qualitative understanding of current and previous permitted chemical products and application practices is used to assess risks to production of safe drinking water. TCDD is not directly monitored. However, since 2014 Seqwater's passive samplers routinely record ng/L to pg/L concentrations of prevalent herbicides and pesticides. In this time, passives samplers in Lake Macdonald have recorded 2,4-D twice, with a maximum recorded value <2 ng/L, and 2,4,5-T has never been recorded.

It is understood that the production of some herbicides up until the 1970s, particularly 2,4,5-T, had manufacturing/production contamination with TCDD. TCDD is a persistent organic pollutant and is listed as an IARC Group 1 carcinogen. Since the 1970s, these chemical production processes have been improved, resulting in orders of magnitude reductions in TCDD contamination. Additionally, circa 1980, 2,4,5-T and its derivative salts were removed from the market in Australia and remain not available for purchase or use.

Based on our understanding of the potential source of TCDD, analyses for 2,4-D and 2,4,5-T are suitable indicators, and are monitored for in the Lake Macdonald water body routinely. As per normal operation for Seqwater, water quality testing is undertaken in Lake Macdonald as part of allowing the storage to be used as a raw water source for water treatment. This will also be the case post-construction and going forward.

2.2 Chapter 2 Project Description

CLARIFICATION

Issue: *Commencement of lowering of Lake Macdonald*

Agency: *Noosa Shire Council*

Comment:

A lowering of the lake over 10-12 weeks, is appreciated to minimize impacts as much as possible. We note that the lake is due to be lowered in late autumn/winter and the reasons for this are listed among several species as mitigating impacts to avoid impact on breeding seasons in spring and early summer. What contingencies are in place should the lowering of the lake be delayed by several months? The most significant impact in this circumstance is potentially on the Giant Barred Frog and while the frogs themselves may be able to move away, their eggs will not, so a breeding season will be lost.

Response

Seqwater expects that a construction contractor will be engaged in late 2019 with construction planning already well advanced by that time. The Project commencement will intentionally delay lake lowering until the end of summer, so as to avoid the breeding seasons of key species, as discussed in the draft IAR.

The draft IAR notes that lake lowering will nominally occur around May to July 2020. This has since been rescheduled in light of the timeframe for engagement of a construction contractor. Seqwater has updated the Project schedule and will now bring forward to commence in March 2020, subject to weather and contractual matters. This amended start date remains in line with construction timelines in the draft IAR and will continue to avoid breeding seasons for MNES and platypus.

A March 2020 start for lake lowering will also occur in a relatively higher flow period in keeping with the natural flow regime (avoiding low flow periods) and providing a buffer of several months to the next breeding season window starting in spring.

CLARIFICATION

Issue: *Concrete batching plant and material change of use*

Agency: *Office of the Coordinator General*

Comment: Section 2.4.3

1. *Confirm that the stockpiles for stone aggregate, sand and cement powder are proposed to be located within the concrete batching plant area footprint (brown shading on Figure 2-8 of the IAR).*
2. *Is there an estimate on the footprint required for the batching plant and associated bins/silo?*
3. *Does the traffic assessment undertaken for the project include movement/delivery of raw materials for the concrete batching plant? Is there an estimate on frequency of deliveries?*
4. *It does not appear that the 120kVA silenced generator proposed for the batching plant has been considered in the Air and Noise assessments. Is this correct?*

Response

Responses to the above clarification requests are as follows:

1. Batch plant raw materials will be located within the concrete batching plant footprint (as indicated in draft IAR mapping). Raw materials constitute a large portion of the footprint.
1. Concrete batching plant footprint will depend on the mobile facility selected by a construction contractor. This is estimated to be between 50x50 m and 100x100 m.

2. The draft IAR traffic assessment does include delivery of raw materials for the temporary concrete batching plant, although the traffic assessment focussed on peak traffic periods and included a peak of expected construction vehicles, both personnel vehicles and heavy goods vehicles during those periods. The inclusion of heavy goods vehicles was not specifically related to the concrete batching plant, but for any heavy goods vehicles during peak periods. Estimates are available for concrete raw materials deliveries, but note that these are subject to change depending on the type of truck used, concrete batching plant selected, and target concrete production volume. These parameters are not yet set because the plant will be temporary and selected to meet a construction contractor's construction schedule and methodology. Assuming that concrete batching for the majority of concrete is undertaken over a four month period, the current estimate of raw material deliveries is three to four trucks per hour for that period. This assumption is based on Seqwater's construction planning, including independent quantity surveyor. Seqwater will be in a much better position to provide delivery frequency and scheduling information once a construction contractor is appointed in late 2019.
3. Concrete batching plant is included as 'equipment' in the Stage 2/spillway construction activities for both air and noise assessments. A representative silenced generator is included in the concrete batching plant equipment and is therefore incorporated in the noise assessment.

CLARIFICATION

Issue: *Clearing – Figure 2-8*

Agency: *Office of the Coordinator General*

Comment:

All clearing requirements must be shown on a figure for assessment of MSES and especially MNES. A table identifying all clearing of MNES / MSES would also be helpful. The draft IAR refers to figure 2-8; however there is no information where clearing will occur on this figure and which Regional Ecosystems this encompasses.

Response

A maximum extent of clearing map has been provided in Appendix 1 of this document. Discussion of the regional ecosystems affected by clearing is provided in the draft IAR (Chapter 8 page 8-33).

Within the maximum extent of clearing identified in the above map, the likely disturbance area of woody vegetation will be in the order of 3 ha, of which mapped regional ecosystems are a part.

2.3 Chapter 3 Regulatory Approvals and Planning

COMMENT

Issue: *Environmental authority for ERA 16 2a: Extractive and screening activities at threshold 2a*

Agency: *Department of Environment and Science*

Comment:

Recommended condition:

The Eligibility criteria and standard conditions for extracting material (ERA 16) – Version 2 must be completed and submitted to the Department of Environment and Science (DES) (Connect) for approval.

The proponent must comply with:

1. *the eligibility criteria of the Eligibility criteria and standard conditions for extracting material (ERA 16) – Version 2; and*
2. *the standard conditions of the Eligibility criteria and standard conditions for extracting material (ERA 16) – Version 2; and*
3. *extraction of less than 100,000 tonnes of material in a year.*

COMMENT

<https://environment.des.qld.gov.au/assets/documents/regulation/pres-extraction.pdf>

Response

Seqwater cannot meet the eligibility criteria for ERA 16 standard conditions due to the Project's location in proximity to a water body and a dwelling. Seqwater will be required to submit a 'site specific application'. Despite a standard application/conditions not being applicable, the proposed extraction is a relatively low risk excavation activity, managed through controls outlined in the draft Environmental Management Plan (IAR Appendix B).

Seqwater will complete and submit the 'Site specific application form' before the Project commences.

COMMENT

Issue: *Clearing of koala habitat*

Agency: *Department of Environment and Science*

Comment:

Koala habitat clearing must conform to the Nature Conservation (Koala) Conservation Plan 2017.

Clearing requirements must include sequential clearing, having a koala spotter in attendance and limits on the area of habitat that can be cleared at any one time.

Information on koala legislation and policy, including offsets for State Government supported infrastructure projects are available at:

https://environment.des.qld.gov.au/wildlife/koalas/legislation/#offsets_for_state_government_supported

Response

All clearing will conform to the *Nature Conservation (Koala) Conservation Plan 2017*. The Project Environmental Management Plan (IAR Appendix B), Species Management Plan (IAR Appendix E) and Chapter 8 (Terrestrial Ecology) of the IAR identify the requirement to have a qualified fauna spotter catcher on site during clearing.

COMMENT

Issue: *Page 3-4 Section: Vegetation Management Act 1999*

The applicant has stated that the clearing associated with the development is necessary for the maintenance and safety of the dam, the clearing therefore would be considered exempt clearing work under Schedule 21, Part 2 Item 2 (c) of the Planning Regulation 2017 - Clearing that is necessary for essential management.

This exemption only applies on freehold land. Should the works require clearing in the adjacent road reserve (Collwood road), the applicant would need to apply for operational works approval, and prior to applying for the operational works approval, obtain a relevant purpose determination (s22 determination).

If there is clearing outside of the exemption stated above, dependent on final design and layout, a significant residual impact may occur to Of Concern RE 12.9-10.1 or an Essential Habitat species. The applicant would need to provide further justification as to why they consider the impact will not be a significant residual impact.

If the 'Clay Borrow Area' requires any clearing of the surrounding remnant vegetation the applicant would need to apply for approval and prior to applying for the approval, obtain a relevant purpose determination (s22 determination).

Agency: *Department of Natural Resources, Mine and Energy*

Response

Clearing is not proposed to occur in the adjacent road reserve (Collwood Road). Clearing of remnant vegetation in the clay borrow area is also not proposed. If vegetation clearing requirements for the Project change, reassessment of relevant approvals will be undertaken.

COMMENT

Issue: Section: *Land Act 1994 page 3-9, Section 3.4 Land use and tenure page 3-11 and Table 3-1: Required regulatory approvals page 3-15*

The IAR identifies applications for temporary road closures and/or permit to occupies, may be required for the project.

Until the proponent has the necessary information i.e. finalised plans, and engages with DNRME State Land Asset Management, the most appropriate tenure to resolve the land dealings is unknown. DNRME advises that where appropriate, permanent land dealings i.e. permanent road closures, would be supported over temporary ones.

Agency: *Department of Natural Resources, Mine and Energy*

Response

Temporary road closures, or other requirements, to facilitate construction and access will be determined and applied for once a contractor is appointed and plans are finalised.

Land tenure for permanent development in road reserve will be discussed with the administering authority. Seqwater notes that the *Water Supply (Safety and Reliability) Act 2008* confers authorisations to carry out activities that may apply in this case.

CLARIFICATION

Issue: *Figure 3-1*

Agency: *Office of the Coordinator General*

Comment:

The draft EMP must clearly show a map outlining the extent of clearing proposed for the borrow pit as it is directly surrounded by MSES vegetation. Unintentional clearing is a possibility (and may incur offset requirements). The map provided in Figure 3-1 is not sufficient. A map must show the extent of the borrow pit, the extent of proposed clearing, access roads and demarcation of areas not to be cleared.

Response

A map illustrating the maximum clearing extent has been provided in Appendix 1. An updated version of Figure 3-1 has also been provided in Appendix 1.

Note also that the GPS coordinates for the borrow pit, provided in the draft IAR (Table 3-3), will be confirmed in the construction planning phase and any optimisation will be reflected in updated GPS coordinates for maximum borrow area extent that are stated in the in the Environmental Authority approval conditions (ERA 16). Optimisation is expected to be of a scale that has no additional environmental impact.

CLARIFICATION

Issue: *Koala offsets*

Agency: *Office of the Coordinator General*

CLARIFICATION

Comment: Chapter 3 and Appendix M of the IAR

IAR identifies koala offsets for EA for ERA 16(2)(a). This is most likely an error and may relate to the other impacts. However, clarification is required.

Response

Reference to koala habitat under offsets section of Environmental Authority is incorrect. Any reference in the draft IAR to koala habitat offsets should be disregarded as there is no legislative requirement for these offsets. Seqwater may choose to offset koala habitat based on internal policies, though this is not relevant to the coordinated project process.

It is also noted that Seqwater does not anticipate a significant impact on koala for EPBC Act (MNES) purposes.

2.4 Chapter 5 Matters of National Environmental Significance

COMMENT

Issue: *Clearing permit - protected plants*

Agency: *Department of Environment and Science*

Comment:

A targeted protected plants survey in accordance with the Flora Survey Guidelines – Protected Plants (DEHP 2016) is required to be undertaken.

If protected plants are identified within the areas to be cleared, a Clearing Permit (Protected Plants) application must be submitted. If no protected plants are present an Exempt Clearing Notification must be submitted to DES.

<https://environment.des.qld.gov.au/connect/>

Response

A targeted protected plants survey will be undertaken once a contractor is appointed and site plans are finalised. If protected plants are identified, a Clearing Permit (Protected Plants) application will be submitted. If no protected plants are present, an Exempt Clearing Notification will be submitted in accordance with required timeframes.

COMMENT

Issue: *Permit to tamper with animal breeding places – SMP – High Risk Impact – All protected wildlife*

Agency: *Department of Environment and Science*

Comment:

A Species Management Program (SMP) for tampering with animal breeding places (high risk of impacts) must be completed and submitted to DES (Connect) for approval.

This covers species listed as endangered, vulnerable, near threatened, colonial breeding or special least concern that are identified as likely to be impacted by the proposed project.

Note: this SMP would also be approved to apply to least concern animals

- This would capture the four species of least concern freshwater turtles identified in the project area that would likely make-up the majority of turtles that require salvaging.

COMMENT

The SMP assessment requires three key elements: Appendix 1: map or plan of the proposed impact area; Appendix 2: animal breeding place survey report; Appendix 3: impact management plan. The SMP must be prepared generally in accordance with:

- *Appendix E – Species Management Plans; and*
- *Chapter 3 – Regulatory Approvals and Planning – Table 3-5.*

The SMP must detail how the population and habitat of the following threatened species would be effectively managed during the construction and operation stages of the proposed project:

- *White-throated snapping turtle (Elseya albagula)*
- *Mary River turtle (Elusor macrurus)*
- *Giant barred frog (Mixophyes iteratus)*
- *Platypus (Ornithorhynchus anatinus)*
- *Tusked frog (Adelotus brevis)*
- *Richmond birdwing (Ornithoptera richmondia)*

Note: There are four conditions of approval listed in section 3 of the SMP.

<https://environment.des.qld.gov.au/licences-permits/plantsanimals/species-management-program/>

Response

Two draft Species Management Programs (SMP) have been prepared for the project and provided in IAR Appendix E. The first SMP is for species that are Matters of National Environmental Significance, while the second SMP is for species listed under the *Nature Conservation Act 1992*. The SMPs have been prepared in accordance with *Species Management Program (SMP) for tampering with animal breeding places (high risk of impacts)* and will be submitted for approval before works begin.

COMMENT

Issue: *Additional mitigation measures required for platypus in E2.4 Mitigation management of Appendix E – Species Management Plans*

Agency: *Department of Environment and Science*

Comment:

Section E2.4 Mitigation Assessment Platypus:

Recommendations:

Amend to include:

Freshwater habitat loss: include in design project phase:

- *Plan a drawdown program outside of platypus breeding season (August to November)*

Freshwater habitat loss: include in pre-construction project phase:

- *Prior to clearing/inundation of vegetation undertake preclearance surveys in the impact area to identify the presence of platypus.*
- *Pre-clearance surveys must:*
 - *be undertaken in accordance with a survey methodology agreed by DES prior to surveys being undertaken*
 - *be undertaken by a suitably qualified person/s*

COMMENT

- identify measures to prevent mortality of platypus.

Freshwater habitat loss: include in construction project phase:

- *Maintain refugial pools for platypus within the home range in the Lake Macdonald footprint and monitor water quality, macroinvertebrate density and diversity and triggers for remedial actions. Implement suitable triggers for action and undertake effective remedial measures, as required.*

Fauna fatalities and encounters: include in pre-construction project phase (site induction):

- *Platypus burrows can be identified as a neat hole with or without track marks up to the entrance, well concealed by riparian vegetation, up to and including 25cm in size, in the banks of a freshwater way with overhanging vegetation.*

- *Platypus are likely to move over land to areas where water will persist for the duration of the proposed project. This substantially increases the risk of predation or injury/death.*

Fauna fatalities and encounters: include in construction project phase:

- *Hoop-traps should be used with an attached holding pen accessed via a one-way entrance. These traps can be set with the top of the holding pen above water (so trapped turtles or platypus can breathe).*

- *Regularly monitor the use of weighted gill nets and fyke nets (eel nets) set below water level (targeting fish and turtles). These nets may pose a risk of drowning the air-breathing platypus which may be unable to rapidly reach the water surface and/or are not released shortly after capture.*

- *A comprehensive salvage operation is likely to be required for platypus. However, the success of relocating platypus (a territorial species) to other freshwater systems is largely unknown. A comprehensive survey and assessment of the existing platypus population in the proposed relocation area would be required to determine if habitat requirements are adequate and occupancy is available.*

Response

Before submission for approval by the Department of Environment and Science, the SMPs will be updated to include the recommended information listed above. However, some points will need to be clarified before updating, specifically:

- what is intended by 'clearing/inundation of vegetation'
- the intent of macroinvertebrate monitoring, given macroinvertebrate diversity and abundance can be highly variable both spatially and temporally.

In addition, it is noted that gill nets will not be used for the project.

COMMENT

Issue: *Animal breeding place register (excel document on website: details all animal breeding places tampered with and the location of relocated animal breeding places). Covers salvage operations.*

Agency: *Department of Environment and Science*

Comment:

Registered entities with a SMP will be required to maintain an Animal Breeding Place register concerning tampering with animal breeding places. The Animal Breeding Place register must include the details of the action undertaken, authorised under the SMP, and is to be submitted to wildlife@des.qld.gov.au

Response

An animal breeding register will be maintained for the Project in accordance with the SMP requirements.

COMMENT

Issue: *Damage mitigation permit*

Agency: *Department of Environment and Science*

Comment:

An application form for a damage mitigation permit (removal and relocation of protected animals) must be completed and submitted to DES (Connect) for approval.

This will be required for aquatic and terrestrial fauna subject to loss of habitat and salvage such as freshwater turtles, threatened frogs, koala and platypus.

https://environment.des.qld.gov.au/licences-permits/plantsanimals/native_animal_management.html

Response

It is noted that advice provided by the Permit and Licence Management section of the Department of Environment and Science on 17 July, 2018 indicated that a Damage Mitigation Permit was not suitable for the fauna salvage operation and therefore it was not included in the likely permits associated with the lake lowering adaptive management plan (IAR Appendix C).

If a damage mitigation permit is confirmed as a requirement, this will be provided by the specialists who are employed to lead/supervise the aquatic fauna salvage and relocation. This would be similar to permits required for spotter/catchers used for terrestrial clearing. As permits under the NC Act are not coordinated under the SDPWO Act, these have not been included in Chapter 3 of the draft IAR.

COMMENT

Issue: *Downstream impacts*

Agency: *Department of the Environment and Energy*

Comment:

- *Further consideration of the potential impacts of water releases under the range of known potential scenarios is needed to allow a full evaluation of potential impacts, propose appropriate management measures, and consider the likely effectiveness of proposed monitoring, setting of monitoring thresholds and management or corrective measures where thresholds are exceeded:*
 - *Under a 12 week lowering scenario the potential impacts of a sustained release on MNES have not been sufficiently considered. Further analysis should be provided about what potential impacts may result from a sustained 12 week release. This analysis could be based on historical data on water and habitat quality impacts associated with shorter term flooding events, used to assess the potential impacts of a sustained release. This could reasonably include consideration of the impacts on key habitat attributes over the 3 month duration - such as pool and bank structure, scour, changes to in-stream habitat attributes (e.g. logs, weeds, sediment), and impacts on water quality from sustained reductions to dissolved oxygen, increased turbidity, temperature changes etc.*
 - *The documentation and subsequent discussions with the proponent (meeting of 22 February) acknowledge that where there is significant rainfall during the drawdown period, it may be necessary to release a much higher volume of water over a much shorter period than has been considered in the assessment documentation (potentially the equivalent amount of water released over the 12 week period in approximately 10 days). This scenario has not been evaluated in the documentation, so the full range of potential impacts on MNES has not been considered. As for the 12 week scenario above, historical data from this river system (or other similar river systems) could be used to support an informed consideration of potential impacts under this scenario.*
- *A suitable range of mitigation, management and monitoring measures is needed, together with an assessment of how these measures would avoid or minimise adverse impacts on MNES under these scenarios.*

COMMENT

- *Further consideration of potential residual impacts is needed. If the assessment identifies any residual impacts are likely after mitigation measures are implemented, appropriate corrective actions or offsets would be required.*
- *The information provided does not clearly outline how downstream environmental flows will be maintained during the construction phase once the dam level has been lowered.*

Response

Additional assessment of potential downstream impacts is provided in Appendix 2.

Regarding downstream environmental flows – once completed, the flow regime of Six Mile Creek Dam will be unchanged in comparison with the existing situation. During construction, the flow regime is likely to be slightly improved, compared with the existing situation, because the lowered lake will have less buffering capacity due to lower volume and lack of water extraction for water treatment. As such, during the construction phase, catchment inflows will be passed downstream through the construction coffer dam and low flow channel in a more natural fashion that exists with the dam in place.

COMMENT

Issue: Dam construction

Agency: Department of the Environment and Energy

Comment:

- *Chapters 5 and 7 of the IAR should include an explanation (or at a minimum reference relevant sections) detailing how the labyrinth spillway design aims to prevent fish fatalities with particular reference to MNES.*
- *The documentation should also evaluate impacts of the labyrinth spillway design on MNES over time, comparing these impacts with those of any feasible potential alternative designs (or if there are none explain why there are no alternatives).*

Response

It should be noted that since submission of the draft IAR, Seqwater has reviewed and endorsed a design change for the spillway. Information regarding the background and outcome of this design change as well as potential impacts of the spillway design for aquatic fauna (including MNES) is provided in Appendix 3, which updates IAR Appendix O. Chapter 7 of the draft IAR refers to IAR Appendix O for discussion around safe fish passage over the spillway.

In addition, responses to the Queensland State Code 18 (Constructing or raising waterway barrier works in fish habitats) have been updated to reflect the spillway design change. This is provided in Appendix 4. Of particular relevance to these comments are responses to PO5, PO6 and PO8.

COMMENT

Issue: Translocation

Agency: Department of the Environment and Energy

Comment:

Have alternatives to translocation of fish from the dam lowering in Lake Macdonald been considered? If so the reasoning to support translocation should be included.

Response

Seqwater has demonstrated the need to lower Lake Macdonald to undertake the upgrade works in safe conditions, and also the need for the dam safety upgrade itself (draft IAR sections 2.1.2 and 2.1.3 in Chapter 2 Project

Description). Lake bathymetry for the target safe construction lake level indicated that the remaining habitat would be greatly reduced (refer to Appendix 5). In particular, the bathymetry showed that the remaining pools would generally be shallow, despite the apparent surface area covered, and more likely to be affected by impaired water quality. As such, a workshop was held to discuss the lowering of Lake Macdonald.

The workshop focused on the need to lower the lake, the potential impacts to aquatic flora and fauna (including MNES), and suitable mitigation and management measures. Attendees included aquatic ecologists (Dr Ben Cook – frc environmental, Andrew Berghuis – Aquatic Biopassage, Dr David Roberts – Seqwater), a representative from the Mary River Catchment Coordinating Committee (responsible for the Mary River cod hatchery), and representatives from Seqwater (senior dam engineer, senior field ranger – Lake Macdonald, principal environmental manager, and the project team). The workshop:

- confirmed there were no safe viable alternatives to the lake lowering
- identified that conditions in the water remaining in Lake Macdonald would be substantially impaired and largely unsuitable for aquatic fauna – it was noted that conditions would be particularly unsuitable for MNES species that prefer water deeper than 3 m as areas of this depth would be reduced to approximately 0.4 ha if the water level was equivalent to 89 m AHD
- found that the options to improve conditions in the remaining water were limited, with aeration through use of the destratification unit or other machinery and, as a last resort, dilution with water from the Mary pipeline the only feasible active controls available
- identified that fauna crowding, reduced resources (i.e. food), and increased predation may be a concern in the remaining water
- noted that there were few examples of a dam lowering of this scale previously occurring in Australia (the only comparable example identified was Kangaroo Creek Dam in South Australia, which is mainly occupied by exotic species, particularly carp).

It was therefore agreed by all attendees that a fauna salvage and relocation program would be necessary as an additional mitigation measure:

- as the potential for active management of conditions in the remaining water in Lake Macdonald was limited
- to ensure MNES species had access to suitable habitat to facilitate their survival
- to minimise potential crowding of fauna and associated issues.

Relocation is a common strategy for situations where habitat is disrupted and is successfully undertaken with many fish and turtle species. This typically occurs on a smaller scale than Lake Macdonald, and consequently Seqwater acknowledged the need to undertake further assessment of potential relocation sites, involve experts and suitably qualified persons, and develop a comprehensive adaptive management plan for the lake lowering (IAR Appendix C).

COMMENT

Issue: *General*

Agency: *Department of the Environment and Energy*

Comment:

- *The extent of impact to Koala and the Grey-headed Flying-Fox habitat remains unclear.*
- *Where available, referring to previous environmental studies/reports would help to substantiate claims, such as the claim that there is no Australian Lungfish breeding habitat downstream of the Dam.*
- *Reference to comparable projects where similar impacts have been effectively managed would support conclusions around potential impacts and demonstrate the effectiveness of proposed monitoring and management measures.*

Response

The maximum extent of impact to potential koala and grey-headed is the same as the maximum extent of vegetation clearing as shown in Appendix 1.

Reference to previous environmental studies and reports has been included where appropriate (primarily within the technical reports). The assessment of the occurrence Australian lungfish breeding habitat in Six Mile Creek was completed by Dr Ben Cook, a freshwater ecologist with 20 years of experience. It was based on seasonal field surveys completed in 2015 and consultation with key experts in 2015/2016, including from the Department of Natural Resources, Mines and Energy, after the publication of much of the literature relevant to Six Mile Creek. As such, Dr Cook is confident that Six Mile Creek does not provide breeding habitat for Australian lungfish. Information on consultation with key experts and field surveys is included in the IAR (Chapter 5, Chapter 7 and IAR Appendix G).

There are no known comparable projects with similar impacts that have been undertaken in Australia. The only identified project of a similar scale and potential impact was for Kangaroo Creek Dam on the Torrens River in South Australia. This dam has a capacity of 19 GL and was lowered to 1% of capacity. However, there are no aquatic MNES species in the dam, and the fauna salvage was undertaken by a commercial carp fisherman, with 99% of the fish collected being carp, with some redfin and one native catfish (pers. comm. E. von Wielligh, SA Water, 2018). Turtles and yabbies were not salvaged from Kangaroo Creek Dam and no impact on these fauna was recorded.

COMMENT

Issue: *Management plans*

Agency: *Department of the Environment and Energy*

Comment:

- *Appropriate threshold trigger values and corrective actions, relevant to each MNES, will be required to protect MNES.*
 - This information is necessary to inform monitoring triggers, threshold impact limits for key habitat and water quality attributes, and what responses would be initiated where an exceedance is detected. For example, is shutting down the release of water for a specified time an effective option to control water quality?
- *Development and implementation of mitigation measures during spillway construction to manage contingencies such as floods or a deterioration in water quality. This relates to dam water level lowering and coffer dam discharges used to maintain dam water levels at 89 m AHD.*
- *Further information will be required demonstrating why the method of translocation proposed for each species is the most suitable.*
- *Further information will be required demonstrating the suitability for the final selection of translocation sites by species, for both temporary holding and for permanent relocation.*

Response

Trigger thresholds (performance criteria), management measures and corrective actions for water quality, erosion and sediment, aquatic flora and fauna, and biosecurity for the dam water level lowering are identified in the lake lowering plan (IAR Appendix C). These include the active lowering period and the period during which lower water levels are maintained (i.e. will be in place during all project phases). The plan is designed to be adaptive and will be updated to incorporate triggers and thresholds for

- aquatic fauna salvage as the program is developed
- aquatic habitat based on the addition of a habitat monitoring program in Six Mile Creek.

Trigger thresholds (performance criteria), management measures and corrective actions for project matters not specific to the lake lowering are identified in the environmental management plan (IAR Appendix B). The trigger thresholds are based on existing guidelines (e.g. the Mary Water Plan), where available, that are designed to protect aquatic ecosystems.

Corrective actions are not prescriptive, because the specific conditions and their implications for aquatic fauna are intended to be assessed on a case by case basis. Suggested actions are noted in the relevant section (incidental fauna salvage, reduced rate of release during lowering, or increasing of aeration) and further indicative actions are provided in the Incident and Contingency planning section of the lake lowering plan (C.8.3.2).

Further information on translocation methods and sites will be incorporated into the lake lowering plan and provided before the project begins. This information will be based on the outcomes of investigations undertaken to identify suitable relocation sites, as the methods used may be dependent on the relation destination (i.e. size of truck, holding time etc.).

COMMENT

Issue: *Koala assessment*

Agency: *Office of the Coordinator General, Department of Environment and Energy, Department of Environment and Science*

Comment: *Table 5-13 – Koala habitat assessment tool:*

It is unclear how the koala occurrence score was “0” (zero), stating no evidence of koalas within 2km of the edge of impact area when only the Atlas of Living Australia and Species Profile Search was conducted.

WildNet and the database from Noosa Shire Council should have been consulted. For example, WildNet contains several koala records in the general area.

Without information where the clearing will take place, what the clearing will include (i.e. new tracks of land; widening existing infrastructure, REs, etc.); and the proposed footprint of clearing (1.25 or 1.45 ha), the evaluation of the IAR impact assessment is not possible.

Response

The assessment of koala occurrence was based on desktop and field assessment by suitably qualified persons.

Section 5.4.2 Terrestrial Ecology and Section 8.3.2 (page 8-27, Fauna Species) indicate that the DES Wildlife Online database (which sources data from WildNet) was used in the assessment of fauna and their likelihood of occurrence in addition to a survey of the site. Note that the project team has not been able to locate a publicly available database from Noosa Shire Council.

Nevertheless, records contained in BioMaps (which draws data from the WildNet) were double-checked. This check identified one 2015 record of a koala 1 km downstream of Lake Macdonald. The koala assessment tool table was therefore updated; however, this did not result in a change in the overall assessment of impacts to koala.

The updated koala assessment tool table has been provided in Appendix 6.

2.5 Chapter 6 Water Resources

COMMENT

Issue: *page 6-17, Section: Existing water users*

There are no water allocations in Six Mile Creek.

There is no acknowledgement of land holder riparian rights to Six Mile Creek

No information has been supplied explaining the impacts of dam construction on water entitlements and the proposed mitigation measures.

Agency: *Department of Natural Resources, Mine and Energy*

Comment:

Delete reference to ‘water allocations’, replace with ‘water licences’.

This section only identifies the licenced water users. Under the Water Act 2000, any land owner riparian to Six Mile Creek can take water, without a water licence, for stock and domestic purposes. It is likely that there are persons

COMMENT

taking stock and domestic water from the watercourse downstream of the dam. It is suggested that this needs to be noted.

The text states that the entitlements may be affected by the dam construction works. It is suggested that the section include text explaining what those impacts may be, and how they may be mitigated.

Response

All references to water allocations in the draft IAR should be read as water licences. It is also acknowledged that other persons may take stock and domestic water from the watercourse downstream of the dam, which is authorised under section 96 the *Water Act 2000*.

The draft IAR (Chapter 6, page 6-17) does note that downstream entitlements could be impacted by the Project, generally because persons authorised to take water are located downstream of Six Mile Creek Dam. Further context on the potential for impacts is provided in the Six Mile Creek Dam – existing operation section in the draft IAR (Chapter 6, page 6-18), which states that the dam is ungated and Seqwater does not release water for downstream water users. This will continue to be the case during construction and with the new dam in place. The flow regime from Six Mile Creek Dam is likely to be slightly improved during the construction phase, as the lowered lake will have less buffering capacity due to lower volume and lack of water extraction for water treatment. The flow regime from the upgraded Six Mile Creek Dam will be the same as the existing situation once the lake has refilled following completion of construction.

This potential impact is closed out in the draft IAR (Chapter 6, Table 6-16 – Residual Impact Assessment, Water availability for water licence holders).

COMMENT

Issue: page 6-18, Table 6-6

The bottom of the table lists a licence for the Mary River (Figure Ref. No – 26). This relates to a water licence for a low rock weir held by Gympie Regional Council. The weir no longer impounds water, and is not relevant to the project. In addition, it is unlikely that any Mary River entitlements would be affected by the proposed dam upgrade works.

Agency: Department of Natural Resources, Mine and Energy

Comment:

References to the Mary River in Table 6-6 should be deleted.

Response

References to the Mary River in Table 6-6 of the IAR should be taken as not relevant to the Project.

COMMENT

Issue: page 6-20, Table 6-7 Expiry Date

The expiry date of nearly all water licences in Queensland is 30 June 2111. This occurred following an amendment to the Water Act 2000.

Agency: Department of Natural Resources, Mine and Energy

Comment:

Change the expiry date for water licence to 30 June 2111

Response

The expiry date of the water licence referred to in Table 6-7 of the IAR should be read as 30 June 2111.

To address any confusion, Seqwater notes that publicly available information for the Mary Basin water plan area (<https://www.business.qld.gov.au/industries/mining-energy-water/water/catchments-planning/water-plan-areas/mary-basin>) references the Mary Basin Resource Operations Plan (ROP), which names the licence expiry as per the information in the draft IAR. Where a reader accesses the public information, the reader should note that the Mary Basin ROP does not contain up to date information.

COMMENT

Issue: page 6-20 and page 6-21, Section: Six Mile Creek Dam – Licenses and Conditions

Text in paragraph at bottom of page 6-20 and top of page 6-21 states that the SEQ Water grid manager holds the 3495ML licence to take water from the dam. This is incorrect – the Queensland Bulk Water Supply Authority currently holds all the licences associated with Lake MacDonald.

Agency: Department of Natural Resources, Mine and Energy

Comment:

Text should be amended to show the Queensland Bulk Water Supply Authority currently holds all the licences associated with Lake MacDonald.

Response

All references to South East Queensland Water Grid Manager in relation to licences should be read as the Queensland Bulk Water Supply Authority.

To address any confusion, Seqwater notes that publicly available information for the Mary Basin water plan area (<https://www.business.qld.gov.au/industries/mining-energy-water/water/catchments-planning/water-plan-areas/mary-basin>) references the Mary Basin Resource Operations Plan (ROP), which names the licensee as per the information in the draft IAR. Where a reader accesses the public information, the reader should note that the Mary Basin ROP does not contain up to date information.

COMMENT

Issue: page 6-60 – 1st and 2nd paragraphs of Section: Reduction of environmental flows.

Incorrect reference is made to Mary Basin ROP

Agency: Department of Natural Resources, Mine and Energy

Comment:

Delete references to Mary Basin ROP, replace with ‘in accordance with the environmental release requirements of the water licence for Lake MacDonald’.

Response

All references to the Mary Basin ROP in the draft IAR should be read as, in accordance with the environmental release requirements of the water licence for Six Mile Creek Dam.

To address any confusion, Seqwater notes that publicly available information for the Mary Basin water plan area (<https://www.business.qld.gov.au/industries/mining-energy-water/water/catchments-planning/water-plan-areas/mary-basin>) references the Mary Basin Resource Operations Plan (ROP). The Mary Basin ROP will be superseded under the new water planning framework.

COMMENT

Issue: page 6-63, Section: 6.5.1, Surface Water Hydrology

Incorrect terminology is used in this section

Agency: Department of Natural Resources, Mine and Energy

Comment:

Amend text to delete the words 'licenced water users' and substitute with 'persons authorised to take water from Six Mile Creek'.

Response

All references to licenced water users in the IAR should be read as persons authorised to take water from Six Mile Creek.

CLARIFICATION

Issue: Groundwater impact

Agency: Noosa Shire Council

Comment:

It is unclear how groundwater will be impacted during the drawdown period. If there is insufficient recharge from rainfall during the drawdown, vegetation such as in the Botanic Gardens, could be impacted from changes to hydrology.

Response

A groundwater assessment is presented in the draft IAR Water Resources Chapter (6.4) and associated technical report (IAR Appendix F).

The potential impacts discussion states that the potential risk of groundwater drawdown to groundwater users, including groundwater dependent ecosystems, is negligible.

With respect to the Noosa Botanic Gardens, the groundwater assessment is relevant for that location also. The site is located on a steep bank of Lake Macdonald, with most of the site situated between 5 and 15 m above Full Supply Level. Some parts of the site may be impacted by temporary lowering of the lake level, however the site is actively managed, such that additional watering could be implemented by curators as required.

CLARIFICATION

Issue: Water quality relating to decomposition of aquatic vegetation

Agency: Noosa Shire Council

Comment:

It is unclear how groundwater will be impacted during the drawdown period. If there is insufficient recharge from rainfall during the drawdown, vegetation such as in the Botanic Gardens, could be impacted from changes to hydrology.

Response

Water quality in relation to the lake drawdown is discussed in the draft IAR (IAR Appendix C).

2.6 Chapter 7 Aquatic Ecology

COMMENT

Issue: Section 7.5 Impact Mitigation and Management, Fish Passage page 7-30 and Table 7-10 Mitigation and management measures proposed to manage aquatic ecological impacts, Fish Passage Page 7-43

It is proposed that an aquatic passage structure be constructed on top of the existing Gympie gauging weir. The future of this weir is uncertain as new stream flow monitoring technology—that doesn't require the need for a control weir—is being considered separate to this dam safety project. If adopted, this new stream flow monitoring technology would be a more cost effective and better outcome for bio passage than a mechanical fishway retrofitted to the existing Gympie gauging weir. There are also stream bank erosion risks from changes in streamflow associated with building a fishway at the Gympie gauging weir.

Agency: Department of Natural Resources, Mine and Energy

Comment:

Where the IAR refers to building fish passage devices, it is recommended that this be amended to ensure that the proponent reviews all future options relating to aquatic passage within the catchment and the impacts on stream stability.

Response

Seqwater acknowledges advice from DNRME and has committed to review of options for Gympie gauging weir. This commitment is discussed in response to the State Development Assessment Provisions (State Code 18 – Constructing or raising waterway barrier works in fish habitats). This information has been updated and is provided in Appendix 4. Of particular relevance to this comment is the response to Performance Outcome 5.

With regard to the future of the weir being uncertain, Seqwater notes that the gauging weir is a Seqwater asset, which provides Seqwater with an accurate monitoring point of flows through the Mary Valley Water Supply Scheme (operated by Seqwater under provisions of the *Water Act 2000*). It is currently an essential asset for operation of the Mary Valley Water Supply Scheme.

COMMENT

Issue: Review of all IAR chapters and appendices against SDAP State Code 18 – Constructing or raising waterway barrier works in fish habitats

Agency: Department of Agriculture and Fisheries

Comment:

Proponent to provide

Response

Detailed responses to SDAP State Code 18 are provided in Appendix 4.

COMMENT

Issue: Fish Passage

Agency: Department of Agriculture and Fisheries, Department of the Environment and Energy, Office of the Coordinator General

Comment: pg 7-28

COMMENT

This section states impacts from the upgraded dam are not expected to differ from existing impacts, however Appendix O states that the labyrinth spillway design and its vertical drop will cause fish injury. The IAR fails to demonstrate how the design of the labyrinth spillway provides for safe downstream fish passage (maintains the health of fisheries resources). The IAR fails to demonstrate that it can meet the State Code 18 Performance Outcomes or Purpose Statement.

Response

Detailed responses to SDAP State Code 18 are provided in Appendix 4.

It should be noted that since submission of the draft IAR, Seqwater has reviewed and endorsed a design change for the proposed spillway. Information regarding the background and outcome of this design change as well as potential impacts on safe downstream fish passage is provided in Appendix 3, which updates IAR Appendix O of the draft IAR.

Where the draft IAR refers to a labyrinth spillway design, this should be read in the context of a subsequent design update, as outlined in Appendix 3. This spillway design update has been incorporated into the SDAP State Code 18 responses in relation to safe downstream fish passage.

CLARIFICATION

Issue: Lake lowering

Agency: Noosa Shire Council

Comment:

The Impact Assessment Report states 'There will be a temporary loss of approximately 97.2% of aquatic habitat (by water volume) in Lake Macdonald, which requires additional mitigation in the form of a comprehensive aquatic fauna salvage operation'. It is likely there will be a concentration of aquatic species (fish, eels) contained within the reduced lake and within smaller pools during the drawdown'. There is potential for oxygen depletion. A 'fish kill' contingency plan is recommended in case of an event including information on management and disposal of carcasses.

Response

Water quality, including maintaining dissolved oxygen, and management of aquatic fauna is outlined in the draft IAR (IAR Appendix C).

2.7 Chapter 8 Terrestrial Ecology

CLARIFICATION

Issue: Vegetation clearing

Agency: Office of the Coordinator General

Comment: pg 8-33

DIAR states that 1.2ha of RE 12.8-10.1 will be cleared. However, this clearing is not shown on a map or described in detail. Confirm the purpose of this proposed clearing.

Response

Proposed vegetation clearing is associated with the construction footprint and associated activities to support construction – site offices, laydown, stockpiles and material conditioning, machinery etc. A map illustrating the maximum clearing extent has been provided in Appendix 1.

CLARIFICATION

Issue: *Essential habitat*

Agency: *Office of the Coordinator General*

Comment: pg 8-32

Discusses the removal of essential habitat for the koala and the glossy black cockatoo. Confirm if this includes the same clearing as for RE 12.8-10.1 (above).

Response

Confirmed – the essential habitat affected is the same area as the regional ecosystem vegetation clearing identified in the draft IAR (Chapter 8, page 8-33).

CLARIFICATION

Issue: *Vegetation clearing*

Agency: *Office of the Coordinator General*

Comment: pg 8-51

The loss of 1.45 ha is discussed; however it is not clear where this figure of 1.45 ha came from and what type of habitat is lost (other than the RE description). Confirm if this is in addition to the 1.25 ha.

Response

The description of clearing is provided under discussion for each regional ecosystem in the draft IAR (Chapter 8, page 8-33), which discusses clearing extents within regional ecosystem types present in the Project area – 1.2 ha within RE12.9-10/1 and 0.25 ha within 12.3.2. As such, a maximum total of 1.45 ha of mapped regional ecosystem vegetation is proposed for clearing.

A map illustrating the maximum clearing extent has been provided in Appendix 1.

CLARIFICATION

Issue: *Riparian vegetation*

Agency: *Noosa Shire Council*

Comment:

Does the proposal ensure that some level of environmental flows are available downstream from the lake to maintain vegetation and habitat in riparian corridors? It is recommended that there be consideration of what can be done upstream from the lake, where typically the lake provide a 'backing-up' effect, with water-dependent vegetation growing on the edges. Upstream and adjacent to Cooroy Noosa Road contains Vegetation Offsets required by the Department of Natural Resources, Mines and Energy (DNRME) under the Vegetation Management Act 1999. Contingency measures should be in place to monitor health of ground water dependent ecosystems, be they mapped vegetation, regrowth or riparian sedgeland. Landholders may need financial assistance if trees/vegetation die as a result of the draw down.

Response

The functionality of the construction phase coffer dam in relation to passing catchment inflows is discussed in the draft IAR and summarised in section 2.1 of this report (refer to clarification: Issue: Cofferdam and low flow channel).

The draft IAR Terrestrial Ecology chapter discusses MSES, including wetlands, their occurrence and potential impacts. The draft IAR groundwater assessment (section 6.4) also discusses groundwater dependent ecosystems.

In general, regarding the upper reaches and upstream of the lake, this area is susceptible to wetting and drying cycles experienced in lake level fluctuation and should be adapted to this cyclical environment. It is noted that the period of time for the dry cycle (during the Project) will be greater than naturally experienced for the riparian environments, which have adapted to the lake environ since the current lake footprint was formed around 1980. It is also noted that the creek lines in the upper reaches will persist and flow relatively frequently due to catchment inflows.

With respect to vegetation offsets, a current 'Regulated Vegetation Management Map' for the upper reaches of Lake Macdonald does not show any Category A mapped areas, which would be indicative of legally secured vegetation offsets. The potential impacts would depend on the specific location, type and maturity of the vegetation. Nonetheless, the vegetation is assumed to be riparian rather than wetland (inundated). Riparian vegetation may be impacted to some extent by lake lowering and associated effects for groundwater, though assessment shows groundwater impact is negligible. It's unlikely that tree health would be permanently affected.

2.8 Chapter 9 Traffic and Transport

CLARIFICATION

Issue: *Schedule*

Agency: *Office of the Coordinator General*

Comment: *Section 9.3.1*

Confirm the timing for when the construction planning phase scheduled.

Response

Seqwater is currently reviewing tenders from construction contractors to enter into an Early Tenderer Involvement (ETI) phase of procurement. During the ETI phase, the shortlisted contractors will work with Seqwater to outline and refine their detailed construction planning and methodologies for scope and costing purposes. The ETI phase is anticipated to commence in April 2019 and contract award is expected in November 2019. Construction planning from the ETI phase will then be formalised into management plans and detailed scheduling.

2.9 Chapter 12 Social

CLARIFICATION

Issue: *Stakeholder and community engagement*

Agency: *Office of the Coordinator General*

Comment:

Confirm details of the proposed stakeholder and community engagement strategy going forward (post the IAR process)?

Response

Following the IAR process, Seqwater will continue work to increase awareness, understanding and support for the project by keeping the community and key stakeholders informed of project outcomes through a range of methods and channels. These include, but are not limited to, the following:

- Continue Community Reference Group (CRG) meetings so as to maintain effective relationships with primary stakeholders through the timely provision of project updates and outcomes.
- Regular distribution of e-update subscription service so to provide monthly updates and relevant notifications to subscribers leading into the construction period.

- Maintain and update the Project website platform at <https://yourseqwater.com.au/lake-macdonald-dam-upgrade> with FAQs and fact sheets.
- Project notification flyers to be distributed to neighbouring areas to inform residents of upcoming work on the project and recreation changes.
- Maintain and monitor the email address and 1800 number dedicated to the Project.
- Issue media statements to advise the community of changed conditions and significant upcoming work such as site establishment & construction start
- Maintain and update Project signage at project entrance
- Continue to attend or host community events (such as the Noosa festival of water, community BBQ's) to promote the project and Seqwater's role in the water supply process
- Continue to engage with primary stakeholders including neighbouring residents, elected representatives and government departments to discuss any specific construction impacts, concerns or areas of interest.
- Continue to engage with environmental groups, businesses and community groups so that there is understanding of the project need, areas of concern and opportunities to mitigate concerns.

CLARIFICATION

Issue: Recreation

Agency: Department of Housing and Public Works

Comment:

The department is aware that there are a number of recreation activities on and around Lake MacDonalld. We are satisfied that consultation undertaken with community organisations using the facilities has made the users aware of the proposed changes. While there will be temporary loss of community facilities the department notes that recreation activities will resume following the completion of the dam upgrade.

The department understands that the Lake MacDonalld Rowing Club Inc. has been in consultation with Noosa Shire Council regarding the potential impact on its activities. The club will continue to negotiate with SEQ Water regarding alternatives that may include short term relocation. The department notes that works may also impact local mountain bike and horseback trails in the short term. We request that these impacts are mitigated during construction where possible, including additional directional signage or linking to alternative routes where possible.

Response

As per the draft IAR Project Description (2.2.4), on-water access to Lake Macdonald will not be permitted during construction. Project impacts on other recreation facilities are also described in section 2.2.4 and recommencement of recreational activities and facilities is discussed later in the chapter. In relation to the Lake Macdonald Rowing Club, the club was made aware of the Project need and likely access impacts at the time of Seqwater granting a licence to store equipment on-site. The licence was provided on a short-term basis and for temporary structures only, with an acknowledgement that relocation would be required on commencement of Project construction.

The multi-use trail heads north of Lake Macdonald are recognised in the draft IAR Social Impact Assessment (12.5.2). Discussion of access impacts on this recreational activity is outlined in sections 12.5.2 and 12.6 (Table 12-4), and further background information provided in Appendix N. Seqwater is also working with Noosa Shire Council on temporary and permanent changes to the trails to maintain connectivity of the trail network across Six Mile Creek.

2.10 Appendix B Environmental Management Plan

CLARIFICATION

Issue: *Relevance to Project aspects*

Agency: *Office of the Coordinator General*

Comment:

Confirm whether the CEMP will apply to individual components of the project (i.e. batch plant) or if it will address the entire project scope.

Response

The Draft EMP encompasses the whole project area and scope, noting that it will also operate in conjunction with the Lake Macdonald Water Lowering – Adaptive Management Plan.

2.11 Appendix C Lake Macdonald Water Lowering Adaptive Management Plan

COMMENT

Issue: *C.6 Aquatic Fauna Salvage and Relocation – The capture of turtles should record additional information.*

Agency: *Department of Environment and Science*

Comment:

Section C.6.6 Capture Methods

Amend to include:

All turtles captured and/or relocated should be tagged with foot tags and where possible carapace notching and with Passive Integrated Transponder tags for threatened species along with data recorded on dates, species, size and capture and release locations. All tagging data should be provided to the DES Queensland Freshwater Turtle Database.

Response

Seqwater considers that tagging all turtles with foot tags while also undertaking general aquatic fauna translocation would be logistically difficult and time-consuming. This may have implications for the management of animal welfare.

Nevertheless, Seqwater proposes to collaborate with DES for staff and experience to undertake turtle tagging and data collection, which may also provide for wider information and research purposes. DES staff are well equipped with previous knowledge and experience to undertake a sorting and tagging exercise on a large scale.

If a DES collaboration is not feasible or does not come to fruition, Seqwater does not agree that tagging all turtles is feasible for the aquatic fauna salvage/translocation team. This view is based on the logistics for managing all fauna and their welfare. Tagging of threatened turtles is considered reasonable given their significant and the anticipated low numbers.

COMMENT

Issue: *C.6 Aquatic Fauna Salvage and Relocation – Additional monitoring requirements for turtles in relocation sites is required.*

Agency: *Department of Environment and Science*

Comment:

COMMENT

Section C.6.8 Monitoring

Amend to include: Quantify mortality, dispersal and/or residency of relocated turtles.

Response

The lake lowering plan will be updated to incorporate a monitoring program for all common turtle species at the relocation sites during the 12 week lowering period and for up to two weeks after the completion of the water lowering. This will be done to assess the success of the turtle relocation and suitability of relocation sites. The monitoring frequency and methods will be determined in collaboration with DES.

A monitoring program for MNES turtle species will be developed with DES in conjunction with the collaboration turtle tagging collaboration described above.

COMMENT**Issue:**

C.8 Incident and Contingency Planning C.8.1 Lowering of Lake Macdonald

It is stated that “Due to Project scheduling demands, drawdown after high flow events may need to be rapid (i.e. two weeks or less)”, p. C-25. It is noted that no analysis of the likely impacts on aquatic fauna in Six Mile Creek has been provided.

Table 7-10 of Chapter 7 – Aquatic ecology

The lake drawdown potential impact is: changes to hydrological conditions – prolonged release of water during drawdown.

A mitigation measure is suggested in Appendix C and E to address this issue.

Agency: *Department of Environment and Science*

Comment:

Section C.5.4 Management Measures, Table C.5-2; Mitigation measures

Section E1.4 Mitigation and management, Table E1-7; ‘Freshwater habitat reduction’ risk; ‘construction’ project phase.

Amend to include:

Monitor impacts on breeding success, reduced water quality, and loss of habitat for identified MNES and MSES fauna species in Six Mile Creek during and post the drawdown period. Implement suitable triggers for action and undertake remedial measures, as required.

Response

Additional assessment of potential downstream impacts is provided in Appendix 2.

Seqwater notes that timing of the lowering phase has been selected to be outside of breeding periods for threatened species (particularly Mary River Cod). No impacts on breeding are anticipated during lowering, as:

- breeding for key species will not be occurring at that time
- the additional assessment indicates that the range of flow conditions associated with the lowering are within the range of conditions experienced by fauna in Six Mile Creek downstream of the dam.

Impacts to aquatic habitat are also anticipated to be minor and thus considered unlikely to affect breeding. A habitat monitoring program and management plan (within the lake lowering plan) will be implemented during the project to ensure potential impacts to breeding habitat are minimised (refer to Appendix 2).

COMMENT

Issue:*C.8 Incident and Contingency Planning*

It is stated that if the species is a platypus it will be transported as quickly as possible to a wildlife carer or veterinarian.

It is considered that specialist facilities are required to house/care for platypus.

Agency: Department of Environment and Science

Comment:*C.8.2.2 Fauna Injury or Death, C.8.2.3 Platypus*

Amend to include:

Delete references to wildlife carer or veterinarian and substitute with “pre-arranged and suitably equipped wildlife facility”.

Response

References to wildlife carer or veterinarian in relation to platypus will be updated to state that the first preference for platypus care is a pre-arranged and suitably equipped wildlife facility. However, references to pre-arranged wildlife carers and veterinarians will be retained to account for emergency situations such as being unable to contact the facility.

CLARIFICATION

Issue: Lungfish

Agency: Office of the Coordinator General, Department of Environment and Energy

Comment: Section C.5.2

The IAR refers to the closest record to be in the Six Mile Creek near the tailwater pool. It is unclear from this where the lungfish was found on Six Mile Creek; if this is a record from the field surveys undertaken for the project or from database searches. This is important to understand the population of the lungfish in Six Mile Creek and potential impacts from the drawdown of the lake.

Response

As stated in Appendix F of the Aquatic Ecology technical report (IAR Appendix G) ‘The Department of Natural Resources and Mines provided fish data for a survey (November 2015) of large bodied fish (boat electrofishing) at the Lake Macdonald tail water, which included records for Mary River cod and Australian lungfish at this site.’

CLARIFICATION

Issue: Potential for Downstream erosion during lake lowering

Agency: Noosa Shire Council

Comment:

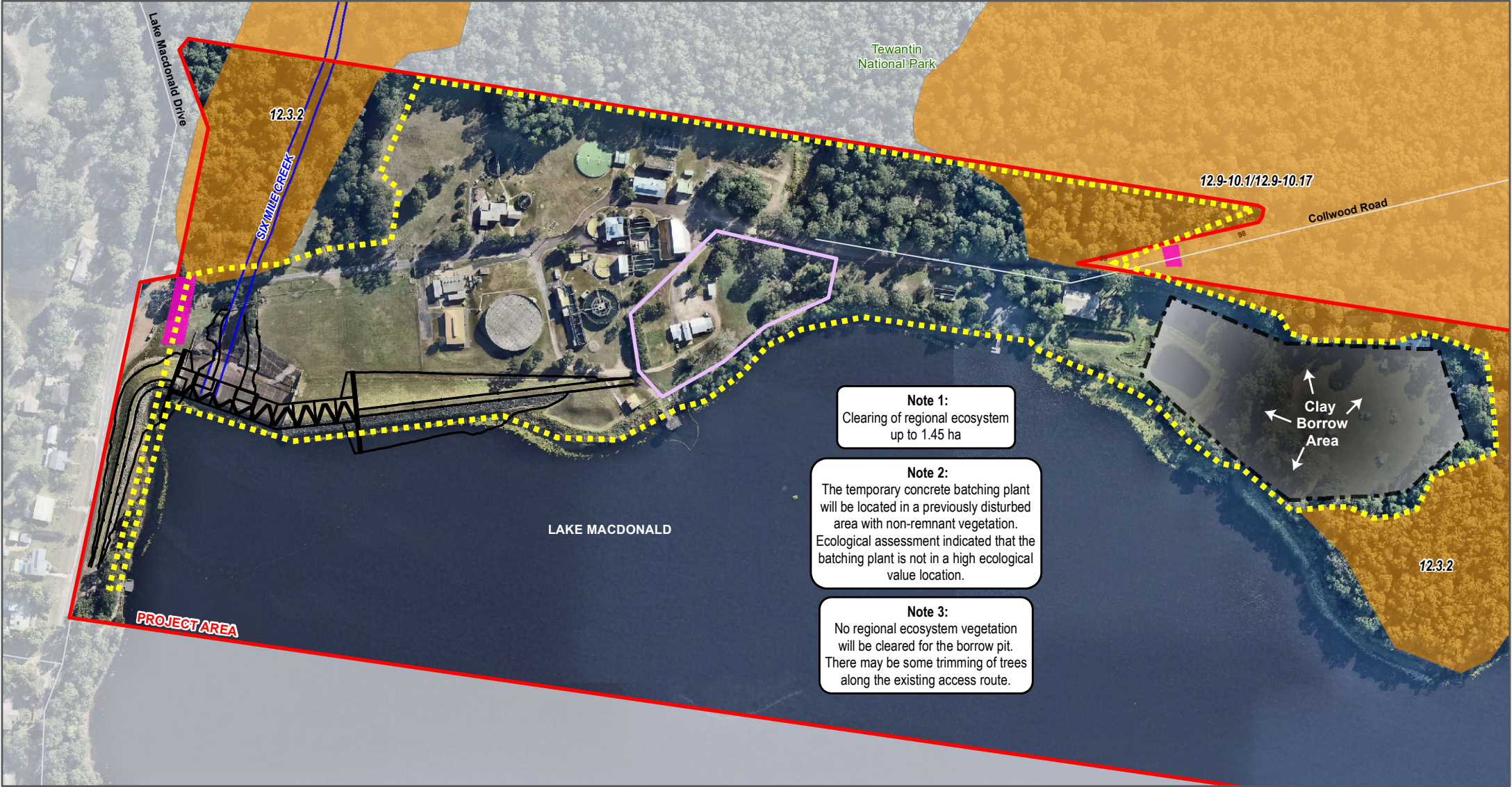
Will monitoring be undertaken to monitor erosion in downstream water during the lowering? What sort of mitigation can be put in place if this occurs?

Response

Releases for lake lowering will be discharged into an appropriate erosion control structure, likely to be the existing spillway apron and energy dissipation structure. This is expected to perform adequately for erosion control, in line with the current dam spillway, but this will be visually monitored during the lowering.

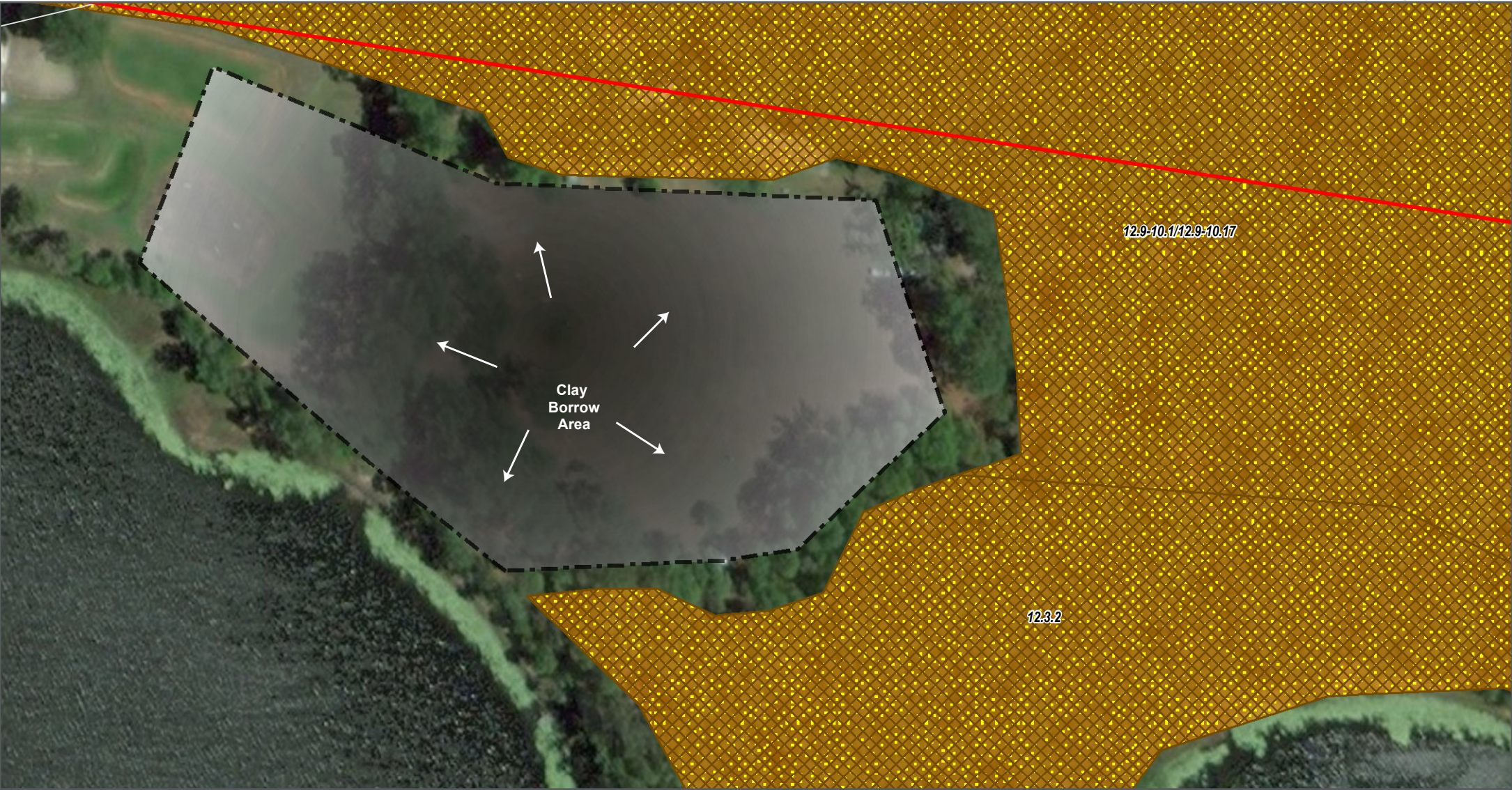
Regarding potential for erosion further downstream in Six Mile Creek. Information is provided in Appendix 2.

Appendix 1 Vegetation Impact Maps



PROJECT NO: 30041832 CREATED BY / DATE: BM14706, 5/04/2019 VERSION: DRAFT F PAGE SIZE: A4 DISCLAIMER: © SMEC Australia Pty Ltd 2017. All Rights Reserved. While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, this map contains data from a number of sources - no warranty is given that the information contained on this is free from error or omission. Any reliance placed on such information shall be at the sole risk of the user. Please verify the accuracy of all information prior to using it. This map is not a design document.	SOURCES: 1. Localities, Roads, LGA, Waterways, Waterbody, Protected Areas © QLD Spatial Catalogue, State of Queensland (Department of Natural Resources, Mines and Energy) 2018 2. Basemap © Nearmap, 2018 seqwater WATER FOR LIFE	LEGEND - Local Roads - Six Mile Creek - Upgraded Dam Layout (after construction) - Project Area - Regional Ecosystems (Of Concern - Dominant) Construction Site Layout - Access Gate - Extent of Borrow Pit - Concrete Batching Plant - Maximum Clearing Extent	OVERVIEW PROJECT AREA Main Map Extents Collwood Road Lake Macdonald Drive Lake MacDonald
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FIGURE 3-1: PROPOSED LOCATION OF BORROW PIT



PROJECT NO: 30041832 CREATED BY / DATE: BM14706, 5/04/2019 VERSION: DRAFT G PAGE SIZE: A4 DISCLAIMER: © SMEC Australia Pty Ltd 2017. All Rights Reserved. While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, this map contains data from a number of sources - no warranty is given that the information contained on this is free from error or omission. Any reliance placed on such information shall be at the sole risk of the user. Please verify the accuracy of all information prior to using it. This map is not a design document.	0 15 30 Metres SOURCES: 1. Localities, Roads, LGA, Waterways, Waterbody, Protected Areas © QLD Spatial Catalogue, State of Queensland (Department of Natural Resources, Mines and Energy) 2018 2. Basemap © Nearmap, 2018 3. Regulated vegetation management map v 2.8 @ State of Queensland (Department of Natural Resources, Mines and Energy) 2018	LEGEND - Local Roads (Collwood Rd) - Project Area - MSES Regulated Vegetation (Category B) - Extent of Borrow Pit - Area not to be cleared Regional Ecosystems - Of Concern - Dominant	OVERVIEW PROJECT AREA Main Map Extents Collwood Road Lake Macdonald Lake MacDonald metres 0 125 250
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Appendix 2 Assessment of Downstream Impacts

Memorandum

Prepared for:	Seqwater	Attention:	Steven Cox
From:	Nirvana Searle		
Subject:	Supplementary Assessment of Potential Impacts Downstream of Lake Macdonald		
Approved by:			
Date of Issue:	29 March 2019		
Project Name:	Six Mile Creek Dam Safety Upgrade Project Impact Assessment Report		
Project Number:	30031970	Document Number:	Rev B
Attachments:			

1 Background

A draft impact assessment report (IAR) was prepared for the Six Mile Creek Dam Safety Upgrade Project and submitted to the Office of the Coordinator General for consideration on 29 January, 2019. Following review by relevant regulatory agencies and the Office of the Coordinator General, feedback and a request for further information was issued to Seqwater. This included a request for further assessment of potential downstream impacts in Six Mile Creek, specifically:

- further consideration of the potential impacts of water releases during the lowering of Lake Macdonald, including the proposed 12-week drawdown and a contingency release associated with significant rainfall
- a suitable range of monitoring, management and mitigation measures
- proposed monitoring, monitoring thresholds, and management or corrective measures where thresholds are exceeded
- consideration of potential residual impacts and appropriate corrective actions or offsets.

2 Existing Environment

A description of the environment in Six Mile Creek downstream of the dam was provided in the IAR in Chapter 6 – Water Resources and Chapter 7 – Aquatic Ecology. This information has been briefly summarised below and additional information provided where required.

2.1 Hydrology

Summary flow statistics for Six Mile Creek at the Cooran gauging station, which is approximately 22 km downstream of Six Mile Creek Dam, were provided in Table 6-4 of the IAR. Data from this gauging station indicates that flow:

- greater than 10 ML/day occurs in Six Mile Creek approximately 70% of the time
- is highest in February / March and lowest in the winter months
- magnitude is highly variable on daily and annual basis
- corresponds closely with rainfall in the catchment.

The seasonality and variability of flow is illustrated in Figure 1 to Figure 4. These figures also indicate that Six Mile Creek regularly experiences very high flow events that persist over a number of days. High flow events are typically between 5,000 ML/day and 10,000 ML/day, but flows greater than 10,000 ML/day were recorded 17 times between 1981 and 2019 at Cooran Gauging Station.

A comparison of flow in Six Mile Creek at the Lake Macdonald spillway indicates that flows are lower at this location, with flow greater than 10 ML/day occurring approximately 40% of the time (Figure 3 and Figure 4). However, the flow regime mirrors that at Cooran Gauging Station.

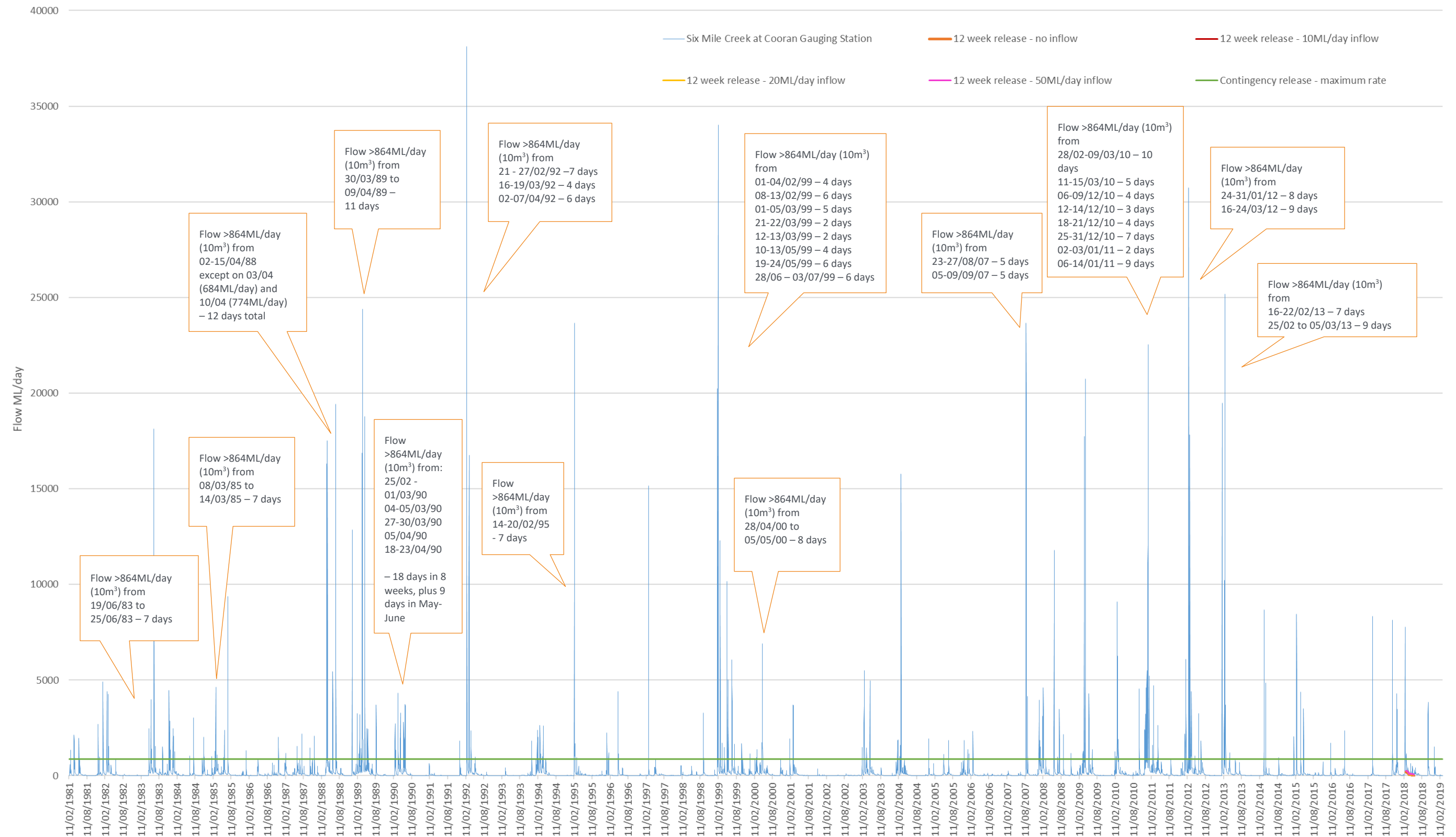


Figure 1: Flow in Six Mile Creek at Cooran Gauging Station from February 1981 to March 2019.

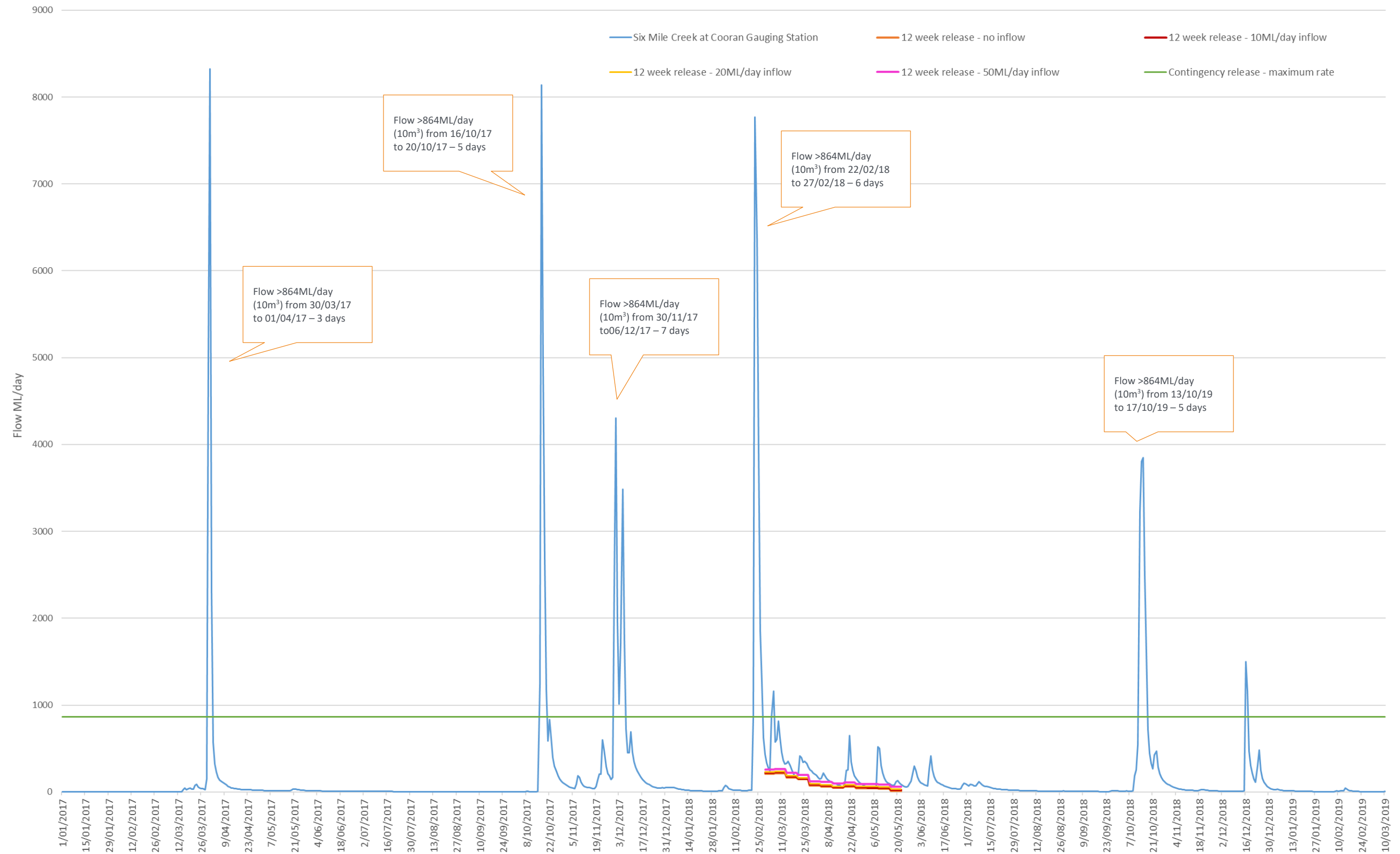


Figure 2: Flow in Six Mile Creek at Cooran Gauging Station from January 2017 to March 2019.

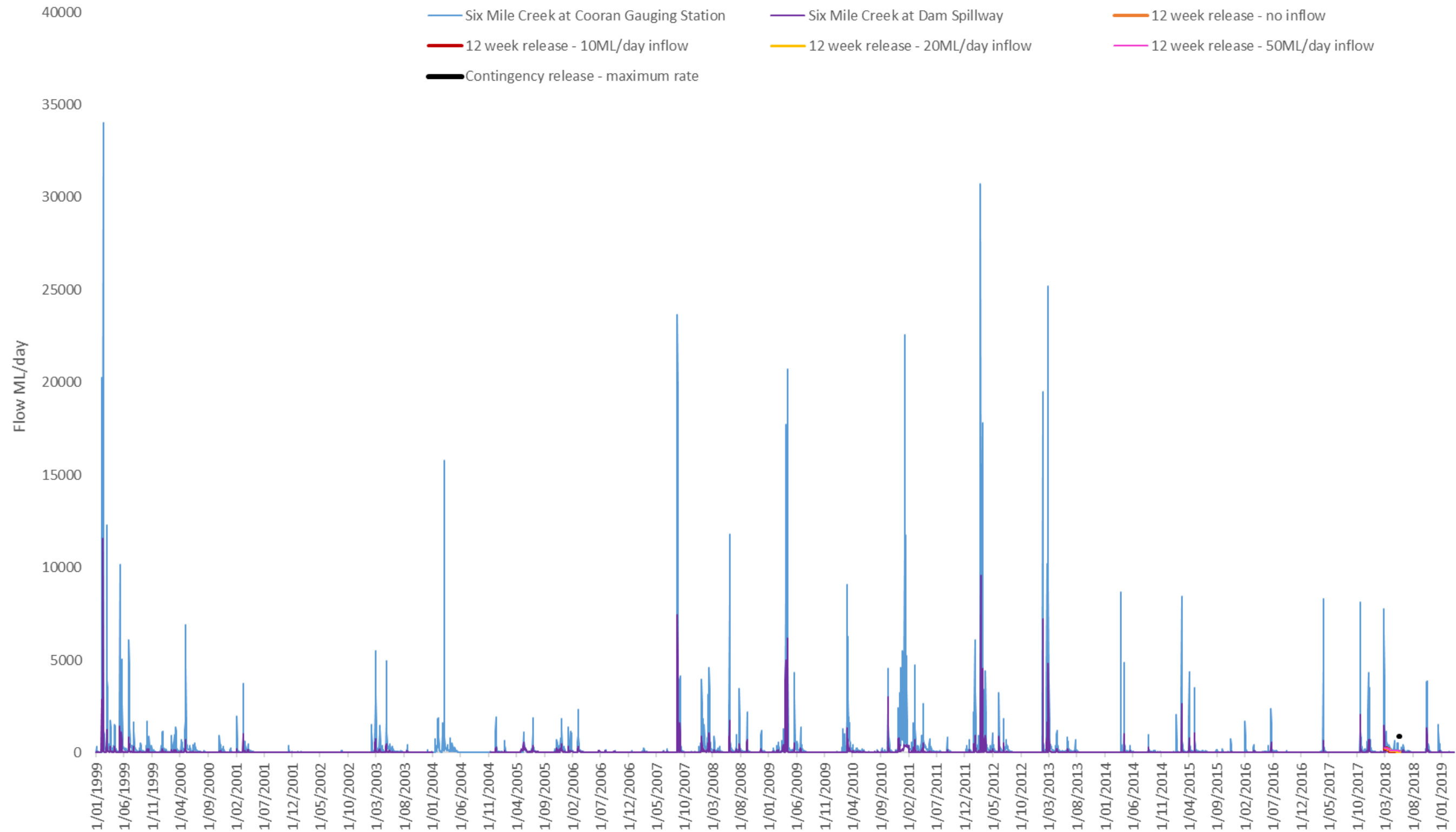


Figure 3: Comparison of flow in Six Mile Creek at Cooran Gauging Station and at Lake Macdonald spillway from January 1999 to March 2019.

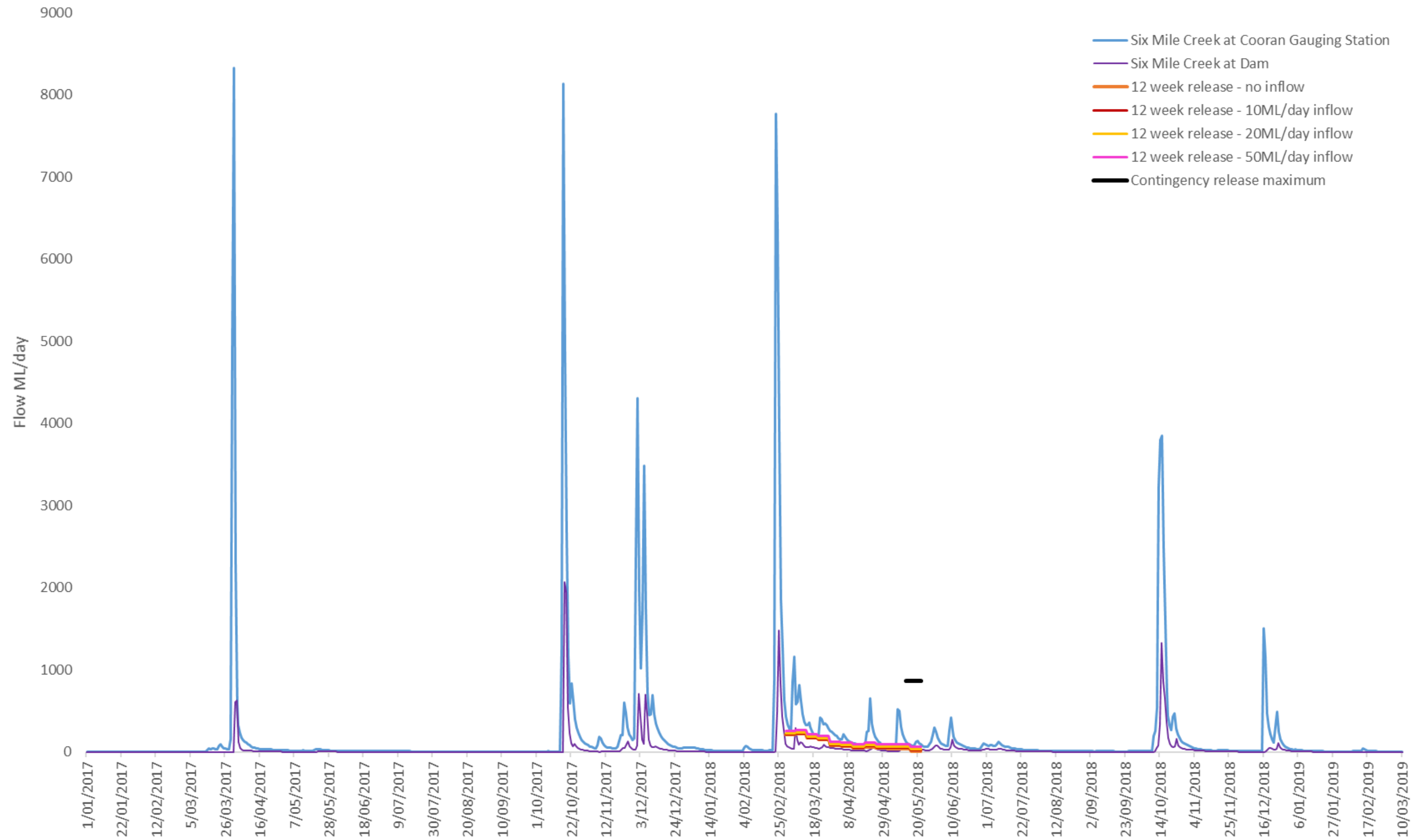


Figure 4: Comparison of flow in Six Mile Creek at Cooran Gauging Station and at Lake Macdonald spillway from January 2017 to March 2019.

2.2 Aquatic Habitat

As described Chapter 7 and Appendix G of the IAR, Six Mile Creek is a low-gradient, low energy stream, with notophyll vine forest the dominant native riparian vegetation (DNRM 2004). Extensive deposits of large woody debris are an important natural feature of low energy streams, and are a common habitat element in Six Mile Creek (DNRM 2004). Medium length pools (i.e. between 6 and 12 channel widths in length) that are less than 2 m deep are common in Six Mile Creek, with riffles and shallow glides over sand also present (DNRM 2004).

Habitat surveys undertaken in Six Mile Creek from 2013 to 2018 using methods that are employed for the NPI2 Aquatic Habitat Monitoring Program (for Seqwater), which were modified from State of the River methodology (Anderson 1993a, Anderson 1993b) and developed to specifically assess suitability of aquatic habitat for Mary River cod, Australian lungfish, Mary River turtle and white-throated snapping turtle at each site. The habitat assessment included:

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

Overall the survey results were consistent with the habitat description in the 2004 Mary Basin Draft Water Resource Plan: Environmental Conditions Report including Mary River, Burrum River and Beelbi Creek Catchments (Department of Natural Resources and Mines). This suggests that the survey sites are representative of the habitat that occurs downstream of the dam. The following key habitat features were identified in Six Mile Creek downstream of the dam during the surveys:

- well-defined channel with high steep banks, and undercut banks present at most sites
- substrate dominated by clay and silt, with gravel riffles present at most sites and bedrock present at some sites
- high variation in flow, with riffles, runs and shallow and deep pools present at most sites
- low abundance of submerged aquatic flora, except immediately downstream of the dam where there was some *Cabomba caroliniana* and *Nymphoides indica*
- abundant large woody debris and leaf packs at each site
- riparian vegetation in good condition, providing shade and a supply of fine and large woody material
- suitable breeding locations for Mary River cod, but very limited breeding habitat for Australian lungfish
- absence of suitable turtle nesting habitat and few places for turtle basking.

Photos and a map of the survey sites in Six Mile Creek downstream of Lake Macdonald are provided in Appendix A. These photos illustrate conditions at the survey sites from 2013 to 2017 for the sites further downstream of the dam (SMC4 and SMC5), and from 2015 to 2018 for sites closer to the dam (SMCDS04 to SMCDS01).

In general, the habitat was similar at all of the survey sites, regardless of their proximity to the dam (i.e. whether they are immediately downstream or further downstream past Cooran). This suggests that the differences in hydrology (scale of base flow, flood peaks) along the length of Six Mile Creek between the dam and the Mary River do not have a substantial influence on the habitat structure. There is also little evidence of change in the aquatic habitat condition between surveys despite a number of high flow events occurring during these time periods (Figure 1 and Figure 4).

As further illustrated in the photographs in Figure 5 and Figure 6, which were taken on 7 December 2017 immediately downstream of the dam, the banks of Six Mile Creek downstream of the dam are heavily vegetated. The flow at the dam spillway was approximately 76 ML/day on 7 December 2017, compared to 703.3 ML/day on 30 November, 694 ML/day on 4 December, and 143.4 ML/day on 6 December. The vegetation along the banks likely contributes to flow staying largely within the banks and minimises the potential for erosion and scouring.



Figure 5: High flow in Six Mile Creek downstream of Six Mile Creek Dam



Figure 6: High flow in Six Mile Creek immediately downstream of Six Mile Creek Dam

Water quality in Six Mile Creek is generally good and typically achieves the WQO for the protection of aquatic ecosystems EV, although dissolved oxygen levels are often low due to decomposition of organic matter from the adjacent rainforest canopy (DNRM 2004). DNRM (2004) also report that water quality typically achieves other EVs identified for Six Mile Creek. Survey data for water quality measured in situ since 2013 indicated that in Six Mile Creek downstream of the dam:

- electrical conductivity, pH and turbidity complied with the water quality objectives
- the percent saturation of dissolved oxygen was below the water quality objectives.

2.3 Flora and Fauna

Aquatic flora and fauna in Six Mile Creek are described in detail in Chapter 7 – Aquatic Ecology and Appendix G of the IAR.

Aquatic plants are absent or rare in Six Mile Creek downstream of the dam, although they are common in the Lake Macdonald, with the noxious weed *Cabomba caroliniana* growing prolifically in the dam (DNRM 2004).

There are five Matters of National Environmental Significance species that are known to occur, or that may occur, in Six Mile Creek downstream of Six Mile Creek Dam. These are 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*). The ecology and distribution of these species is described in detail in Chapter 5 – MNES of the IAR. Both the Mary River cod and Australian lungfish have a preference for deep pool habitats with large woody debris and have been caught downstream of the dam. However, while Six Mile Creek is known to provide important breeding habitat for Mary River cod, which spawn in spring, habitat in the creek is not considered suitable for Australian lungfish to breed. Australian lungfish spawn in slow-flowing shallow pools among aquatic plants between August and December. As aquatic plants are absent or rare in the creek downstream of the dam, it is unlikely that Australian lungfish are spawning in this area.

Six turtle species have potential to occur in Six Mile Creek downstream of the dam. Of these, the four common species were caught during surveys for the IAR. These were: Krefft's river turtle (*Emydura macquarii krefftii*), saw-shelled turtle (*Wollumbinia latisternum*), eastern long-necked turtle (*Chelodina longicollis*), and broad-shelled river turtle (*Chelodina expansa*). The Mary River turtle and white-throated snapping turtle were not caught during field surveys and there are no confirmed records of these species in Six Mile; however, it is believed that they may occur in the lower reaches of the creek, close to the confluence with the Mary River, where suitable habitat is present. No suitable breeding habitat for turtles was identified along Six Mile Creek during surveys for the IAR.

The giant barred frog prefers rainforest and wet sclerophyll forest, and moist riparian habitat with deep leaf litter. There is suitable habitat for this species along Six Mile Creek, and individuals were recorded downstream of the dam during field survey for the IAR.

There are confirmed records of platypus from Six Mile Creek downstream of the dam. This species prefers permanent water with stable earthen banks, held by native overhanging vegetation.

3 Potential Impacts

3.1 Hydrology

Due to safety considerations, Lake Macdonald needs to be lowered during the upgrade of Six Mile Creek Dam. Assuming Lake Macdonald is full at the time water lowering begins, a minimum of 7,792 ML of water, will need to be removed before construction can begin. There are two proposed scenarios for the lowering of Lake Macdonald that may impact hydrology in Six Mile Creek downstream of the dam:

1. A gradual lowering over a 12-week period
2. A rapid contingency release over 8-10 days prior to construction start, if rainfall fills the lake at the end of the gradual lowering period.

Gradual Release

The proposed schedule for a gradual lowering is shown in Table 1 and the Lake Macdonald Water Lowering – Adaptive Management Plan (Appendix C of the IAR, Table C.2-1). Over a 12-week period a variable release rate will be used to achieve a target water level and lower Lake Macdonald. The release rate is provided as an indicative guide and ranges from an estimated 264.3 ML/day (assuming a 50 ML/day inflow) to an estimated 10.6 ML/day (assuming no inflow), with a steady release for each seven day period adopted for the purpose of simplified presentation. However, because inflows are unpredictable, an adaptive approach is proposed to be used for the drawdown. It is proposed that the

volume released each day would be based on a percentage of the total decrease in volume required to achieve the required lake level, and allow short peak flow with a ramp up and ramp down period. An indicative varied release is shown in Figure 7. Note that this methodology would be used as a model hydrograph rather than prescriptive rates of release. This is because inflows will necessitate adaptation of the dewatering to match on ground conditions.

The use of mechanical equipment such as pumps and/or siphons to extract water from the lake will enable the release rate to be varied as required during the lowering period while still achieving the same decrease in water level. The maximum potential release rate is 10 m/s³, which is equivalent to 864 ML/day and based on the bank full capacity of Six Mile Creek.

Table 1: Proposed Lake Macdonald dewatering plan.

WEEK	LAKE LEVEL (M AHD)		TARGET DECREASE IN LAKE LEVEL	REMAINING LAKE CAPACITY (% FSV)	DECREASE IN STORED VOLUME (ML)	MINIMUM DRAWDOWN EQUIPMENT CAPACITY (ML/D) TO ACHIEVE LOWERING TARGET FOR DIFFERENT INFLOW RATES ¹			
	Start of Week	End of Week	Change Over the Week			No Inflow	10 ML/d Inflow	20 ML/d Inflow	50 ML/d Inflow
1	95.3	94.7	0.60	81.9	1454	207.7	217.7	227.7	257.7
2	94.7	94.0	0.70	63.2	1500	214.3	224.3	234.3	264.3
3	94.0	93.3	0.70	48.5	1174	167.7	177.7	187.7	217.7
4	93.3	92.6	0.60	35.9	1009	144.1	154.1	164.1	194.1
5	92.6	92.2	0.40	29.6	506	72.3	82.3	92.3	122.3
6	92.2	91.8	0.40	24.2	436	62.3	72.3	82.3	112.3
7	91.8	91.45	0.35	20.2	319	45.6	55.6	65.6	95.6
8	91.45	90.9	0.55	14.3	426	60.9	70.9	80.9	110.9
9	90.9	90.4	0.50	10.5	306	43.7	53.7	63.7	93.7
10	90.4	89.9	0.50	6.7	283	40.4	50.4	60.4	90.4
11	89.9	89.2	0.70	3.7	260	37.1	47.1	57.1	87.1
12	89.2	89.0	0.20	2.8	74	10.6	20.6	30.6	60.6

¹ A 7-day week was assumed for calculations

These figures are provided for information only and don't represent the proposed release methodology, which is based on lake level targets rather than volume due to the effect of unpredictable inflows

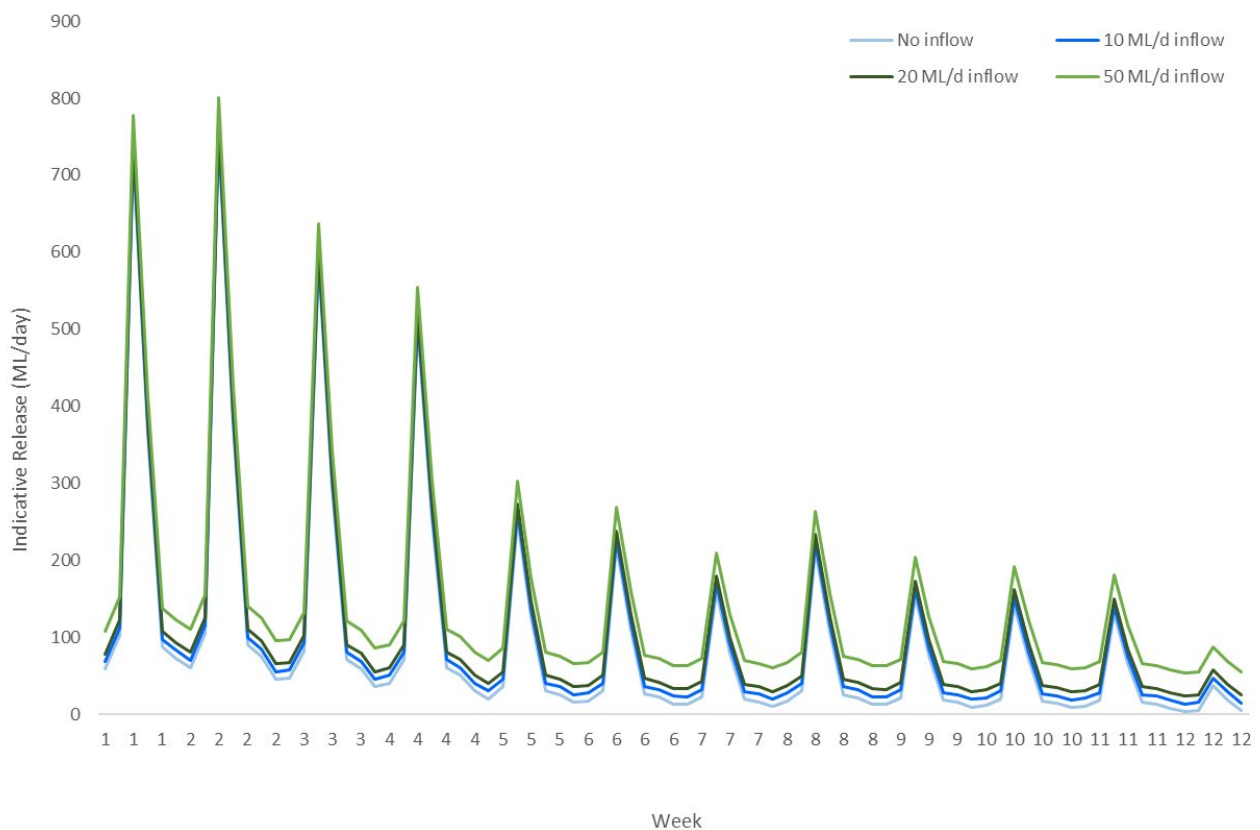


Figure 7: Indicative varied release

As illustrated in Figure 2 and Figure 3, the proposed gradual release volumes are within the flow experienced in Six Mile Creek at Cooran during that period in 2018 and similar to flows experienced at the dam spillway since 1999.

Figure 1 and Figure 2 show the proposed gradual release against historical flow records for Six Mile Creek at Cooran Gauging Station from March to May 2018, which is approximately 22 km downstream of the dam. Review of flow data from Cooran Gauging Station since 1981 indicates that 7 days or longer of flow greater than:

- 257 ML/day (the estimated week 1 proposed release with a 50 ML/day inflow) occurred 81 times
- 112 ML/day (the estimated week 6 proposed release with a 50 ML/day inflow) occurred 148 times, with flows often persisting for more than 10 days
- 60 ML/day (the estimated week 12 proposed release with a 50 ML/day inflow) occurred 141 times, with flow often higher than 60 ML/day for multiple weeks.

The data from Cooran Gauging Station shown in Figure 1 and Figure 2 indicates that the release scenarios proposed for the drawdown of Lake Macdonald are likely to have negligible impact on Six Mile Creek at Cooran or further downstream, as the proposed flows are within the stream conditions in this section of the creek.

Data from the dam spillway indicates that the proposed release scenarios are slightly higher than typically occur for extended periods in that stretch of Six Mile Creek (Figure 3 and Figure 4). However, the proposed release scenarios are within the maximum flow conditions that occur in that section of the creek over short periods, with flows:

- >864 ML/day occurring 55 times since 1999, typically for a period of one to three days
- >257 ML/day occurring 215 times since 1999, and persisting for more than five days on nine occasions, including for 30 days on one occasion.

Potential impacts to hydrology associated with the proposed gradual release include the:

- introduction of higher than typical flows, potentially at a time when flow in Six Mile Creek is naturally low
- sustained release of water for a longer period than is naturally experienced in Six Mile Creek.

Both of the above potential impacts may interfere with or interrupt the natural wetting and drying cycles of Six Mile Creek, which have the potential to subsequently affect aquatic habitat (including water quality), flora and fauna. Impacts to habitat and aquatic flora and fauna are discussed in sections 3.2 and 3.3, respectively.

Flow in Six Mile Creek is typically lowest during the winter months (June-August); however, as shown in Figure 3 and Table 2, there have been instances where high flows occur at this time of year. This indicates that the proposed gradual release is within the range of flows recorded in Six Mile Creek during both the wet and dry seasons since 1981 at Cooran and since 1999 at the dam spillway.

The gradual release also has the potential to sustain higher flows for a longer period than would otherwise be experienced in Six Mile Creek. High flow events generally peak for a short time, but the duration of the tail of the event often varies. As noted above, and shown in Figure 1 and Figure 2, high and moderate flow events consistent with proposed release rates often occur for at least 7 days in Six Mile Creek at Cooran Gauging Station. Since 1981, flow greater than 60 ML/day (the estimated week 12 proposed release with a 50 ML/day inflow) have persisted for more than 12 weeks on 14 occasions, with the duration ranging from 88 days to 197 days. Therefore, the proposed gradual release is within the flow durations and rates that currently occur in Six Mile Creek at Cooran.

Sustained high flow events are less likely to occur immediately downstream of the dam; therefore, as shown in Figure 7, it is proposed to vary the release rates within each week to more effectively mimic a peaking flow regime that might be experienced naturally. Flow events at the dam site and immediately downstream typically have a short peak with a small ramp up and ramp down period, but the total volume of water may be high (Figure 3 and Figure 4). A similar flow regime will be facilitated by using weekly release periods where the daily rate is based on a percentage of the total volume to be released. Nonetheless it must be noted that this cannot be a fixed percentage or rate because inflows will require adaptations of the plan.

Table 2: Range of mean monthly flows in Six Mile Creek at Cooran Gauging Station from 1981 to 2019.

MONTH	LOWEST MEAN FLOW (ML/DAY)	HIGHEST MEAN FLOW (ML/DAY)
January	0.78	3171.34
February	0	3462.27
March	0	2060.37
April	0.9	3410.92
May	0.9	1286.26
June	4.09	1711.74
July	0.84	1165.39
August	0.07	1675.07
September	0	539.16
October	0	701.85
November	0	553.56
December	0.3	1648.25

Contingency Release

The proposed rate for a contingency release in response to high rainfall is 10 m³/s over a period of eight to 10 days. This is the maximum proposed release rate and is equivalent to 864 ML/day. Potential impacts associated with the contingency release are:

- introduction of high flows at a time when flow in Six Mile Creek is naturally low and high flow events are not expected
- sustained bank full flows for a longer period than is naturally experienced in Six Mile Creek (i.e. a longer than typical flood peak).

Figure 1 and Figure 2 show flow in Six Mile Creek at Cooran Gauging Station in relation to 864 ML/day and highlight some, but not all, high flow events where flow greater than 864 ML/day was sustained. According to the gauging data, high flow of more than 864 ML/day has been sustained for 5-7 days on a number of occasions, in some instances has persisted for 8-9 days, and once for 11 consecutive days. Additionally, there are a number of instances where the flow has decreased for a few days and then increased above 864 ML/day once more. Consequently, the proposed eight to 10 day contingency release is within the conditions experienced in Six Mile Creek 22 km of the dam, but these conditions occur infrequently.

In Six Mile Creek immediately downstream of the dam spillway flows greater than 864 ML/day typically only occur for a period of one to three days, but the flow that occurs in that period may be substantial. For example, between 26 February and 1 March 2013 a total of 7766.19 ML/day was recorded at the dam spillway. This is similar to the total volume of the contingency release, but this type of flow event cannot be replicated for the contingency release as it would require releases higher than the bank full width and have additional downstream safety implications. The contingency release will therefore result in higher than typical flows for a longer period than would otherwise occur downstream of the dam. However, it should be noted that, as illustrated in Figure 3 and Figure 4, this change in flow regime will be temporary and short-lived.

As for the gradual release, impacts to habitat and aquatic flora and fauna are discussed in sections 3.2 and 3.3, respectively.

3.2 Aquatic Habitat

Potential impacts to aquatic habitat from the two release scenarios are as follows:

- Gradual release (12 weeks)
 - changes to flow regime (e.g. sustained presence of water in typically dry period)
 - changes to habitat structure due to sustained release of water (e.g. riffles to pools, movement of instream debris that provides shelter)
 - erosion and scouring due to persistent flow
 - changes to water quality from released water, particularly when the lake water level is low
- Contingency release (eight to 10 days)
 - changes to flow regime (e.g. high flow event at a time when these would not typically occur, high flow sustained longer than a typical flow event, increased velocity)
 - changes to habitat structure due to high flow (e.g. loss of or damage to woody debris and aquatic plants, changes to substrate composition)
 - erosion and scouring due to sustained high flow
 - changes to water quality from released water, particularly when the lake water level is low.

As noted in section 2.2, habitat surveys indicated that aquatic habitat was similar at all sites along Six Mile Creek and results were consistent with the previous assessments, which suggests that the habitat at the sites surveyed is representative of that found through Six Mile Creek downstream of the dam.

Changes to Flow Regime

As discussed in section 3.1, both proposed release scenarios are within the range of flow conditions that currently occur in Six Mile Creek. However, temporary and short-term impacts may still occur, particularly in the area directly downstream of the dam:

- where the gradual release occurs during a dry period, particularly in a year with low rainfall and flow, it will lead to a temporary change in the flow conditions that may otherwise not have occurred at that time
- where the contingency release is required for more than two days, the conditions in Six Mile Creek will not be consistent with those that occur immediately downstream of the dam.

Consistent with the information provided in section 3.1, the IAR risk assessment determined that the consequence of altered hydrology is low, because the most notable change to hydrology will be a one-off, short-duration event during the drawdown phase, and the likelihood is moderate.

However, aquatic habitat downstream of the dam may be more susceptible to impacts from changes in flow because the proposed contingency flows are not consistent with existing conditions, and this could potentially affect aquatic fauna. As such, mitigation and management measures are required for both release scenarios.

Changes to Habitat Structure

Changes to the habitat structure as a result of the gradual and contingency release scenarios could include temporary loss of some habitat types (e.g. riffles to pools), and movement of instream habitat such as woody debris or aquatic plants by high flows. Sedimentation may also occur in association with the gradual release.

As noted in section 2.2, riffles and glides are present in Six Mile Creek. There is limited information regarding the persistence of these habitat types in moderate to high flow conditions; however, it is likely that these areas frequently become temporary pool or run habitat during high flows. Over the gradual release period, riffles and glides close to the dam will likely become pools and runs during the initial stages of the release, when the volumes released are higher, but return to riffles and glides in the later stages as release volumes decrease. The change in habitat types associated with the contingency release will be the same as for the gradual release, but will likely extend further downstream. However, this change would be for a shorter period of time than for the gradual release.

Some movement of woody debris, aquatic plants, and other organic matter (e.g. leaf litter and small woody debris) may potentially occur as a result of the gradual release peak flows or the contingency release, which would be longer than typical high flows. The average stream velocity (across the depth profile) is unlikely to differ significantly between the gradual and contingency release volumes. Once a steady state flow is reached, the stream head remains the same, such that the stream velocity is similar and it is only the water depth that changes to convey a greater flow rate. For Six Mile Creek, downstream of Lake Macdonald, average stream velocity is estimated at around 0.6 m/s for the contingency release (based on hydraulic modelling). This is within the velocity experienced during some high flow events, and as such movement of in-stream habitat is generally expected to be within that currently experienced in Six Mile Creek.

Photographic records of habitat in Six Mile Creek collected during surveys for the IAR (Appendix A), along with information from DNRME for Cooran Gauging Station and a monitoring location 200 m downstream of the dam (pers. comm. A. McDougall, DNRME 2019), indicate that high flow events do not typically have a significant impact on aquatic habitat. There are few differences in the habitat shown at survey sites assessed for the IAR between 2015 and 2019 (Appendix A), despite a number of high flow events occurring in this period (Figure 1). Photographs taken at Cooran Gauging Station on 28 October 2010 (Figure 8 and Figure 9) show the presence of woody debris and no substantial damage to riparian vegetation or banks, despite a high flow event (maximum 7,057.41 ML/day) occurring from 9 to 13 October 2010. Information provided by DNRME for their monitoring location 200 m downstream of the dam also suggests that high flow events in the order of approximately 2,630 ML/day do not have a significant effect on riparian vegetation (Figure 10). Based on this information, high flow events of a similar magnitude may affect loose material and small debris (leaf litter, small woody debris, detached aquatic plants), but significant impacts are unlikely. However, while the proposed release scenarios will generally be of a similar duration and magnitude to other flow events in Six Mile Creek, it is unclear what affect the sustained nature of contingency release may have, as flows of that magnitude do not often exceed seven days. As such, monitoring and management measures are required.

Fine sediments accumulate on the bed of reservoirs (e.g. >90% of sediment is captured in Six Mile Creek Dam, DNRM 2014), and these could be mobilised during drawdown and released downstream (i.e. sedimentation). Sedimentation has the potential to smother benthic habitats, including in-filling pools and interstitial spaces of coarse substrate (e.g. gravels and cobbles), causing cascading impacts to primary producers (i.e. aquatic plants and benthic algae), macroinvertebrates and fishes (Wood and Armitage 1997). This is more likely to occur during the gradual release scenario as the release rate slows and water in Lake Macdonald is lower, which may lead to more suspended solids in the water being released and greater deposition downstream due to slower flow conditions. Monitoring and management measures will therefore be required.



Figure 8: Six Mile Creek looking downstream from Cooran Gauging Station on 28 October 2010



Figure 9: Six Mile Creek looking upstream from Cooran Gauging Station on 28 October 2010

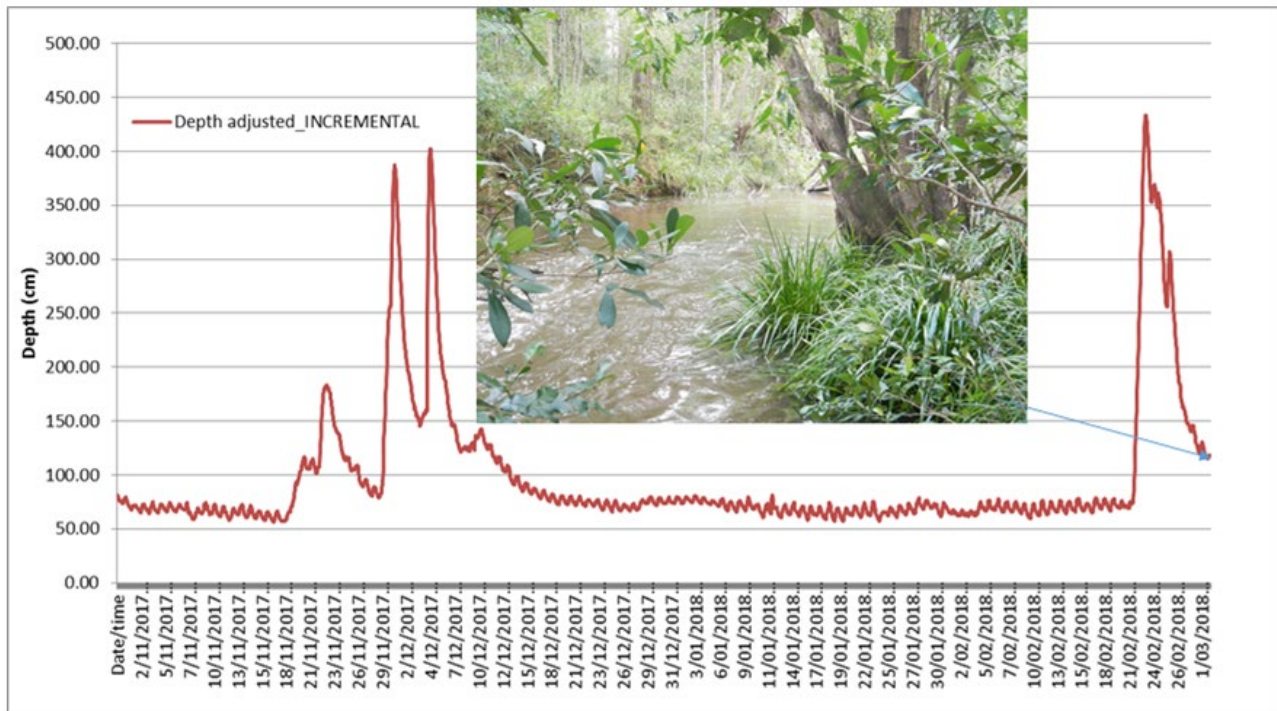


Figure 10: Six Mile Creek 200 m downstream of Six Mile Creek Dam (provided by DNRME 2019).

Erosion and Scouring

High flow events such as those proposed for the two release scenarios have the potential to cause erosion and scouring of the bed and banks in Six Mile Creek. Where erosion or scouring occurs along the banks, there is potential for undercut banks to collapse. However, photographs indicate that the banks are largely protected by extensive riparian vegetation (Figure 5 to Figure 10, Appendix A). The bed composition in the creek is mixed, typically comprising a range of substrate sizes including boulder, cobble, pebble, gravel, sand, and silt/clay, and there are few aquatic plants. Similar to natural high flow events, the proposed release scenarios are likely to move the finer substrates in the bed, and may also move loose soil on the banks. As the proposed release scenarios are largely consistent with naturally occurring flow conditions, and water will be discharged on to the concrete apron of the dam in order to dissipate energy, the likelihood of erosion and scouring is considered low. Nevertheless, monitoring and management measures will be required, particularly in the vicinity of the dam, as some of the gradual and contingency releases may be sustained for a longer period than flows of that magnitude typically occur.

Changes to Water Quality

Potential changes to water quality in Six Mile Creek downstream of the dam due to releases for the lowering of Lake Macdonald include increased turbidity, suspended solids, nutrient and metal concentrations, and decreased pH and dissolved oxygen. The potential changes are similar for both the gradual and contingency releases, with the difference being that the gradual release could lead to changes that are sustained over a period of time.

The potential mechanisms for changes to water quality are:

- disturbance of bed sediments and / or the erosion of bed and banks in the lake leading to high turbidity and total suspended solids in the water released into Six Mile Creek
- disturbance of bed sediments and / or the erosion of bed and banks in Six Mile Creek due to the release, leading to increased turbidity and total suspended solids in the water
- exposing or disturbing potential acid sulphate soils and / or decomposing organic material (e.g. aquatic plants), leading to decreased pH in the release water
- eutrophication or stratification leading to reduced dissolved oxygen in the release water
- high nutrient concentrations in the lake water if eutrophication occurs, leading to increased nutrient concentrations in the release water.

As noted in section 2.2, water quality in Six Mile Creek is typically within the relevant water quality objectives. A review water quality data measured at Cooran Gauging Station indicates that electrical conductivity generally decreases with increased flow, and temperature and pH are largely unrelated to flow (Figure 11). There is currently no data available on changes to turbidity and suspended solids in response to flow events in Six Mile Creek.

The assessment of water quality in Lake Macdonald in the IAR (Chapter 7 – Aquatic Ecology and Appendix G) indicates it is typically within relevant water quality objectives, but as the lake is lowered water quality is expected to deteriorate. Where mitigation and management measures are not implemented to manage the water quality in Lake Macdonald and the releases, water quality in Six Mile Creek may decline. As such, water quality should be monitored within the lake and downstream of the dam.

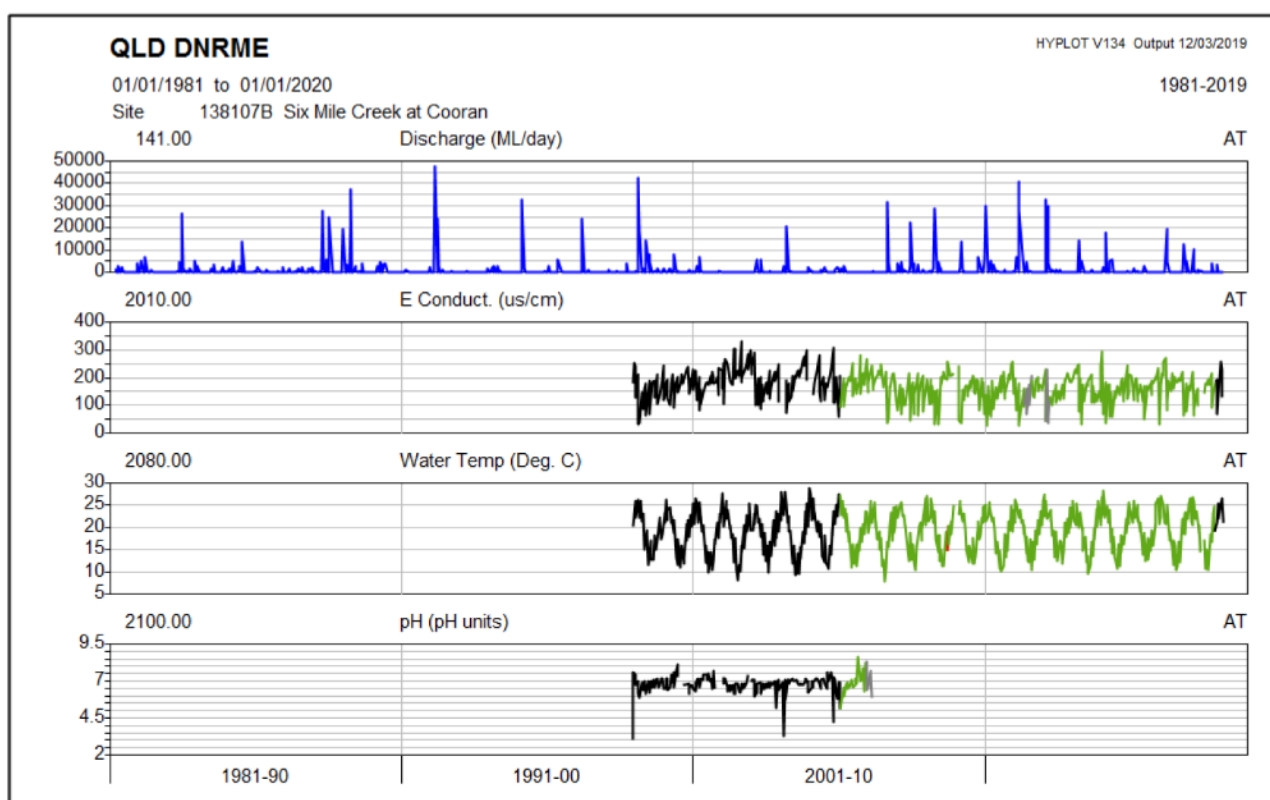


Figure 11: Flow and water quality in Six Mile Creek at Cooran Gauging Station from 1981 to 2019.

3.3 Flora and Fauna

Aquatic flora and fauna in Six Mile Creek downstream of the dam could potentially be negatively affected by the changes in flow and habitat described in sections 3.1 and 3.2.

As aquatic plants are not common in Six Mile Creek, significant impacts to flora are considered unlikely to occur. Significant impacts to Mary River turtle and white-throated snapping turtle are also considered unlikely, as they are only expected to occur infrequently in the lower reaches of Six Mile Creek and there is an absence of suitable breeding places, with limited basking habitat, in Six Mile Creek downstream of the dam.

Other aquatic fauna, including MNES fish species, could potentially be affected by impacts to flow and habitat through the:

- loss of habitat if woody debris is moved downstream, undercut banks collapse, and/or sediment fills pools or interstitial spaces in the substrate
- deterioration in habitat condition due to changes in water quality and/or habitat types (i.e. temporary loss of riffles)
- increased and sustained flow associated with the gradual and contingency release scenarios.

The loss of suitable habitat in Six Mile Creek could reduce the suitability of the creek for fauna species, in particular Mary River cod, Australian lungfish, and platypus. These MNES fish species prefer areas with complex instream habitat that includes submerged logs, underwater crevices and, in the case of Australian lungfish, high aquatic plant cover. Platypus also prefer areas with woody debris as well as stable banks held by overhanging vegetation. If woody debris is removed from the creek or undercut bank collapse, the availability of suitable habitat is reduced leading to a decline in current populations as well as potentially having a negative impact on Mary River cod breeding. An impact on the breeding of Australian lungfish is considered unlikely as suitable breeding habitat is not present in Six Mile Creek downstream of the dam.

Due to the apparent stability of habitat in Six Mile Creek in high flow events (discussed section 3.2), the risk of negative impacts to fauna habitat, including that preferred by MNES species, is generally considered to be low. The exception is for the contingency release, where the risk is considered to be moderate. For this reason, monitoring and management measures are required to assess changes to aquatic habitat, with particular regard to habitat used by Mary River cod and Australian lungfish.

Deterioration in habitat quality could also result in impacts on existing fauna populations and the breeding of Mary River cod. In particular, changes to water quality can have direct impacts on aquatic fauna. Where there is increased turbidity and suspended solids in the water released from Lake Macdonald or as a result of erosion, respiratory and feeding efficiency may be impaired. Small and brief increases in turbidity, consistent with increases in turbidity that occur during natural flow events, would be unlikely to have a significant impact on aquatic fauna (Dunlop et al., 2005). However, significant increases in turbidity, especially turbidity caused by fine silt and clay particles, could adversely impact the health, feeding and breeding ecology of aquatic fauna species (Dunlop et al., 2005).

Detailed discussion of the effects of changes to pH, dissolved oxygen and other aspects of water quality is provided in Chapter 7 – Aquatic Ecology and Appendix G of the IAR.

As the maximum rate for both release scenarios for the lowering of Lake Macdonald is equivalent to bank full flow conditions, and riparian habitat appears to be quite stable even in high flow events, impacts to the giant barred frog are considered unlikely to occur. However, high flow events associated with releases could affect eggs laid when water levels were lower.

Increased and sustained flow associated with the proposed release scenarios could influence fauna behaviour. However, as evidenced by their occurrence in the downstream reaches of Six Mile Creek and in the reaches downstream of the dam, populations of aquatic species such as Mary River cod and Australian lungfish, that occur between the dam and the confluence with the Mary River have demonstrated resilience to higher flows such as those illustrated in the flow data provided for both Six Mile Creek Dam outflow and the Cooran Creek gauging station.

Breeding events and migration for a range of species can be influenced by high flow events. Breeding seasons for the MNES species that are known to occur or that may occur in Six Mile Creek downstream of the dam are:

- White throated snapping turtle – nesting (May – September), Hatching (September – December)
- Mary River turtle – nesting (October -November), Hatching (November to February)
- Mary River cod – September to November
- Australian lungfish – August to December
- Giant barred frog – September to November

As Mary River cod and giant barred frog are MNES species known or likely to breed in Six Mile Creek downstream of the dam, it is proposed to undertake releases for both scenarios outside of the breeding seasons for these species. Overall, releases are not anticipated to influence behaviour and breeding as they will generally be within the range of conditions experienced by fauna in Six Mile Creek. However, where possible, management measures should be implemented to ensure the lowering releases avoid the breeding season of MNES and iconic fauna species to reduce potential impacts.

In general, impacts associated with changes in flow and water quality will be temporary and reversible, as subsequent large flows will naturally flush the creek after the construction phase is completed and the upgraded dam will not change the existing flow regime.

4 Impact Mitigation and Management

4.1 Performance Outcomes

Appropriate mitigation and management measures should be implemented to achieve the following objectives:

- prevent or reduce potential changes to the flow regime in Six Mile Creek downstream of the dam to the greatest extent possible
- prevent or minimise potential impacts to aquatic habitat, in particular that relevant to listed threatened species, including water quality, where minimise means the impact is temporary and reversible
- prevent or minimise potential impacts to aquatic fauna, in particular listed threatened species, where minimise means the impact is temporary and reversible.

Suggested mitigation measures for potential impacts are provided in Table 3, however additional and/or alternative measures may also be appropriate to achieve the objectives identified above.

4.2 Impact Assessment and Mitigation

A summary of potential impacts associated with the release of water to Six Mile Creek during the drawdown of Lake Macdonald is provided in Table 3.

Mitigation measures, response triggers and corrective actions are provided in section 4.3. Key mitigation measures proposed to minimise potential impacts on the downstream environment include:

- capping of lake lowering releases to the bank full width during the lake lowering and construction
- providing the ability to control (i.e. throttle or stop) release flows during the lake lowering and construction
- implementing a 12 week lake lowering program with variable flow rates
- implementing controls (e.g. aeration) to reduce potential impacts to water quality
- avoiding changes to flow during the breeding seasons of Mary River cod and giant barred frog.

Monitoring is also proposed to assess the efficacy of mitigation measures and enable corrective actions as required.

Table 3: Proposed mitigation and management measures for the Lake Macdonald lowering

ECOLOGICAL ASPECT	PROJECT PHASE	POTENTIAL IMPACT	IMPACT RISK BEFORE MITIGATION	MITIGATION AND MANAGEMENT	RESIDUAL IMPACT RISK
Flow regime	Pre-construction – lake drawdown	Changes to hydrological conditions – 12 week gradual release resulting in sustained flows when they may not otherwise occur.	Low – due to release being within conditions currently experienced in Six Mile Creek.	Where possible, vary the release rate within as well as across weeks. Maintain the proposed maximum drawdown release rate so that the bank full width of Six Mile Creek downstream of the dam is not exceeded. Monitor potential impacts to downstream environment (see section 4.3).	Low
		Changes to hydrological conditions – 8-10 day contingency release resulting in high flows for a longer time than typically occurs.	Moderate – due to flows of this magnitude typically occurring for 7 or fewer days.	Where possible, stagger the duration of the release or allow a break of 1-2 days to allow water to decrease. Maintain the proposed maximum drawdown release rate so that the bank full width of Six Mile Creek downstream of the dam is not exceeded. Monitor potential impacts to downstream environment(see section 4.3).	Low

ECOLOGICAL ASPECT	PROJECT PHASE	POTENTIAL IMPACT	IMPACT RISK BEFORE MITIGATION	MITIGATION AND MANAGEMENT	RESIDUAL IMPACT RISK
Aquatic habitat (including water quality)	Pre-construction – lake drawdown	Changes to water quality due to poor quality releases under both drawdown release scenarios.	Moderate	Minimise disturbance and downstream transfer of unconsolidated bed sediments in Lake Macdonald, for example by using a pontoon based pump station. Stabilise exposed sediments in Lake Macdonald as soon as possible, for example by seeding the exposed bed with non-invasive grasses following initial drawdown. Aerate water in Lake Macdonald to maintain dissolved oxygen (e.g. using existing bubble plume destratification unit). Aerate release water as it is transported and discharged downstream (e.g. by mixing or aeration as energy is dissipated). Discharge releases to the dam apron to dissipate energy and reduce potential for erosion and mobilisation of sediment. Arrange intakes of mechanical dewatering equipment to take from several lake water levels to discharge a blended water Implement water quality monitoring (see section 4.3).	Low

ECOLOGICAL ASPECT	PROJECT PHASE	POTENTIAL IMPACT	IMPACT RISK BEFORE MITIGATION	MITIGATION AND MANAGEMENT	RESIDUAL IMPACT RISK
Aquatic habitat (including water quality)		Erosion and scouring under both drawdown release scenarios.		Discharge releases to the dam apron to dissipate energy and reduce potential for erosion. Regularly monitor erosion and scouring at key locations (see section 4.3)	
		Changes to habitat structure under both drawdown release scenarios.	Moderate	Implement management measures identified for Flow Regime. Regularly monitor aquatic habitat at key locations (see section 4.3).	Low
MNES species: Mary River cod Australian lungfish Mary River turtle White-throated snapping turtle	Pre-construction – lake drawdown	Loss of or deterioration in habitat leading to decline in current populations and breeding.	Moderate	Implement management measures identified for Flow Regime and Aquatic Habitat.	Low
		Changes in flow conditions under both release scenarios leading to changes in behaviour, including breeding success.	Moderate	Implement management measures identified for Flow Regime and Aquatic Habitat. Avoid changes to hydrology during the breeding seasons for MNES species known to be in Six Mile Creek downstream of the dam.	Low

ECOLOGICAL ASPECT	PROJECT PHASE	POTENTIAL IMPACT	IMPACT RISK BEFORE MITIGATION	MITIGATION AND MANAGEMENT	RESIDUAL IMPACT RISK
Platypus and other aquatic fauna	Pre-construction – lake drawdown	Changes to habitat associated with both flow release scenarios	High	Implement management measures identified for Flow Regime and Aquatic Habitat. No bank disturbance downstream of the dam should be undertaken until a suitably qualified person has checked the banks for threatened fauna and fauna burrows in the construction area. If any burrows are identified, implement a 3 m x 3 m exclusion zone with flagging tape until approval to impact the burrow has been granted by the suitably qualified person. Conduct the drawdown program outside of platypus breeding season (August to October).	Low
Aquatic plants	Construction	Loss of aquatic plants due to flow release scenarios	Low	Implement management measures identified for Flow Regime and Aquatic Habitat.	Low

4.3 Monitoring and Management

As data from Cooran Gauging Station indicates that the release scenarios are likely to have negligible impact on Six Mile Creek at Cooran or further downstream, monitoring and management measures are focused on the Six Mile Creek stretch within several kilometres of the dam, where it is anticipated that the proposed flows will have minimal impact on habitat, but require monitoring and management during the works to confirm.

Monitoring

A monitoring program will be implemented to assess the potential impacts of the Lake Macdonald drawdown on Six Mile Creek downstream of the dam. The monitoring will be compared to the existing baseline data from surveys completed for the IAR.

An additional baseline assessment will be completed within one month of the lake lowering commencing to capture any changes that may have occurred in the intervening time. This baseline survey will use methods consistent with those for the IAR and establish the photographic and stream gauging (Doppler) monitoring points at selected sites.

Monitoring during the drawdown will comprise:

- Frequency
 - Daily monitoring at two sites on Six Mile Creek during releases – one immediately downstream of the dam (IAR site SMCD01) and one adjacent to Lake Macdonald Drive crossing of Six Mile Creek (IAR site SMCD02), approximately 1.5 km downstream of the dam. These sites have been assessed previously for the IAR and by DNRME.
 - Weekly monitoring of an additional two sites further downstream on Six Mile Creek during releases – one at the IAR site SMCD03 and one at the Louis Bazzo Drive crossing (IAR site SMCD04).
 - Targeted monitoring before and after the drawdown period and in response to photographic and stream gauging (Doppler) results.
- Methods
 - Photographs taken at each sites from a set point, possibly using an automated system.
 - An assessment of aquatic habitat in accordance with the methods used in the IAR and for the NPI monitoring program, which are approved for MNES species in the Mary River catchment. This will include an assessment of erosion and substrate composition (where visible).
 - In situ measurements of water quality as proposed in the IAR and the collection of water quality samples for total suspended solids.
 - Stream gauging using a StreamPro Doppler (or similar) that measures discharge and stream velocities throughout the water column and any stream bed movement.
- Reporting
 - Results will be provided to contractor's environmental representative and Seqwater representative on a daily basis (as results are generated), with a weekly summary at the end of the week.

All monitoring will be completed by suitably qualified persons.

Management

In addition to existing thresholds identified in the project Environmental Management Plan, Species Management Plan and Lake Macdonald Lowering – Adaptive Management Plan, trigger thresholds will be established for key habitat components that support MNES species (e.g. evidence of woody debris changing position or moving more than 50 cm downstream, a measurable change in stream bed movement compared to baseline). Where monitoring results indicate potential impacts on habitat conditions in Six Mile Creek, the releases will be reduced or paused until the cause of the issue can be addressed appropriately, on a case by case basis.

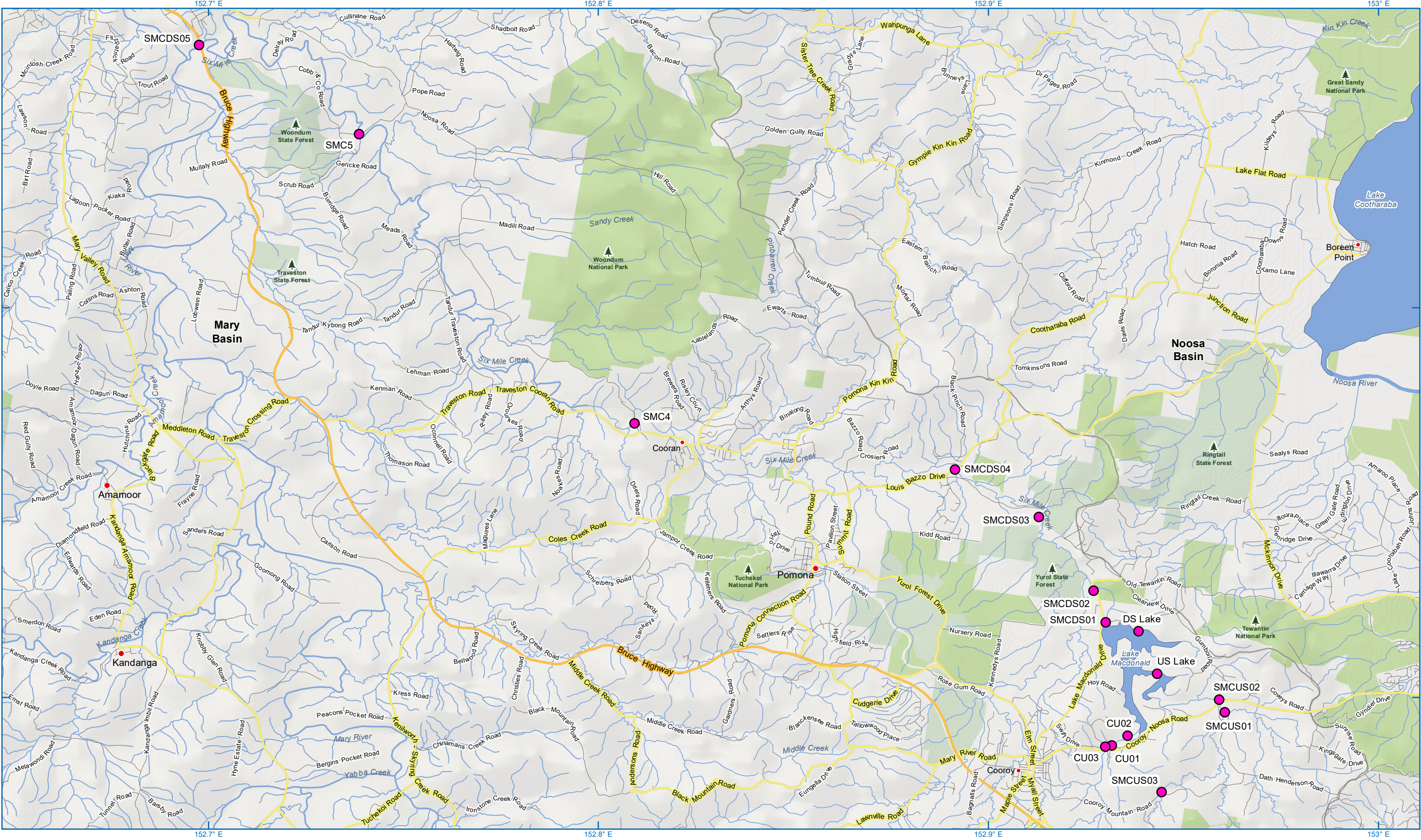
If impacts are noted and flow throttling mitigation is not effective, several options are available including habitat improvements after lowering, through Seqwater's existing relationship with MRCCC and Noosa and District Landcare.

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.

Replenishment of Mary River Cod can also be supported through the Gerry Cook Mary River Cod Hatchery.

The Lake Macdonald Lowering – Adaptive Management Plan will be updated before the lake lowering commences to incorporate the additional monitoring and management measures discussed in this document and will be supported by an updated species management plan for MNES species.

Appendix A Aquatic Habitat in Six Mile Creek Downstream of the Dam



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Lake MacDonald Dam Upgrade Project

Map 4.1: Survey sites

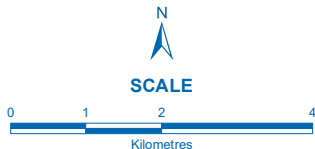
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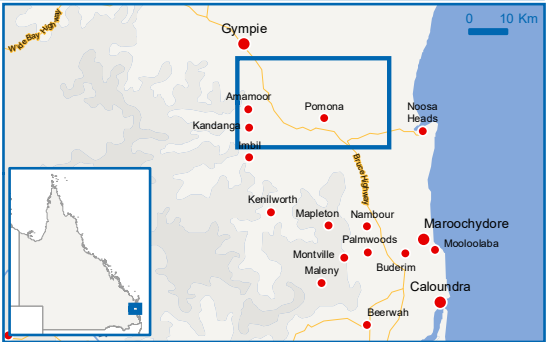
LEGEND

- Sites
 - Watercourse
 - Lake/Reservoir
 - Basin
- Road Network**
- Highway
 - Main Road
 - Local Road
- Protected Area**
- National Park
 - Other Reserve



PROJECTION
Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: Degree

DATE
2018-08-08
DRAWN BY
LP
VERSION
02



Six Mile Creek – Downstream of Lake Macdonald

Site: SMC4	Years surveyed				
	October 2013	November 2014	November 2015	October 2016	November 2017
Photograph (upstream view)					
Habitat features					
Adjacent land use	native forest, road	native forest	native forest, grazing	native forest, railroad, rural residential	native forest, grazing
Riparian vegetation cover	moderate	extensive	extensive	moderate	low to moderate
Dominant type of riparian vegetation	grass, shrubs, trees	shrubs, trees	grass, shrubs, trees	grass and trees	grass and trees
Mean wetted width (m)	6 m	8 m	9 m	12 m	9 m
Flow habitats	–	connected pool, run	connected pool, riffle, run	connected pool	connected pool, riffle, run
Mean water velocity (m/s)	no flow	0.01 m/s	0.12 m/s	0.015 m/s	0.155 m/s
Water level	low	at watermark	low	low	at watermark
Bed substrate composition	sand (60%), silt/clay (40%)	bedrock (5%), sand (85%), silt/clay (5%)	bedrock (5%), sand (80%), silt/clay (15%)	sand (90%), silt/clay (10%)	sand (90%), silt/clay (10%)
Stream bed stability	stable	stable	stable	stable	moderate erosion
Bank material	sand	sand, silt/clay	sand, silt/clay	sand, silt/clay	sand, silt, bedrock
Bank slope	steep to vertical	steep	moderate to steep	steep	flat and steep
Bank shape	convex and undercut	convex and concave	stepped and convex	convex and concave	convex
Extent of bank erosion	moderate	low to high	none to low	low	low
Aquatic Plant cover in water	none	none	none	none	none
Aquatic plant cover on banks	–	none	low	low	low to moderate
Physical in-stream habitat features	individual logs and log jams, 5% cover trailing bank vegetation	individual branches and branch piles, individual logs and log jams, terrestrial leaves and twigs, 5% cover trailing bank vegetation	individual branches and branch piles, individual logs and log jams, terrestrial leaves and twigs, 5% cover trailing bank vegetation	individual branches and branch piles, individual logs and log jams, terrestrial leaves and twigs, 5% cover trailing bank vegetation	individual branches and branch piles, individual logs, terrestrial leaves and twigs, 5% cover trailing bank vegetation
In-stream barriers to aquatic fauna passage	bridge	bridge	bridge	bridge	bridge
Other disturbances	erosion, roads	erosion, roads	erosion, roads	erosion, roads	weeds, erosion, roads

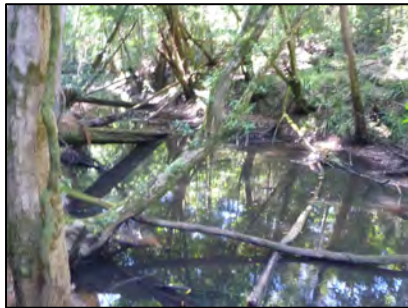
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Site: SMC5	Years surveyed				
	October 2013	November 2014	November 2015	October 2016	November 2017
Photograph (upstream view)					
Habitat features					
Adjacent land use	native forest	native forest, grazing	native forest, grazing	native forest, rural residential	native forest, grazing
Riparian vegetation cover	moderate	low to moderate	extensive	moderate	moderate
Dominant type of riparian vegetation	shrubs, trees	shrubs, trees	shrubs, trees	grass and trees	grass, shrubs, trees
Mean wetted width (m)	7 m	10 m	8 m	10 m	10 m
Flow habitats	–	connected pool, riffle, run	connected pool, riffle, run	connected pool, riffle, run	connected pool, riffle, run
Mean water velocity (m/s)	slow	0.05 m/s	0.45 m/s	0.034 m/s	0.35 m/s
Water level	low	low	low	low	at watermark
Bed substrate composition	boulder (2%), cobble (5%), pebble (3%), gravel (20%), sand (70%)	pebble (5%), gravel (25%), sand (50%), silt/clay (20%)	boulder (7%), cobble (5%), pebble (5%), gravel (5%), sand (60%), silt/clay (18%)	boulder (2%), cobble (3%), pebble (5%), gravel (5%), sand (75%), silt/clay (10%)	bedrock (5%), boulder (15%), cobble (10%), pebble (5%), sand (50%), silt/clay (5%)
Stream bed stability	stable	stable	stable	stable	moderate erosion
Bank material	boulder, cobble, sand	pebbles, gravel, sand, silt	sand, boulder (deposited by trucks)	sand, silt/clay	gravel, sand, clay
Bank slope	steep	moderate to steep	moderate to steep	steep	steep to vertical
Bank shape	convex	stepped	convex and concave	convex and concave	concave
Extent of bank erosion	low	none to low	low	low	low
Aquatic Plant cover in water	none	none	none	none	low
Aquatic plant cover on banks	–	none	low	low	low
Physical in-stream habitat features	large woody debris, terrestrial leaves and twigs, 5% cover trailing bank vegetation	individual branches and branch piles, individual logs and log jams, terrestrial leaves and twigs, 5% cover trailing bank vegetation	individual branches and branch piles, individual logs and log jams, terrestrial leaves and twigs, 50% cover trailing bank vegetation	individual branches and branch piles, individual logs and log jams, terrestrial leaves and twigs, 5% cover trailing bank vegetation	branch piles, individual logs and log jams, terrestrial leaves and twigs, 15% cover trailing bank vegetation
In-stream barriers to aquatic fauna passage	bridge, build up of rocks and logs at the base of the bridge	bridge	bridge	bridge	bridge
Other disturbances	erosion, roads	erosion, roads, access tracks	erosion, roads, weeds, cleared vegetation	erosion, weeds, roads	weeds, roads

– no data

Site: SMCD05	Years surveyed
	August 2015
Photograph (upstream view)	
Habitat features	
Adjacent land use	industrial, native forest, camping
Riparian vegetation cover	low
Dominant type of riparian vegetation	grass, shrubs, trees
Mean wetted width (m)	4 m
Flow habitats	connected pool, riffle, run
Mean water velocity (m/s)	2.0 m/s
Water level	low
Bed substrate composition	boulder (5%), cobble (10%), pebble (15%), gravel (15%), sand (45%), silt/clay (10%)
Stream bed stability	moderate erosion
Bank material	cobble, pebble, gravel, sand, silt/clay
Bank slope	steep
Bank shape	concave
Extent of bank erosion	moderate
Aquatic Plant cover in water	none
Aquatic plant cover on banks	low
Physical in-stream habitat features	individual branches and branch piles, individual logs and log jams, terrestrial leaves and twigs, 5% cover trailing bank vegetation
In-stream barriers to aquatic fauna passage	nil
Other disturbances	erosion, roads, weeds

Site: SMCD04	Years surveyed		
	August 2015	October 2015	February 2018
Photograph (upstream view)			
Habitat features			
Adjacent land use	native forest	native forest	native forest, road
Riparian vegetation cover	moderate	moderate	moderate
Dominant type of riparian vegetation	shrubs, ferns, trees	trees	grass, trees, shrubs
Mean wetted width (m)	15 m	15 m	10 m
Flow habitats	connected pool, run	connected pool	connected pool
Mean water velocity (m/s)	0.1 m/s	0.01 m/s	0.05 m/s
Water level	low	at watermark	at watermark
Bed substrate composition	sand (20%), silt/clay (80%)	sand (10%), silt/clay (90%)	artificial boulder (5%), cobble (5%), pebble (5%), gravel (5%), sand (15%), silt/clay (65%)
Stream bed stability	moderate aggradation	moderate aggradation	stable
Bank material	silt	silt	clay/silt
Bank slope	steep	vertical	moderate to steep
Bank shape	convex	wide lower bench, undercut 20–30%	convex
Extent of bank erosion	low	moderate	some
Aquatic Plant cover in water	none	none	none
Aquatic plant cover on banks	low	low	low to moderate
Physical in-stream habitat features	individual branches and branch piles, individual logs and log jams, terrestrial leaves and twigs, 15% cover trailing bank vegetation	individual branches and branch piles, individual logs and log jams, terrestrial leaves and twigs, 10% cover trailing bank vegetation	individual branches and branch piles, dense terrestrial leaves and twigs, individual logs and log jams, 10% trailing bank vegetation, turtle basking spots present
In-stream barriers to aquatic fauna passage	nil	nil	nil
Other disturbances	roads	roads	roads, erosion

Site: SMCD03	Years surveyed		
	August 2015	October 2015	February 2018
Photograph (upstream view)			
Habitat features			
Adjacent land use	native forest	native forest	native forest
Riparian vegetation cover	extensive	extensive	extensive
Dominant type of riparian vegetation	shrubs, trees	trees	shrubs, trees
Mean wetted width (m)	6 m	3 m	8 m
Flow habitats	connected pool, run	connected pool, riffle, run	connected pool, riffle, run
Mean water velocity (m/s)	0.2 m/s	0.2 m/s	0.02 m/s
Water level	low	at watermark	at watermark
Bed substrate composition	boulder, cobble, pebble, gravel, sand, silt/clay	boulder (3%), cobble (6%), pebble (5%), gravel (5%), sand (50%), silt/clay (31%)	gravel (5%), sand (15%), silt/clay (80%)
Stream bed stability	stable to moderate aggradation	moderate aggradation	moderate aggradation
Bank material	gravel, sand, silt/clay	sand, silt	silt/clay
Bank slope	steep	steep	steep to vertical
Bank shape	concave	concave	concave
Extent of bank erosion	low	moderate	moderate
Aquatic Plant cover in water	none	none	none
Aquatic plant cover on banks	low	low	low
Physical in-stream habitat features	individual branches and branch piles, individual logs and log jams, terrestrial leaves and twigs, 10% cover trailing bank vegetation	individual branches and branch piles, individual logs and log jams, terrestrial leaves and twigs, 10% cover trailing bank vegetation	individual branches and branch piles, sparse terrestrial leaves and twigs, individual logs and log jams, 5% cover trailing vegetation, turtle basking spots present
In-stream barriers to aquatic fauna passage	bridge	bridge	bridge
Other disturbances	access tracks	erosion, roads	erosion

Site: SMCD02	Years surveyed		
	August 2015	October 2015	February 2018
Photograph (upstream view)			
Habitat features			
Adjacent land use	native forest	native forest, residential	native forest
Riparian vegetation cover	low	moderate	moderate
Dominant type of riparian vegetation	shrubs, trees	shrubs, trees	shrubs, trees
Mean wetted width (m)	4 m	4 m	4 m
Flow habitats	connected pool, riffle, run	connected pool, riffle, run	connected in-channel pool, riffle, run
Mean water velocity (m/s)	0.5 m/s	0.01 m/s	0.05 m/s
Water level	low	at watermark	at watermark
Bed substrate composition	boulder (10%), cobble (10%), pebble (10%), gravel (15%), sand (50%), silt/clay (5%)	cobble (5%), pebble (2%), gravel (10%), sand (77%), silt/clay (10%)	cobble (5%), pebble (20%), gravel (25%), sand (25%), silt/clay (25%)
Stream bed stability	moderate erosion	moderate aggradation	stable
Bank material	sand, silt	cobble, sand, silt	clay/silt
Bank slope	moderate to steep	moderate	moderate
Bank shape	convex	concave and undercut 20–25%	uncut 10%, wide lower bank, convex and concave on the left bank; convex and concave on the right bank
Extent of bank erosion	low	moderate	–
Aquatic Plant cover in water	none	none	low
Aquatic plant cover on banks	low	low	low to moderate
Physical in-stream habitat features	individual branches and branch piles, individual logs and log jams, terrestrial leaves and twigs, 10% cover trailing bank vegetation	individual branches and branch piles, individual logs and log jams, terrestrial leaves and twigs, 15% cover trailing bank vegetation	individual branches and branch piles, individual logs and log jams, 10% cover trailing bank vegetation
In-stream barriers to aquatic fauna passage	nil	nil	nil
Other disturbances	erosion, roads	cleared vegetation, roads	tyre debris, roads

– no data

Site: SMCD01	Years surveyed			
	August 2015	October 2015	February 2018	February 2018
Photograph (upstream view)				
Habitat features				
Adjacent land use	native forest, rural	native forest, recreation, SEQ Water	dam, native forest	native forest, national park
Riparian vegetation cover	moderate	moderate	little upstream, extensive downstream	extensive
Dominant type of riparian vegetation	grass, shrubs, trees	shrubs, trees	grasses and trees upstream, trees and others downstream	trees, shrubs
Mean wetted width (m)	6 m	5 m	17 m	12 m
Flow habitats	connected pool, run	connected pool, riffle, run	connected pool, riffle	isolated in-channel pool
Mean water velocity (m/s)	0.5 m/s	0.15 m/s	0.01 m/s	0.01 m/s
Water level	low	at watermark	at watermark	–
Bed substrate composition	boulder (5%), cobble (5%), pebble (10%), gravel (10%), sand (30%), silt/clay (4%)	boulder (2%), pebble (3%), gravel (10%), sand (70%), silt/clay (15%)	boulder (15%), cobble (10%), pebble (15%), gravel (25%), sand (10%) silt/clay (25%)	gravel (10%), sand (10%), silt/clay (80%)
Stream bed stability	stable	moderate aggradation	stable	high
Bank material	pebble, gravel, sand, silt	gravel, sand, silt	clay, silt, pebble, cobble, concrete boulder	silt/clay
Bank slope	steep	moderate	steep, vertical	moderate to steep
Bank shape	convex	concave and undercut 20–25%	convex	–
Extent of bank erosion	none	low	moderate	–
Aquatic Plant cover in water	low	moderate	low	moderate
Aquatic plant cover on banks	low	high	low to moderate	moderate
Physical in-stream habitat features	individual branches and branch piles, individual logs and log jams, terrestrial leaves and twigs, 15% cover trailing bank vegetation	individual branches and branch piles, individual logs and log jams, terrestrial leaves and twigs, 25% cover trailing bank vegetation	individual branches, terrestrial leaves and twigs, 5% cover trailing bank vegetation	large woody debris, 50% cover trailing bank vegetation
In-stream barriers to aquatic fauna passage	dam wall upstream of site	dam wall upstream of site	dam wall upstream of site	old culvert upstream
Other disturbances	weeds	cleared vegetation, roads	roads	culvert

– no data

Appendix 3 Updated IAR Appendix O – Fish Passage Assessment

APPENDIX O

Fish Passage Assessment



Summary Page

Appendix O documentation is provided in the context of spillway safe fish passage assessments for the Project. Spillway assessments have been iterative and undertaken over a long period of time.

The following documents are provided as background on the Six Mile Creek Dam upgraded spillway and to facilitate assessment of relevant approvals.

1. Potential impacts of downstream passage of fauna over a labyrinth spillway at Lake Macdonald, Six Mile Creek
2. Addendum to Potential impacts of downstream passage of fauna over a labyrinth spillway at Lake Macdonald, Six Mile Creek
3. Addendum two – Lake Macdonald (Six Mile Creek Dam) Evaluation of Labyrinth and Ogee Options for the Lower Level Spillway
4. Addendum three – Observations from Six Mile Creek Dam spillway physical model

Item 1 outlines the background of potential impacts on aquatic fauna from downstream passage through a spillway.

The report provides assessment in the context of a labyrinth spillway option, but also provides general criteria for potential impacts of any spillway. This assessment identified the potential impacts to inform the design of a labyrinth spillway.

Item 2 provides an update on the labyrinth spillway option design with respect to the potential impacts identified in Item 1.

In general, the labyrinth spillway option successfully addressed most potential impacts, such as abrasion, water quality and stranding, while a key potential issue of direct strike remained in relation to spillway flows at certain parts of the labyrinth spillway geometry (upstream apexes). Model simulation showed the flow in the upstream apex areas is difficult to disperse in tailwater before impinging on the concrete apron of the stilling basin.

Item 3 provides a design evaluation of an optimised labyrinth spillway option, including the challenges for meeting safe fish passage requirements in conjunction with hydraulic and other design considerations. The document also considers an alternative spillway option for an ogee crest and the reasoning for assessment the alternative option.

Of particular interest for this fish passage appendix are the following sections of the document: Section 2.0 (design criteria), Section 3.0 (design constraints), Section 4.0 (history of spillway design development) and Section 5.0 (hydraulic performance).

Item 4 provides a commentary on observations for safe fish passage in the labyrinth and ogee crest spillway options.

These observations were used to inform a preferred design option (as outlined in Item 3) and also used to inform code assessment for waterway barrier works.

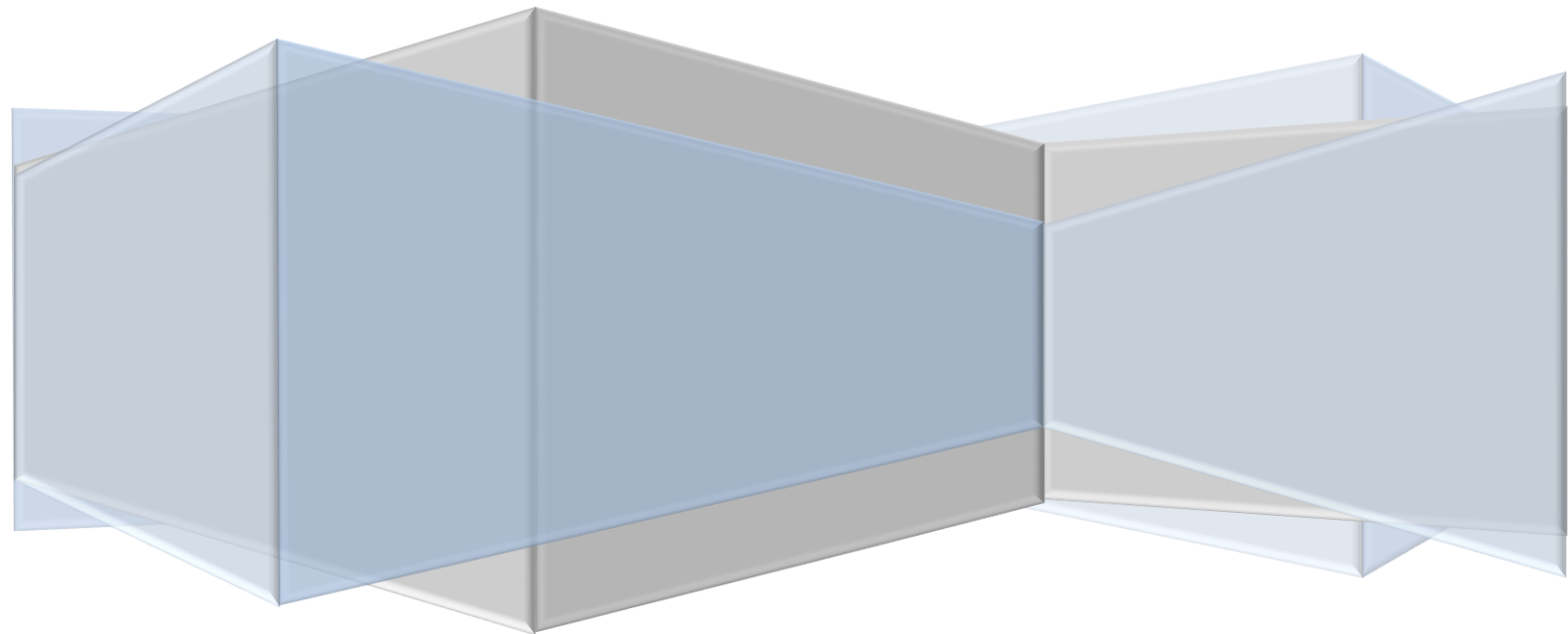


**Potential impacts of downstream passage
of fauna over a labyrinth spillway at
Lake Macdonald
Six Mile Creek**

A. P. Berghuis

December 2017

**Aquatic Biopassage Services
for Seqwater**



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1. Executive summary

Seqwater is undertaking a Dam Safety Upgrade for Lake Macdonald to bring the structure into compliance with current industry guidelines and the requirements of the Water Supply (Safety and Reliability) Act 2008. The upgrade will preserve the storage at its current capacity and height but the spillway configuration will be changed to a labyrinth design. The particulars of the proposed upgrade have been determined to trigger assessable development under the Planning Act 2016, and subsequent consequences under the Fisheries Act 1994.

Aquatic Biopassage Services has been retained by Seqwater to provide services associated with the provision of effective and safe passage of fish beyond Six Mile Creek Dam. The current report provides technical input on the spillway design with respect to aquatic fauna downstream passage.

Aquatic fauna such as fish, turtle, crustaceans, platypus and water rats may be affected by passage over the spillway wall at Six Mile Creek Dam. However, the bulk of knowledge on impacts of dams is on fish and to some degree turtles. In regards to spillway passage it is likely that any works to minimise impact on fish and turtles will be of similar benefit to other aquatic fauna.

A labyrinth dam incorporates a spillway that is folded in plan-view to increase the length of the crest, resulting in a higher discharge capacity relative to straight profile dam walls. A literature review failed to identify any labyrinth spillway designs that specifically addressed safe downstream passage for aquatic fauna. The labyrinth design incorporates a vertical drop to the tailwater and substantial research has been performed on vertical drop spillways.

Eight potential sources of fish injury at dam spillways have been identified in North America. Each of the causes were evaluated in an Australian context and potential implications for the design of the upgraded spillway at Six Mile Creek Dam are provided.

The concept designs developed for the Six Mile Creek Dam upgrade have already considered some of the potential issues with safe downstream passage of aquatic fauna. Further development of the design requires close attention to ensure that:

- the spillway crest shape is the most suitable profile;
- the stilling basin depth is increased to provide sufficient plunge pool depth;
- turbulence in the stilling basin is minimised during all flows;
- sources of direct strike impact for fauna are minimised;
- the potential for predation is minimised by reducing fish aggregations;
- only surface quality water is release from the dam outlet;
- the potential for dewatering and stranding of fauna when flows cease is minimised;
- the potential for entrainment of fauna within the intake structure is minimised.

2. Proposed development

Seqwater is undertaking a Dam Safety Upgrade for Six Mile Creek dam, also known as Lake Macdonald, located on Six Mile Creek near Cooroy. The upgrade will address specific dam safety risks to bring the structure into compliance with current industry guidelines and the requirements of the Water Supply (Safety and Reliability) Act 2008.

The spillway upgrade will preserve the storage at its current 8,000 ML capacity and its Full Supply Level (FSL) of 95.32 m AHD. The spillway configuration will change, but spillway height, spill conditions and discharge to Six Mile Creek will remain the same. The particulars of the proposed upgrade have been determined to trigger assessable development under the Planning Act 2016, and subsequent consequences under the Fisheries Act 1994.

Aquatic Biopassage Services has been retained by Seqwater to provide the following:

1. Provide technical input on assessment and selection of a fishway for the Six Mile Creek Dam upgrade
2. Provide technical advice and input into the detailed design process
3. Provide technical input on spillway design with respect to aquatic fauna downstream passage
4. Support engagement with the regulator (DAF), through technical advice on fishway options assessment

The current report addresses Step 3 above.

3. Proposed works

During a Portfolio Risk Assessment (PRA) of its 26 referable dams, Seqwater identified numerous failure modes for Six Mile Creek Dam and the estimated societal risk was assessed to be unacceptable against the ANCOLD risk criteria. Upgrade options all involve increasing the spillway capacity, to meet the 100% acceptable flood capacity (AFC) requirement, which is estimated at approximately 1:10,000,000 Annual Exceedance Probability (AEP) event.

Site conditions and geotechnical constraints require a highly efficient spillway to limit the overall spillway width and the size of flow dissipation infrastructure. A labyrinth weir was selected as the most hydraulically and cost effective spillway option for achieving AFC requirements.

In addition to a new spillway structure, the proposed dam safety upgrade detailed by AECOM (2016) includes:

- Reconstruction of the right embankment
- Buttressing and partial reconstruction of the left embankment
- Construction of a new saddle dam

4. Labyrinth dams

A labyrinth dam incorporates a spillway that is folded in plan-view to increase the length of the crest, resulting in a higher discharge capacity relative to straight profile dam walls. The hydraulic efficiency of labyrinth weirs provide an effective means of increasing spillway capacity under restricted operating conditions. This type of weir is particularly suited to sites where a low head to high discharge relation is required and the topography restricts the spillway width. An infinite number of geometric configurations can be utilised for a labyrinth type spillway; three general classifications based upon cycle shape are triangular, trapezoidal, and rectangular (Figure 1). Triangular and trapezoidal shaped labyrinth cycles are more considered more hydraulically efficient than rectangular labyrinth weir cycles (Crookston, 2010).

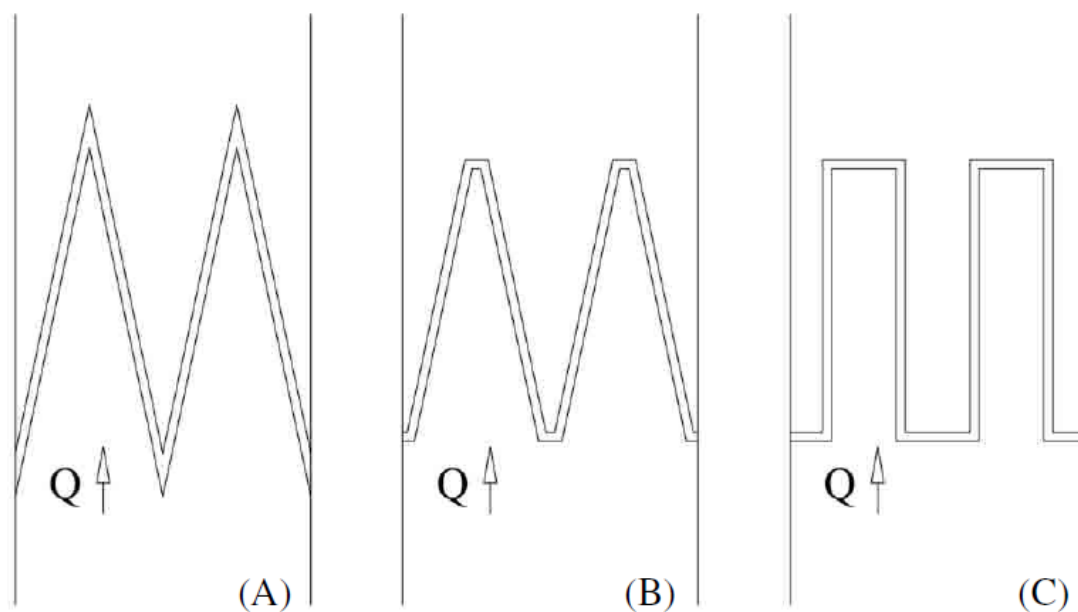


Fig. 2-1. General classifications of labyrinth weirs: Triangular (A), trapezoidal (B), and rectangular (C)

Figure 1. Classifications of labyrinth type spillways, from Crookston, 2010.

A literature review of structures with Labyrinth type spillways identified that they are relatively common overseas and are used extensively at sites where they may be advantageous. Despite potential application at many sites, labyrinth spillways are uncommon in Australia. In 2013, the 13.5 m high Loombah Dam located on Ryan's Creek, approximately 25 km south east of Benalla, Victoria was retrofitted with a rectangular type spillway known as the piano key design (Buchanan *et. al.* 2013). No considerations for fish passage in either direction was implemented into the upgraded structure (Justin O'Connor, Victorian Department of Environment, Land, Water and Planning pers. com.).

Some of the dams and weirs overseas with labyrinth spillways have incorporated fishways for upstream passage, however no mention of downstream fish passage was found for any labyrinth spillway. Many of the retrofitted dams appeared to incorporate a low height labyrinth spillway on top of a previously conventional crest. Very few of the labyrinth spillway designs viewed online incorporate a stilling basin or any type of plunge pool that may protect downstream migrating fauna below the labyrinth spillway, refer Figure 2.



Figure 2. Example of a labyrinth type spillway with no stilling basin or plunge pool, image from Crookston and Tullis (2013).

The spillway crest shape is one of the most important factors that affects the discharge capacity for labyrinth weirs. Figure 3 below illustrates the various crest shapes utilised in labyrinth spillways (Crookston, 2010).

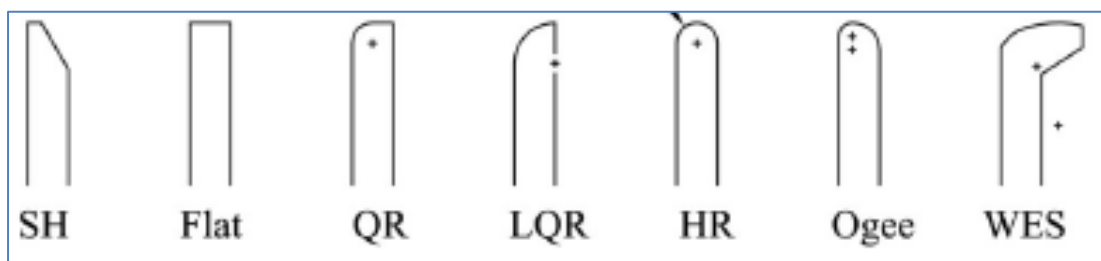


Figure 3. Configurations of crests on labyrinth type spillways, from Crookston, 2010.

SH = sharp, QR = quarter round, LQR = large quarter round, HR = half round, WES = truncated Ogee.

5. Safe passage for fish over spillways

Literature review

Passage over spillways can directly cause fish injury or mortality, or indirectly by increasing susceptibility of disorientated or shocked fish to predation. The manner in which energy is dissipated in the spillway can have a determinant effect on fish injury and mortality rates (Larinier 2000).

The literature review undertaken in the current report failed to identify any locations that utilised labyrinth spillways where the downstream passage of fish was considered. The predominant spill from a labyrinth spillway is a free overfall design with vertical drop to the surface below. Accordingly, most of the aspects that impact on fish survival at any vertical fall spillway apply to the labyrinth spillway design.

A vertical fall from a spillway into a deep plunge pool or tailwater can have negative impacts on fish health. Experiments have shown that significant damage such as injuries to gills, eyes and internal organs occurs when the impact velocity of the fish on the water surface in the downstream pool exceeds 16m/s (Bell & Delacy, 1972). A column of water reaches this critical velocity for fish after a drop of 13 m, beyond this limit injuries may become significant and mortality will increase rapidly in proportion to the drop (Ruggles, 1983).

Passage through a spillway under free-fall conditions (separate from the column of water) is less hazardous for small fish. For larger fish, the hazards are identical whether they pass under free-fall conditions or are contained in the column of water. Passage is generally less hazardous for fish if there is a pool of sufficient volume at the base of the spillway (Larinier 2000). Numerous sources of literature reference the previous statement in Larinier (2000), however no guides were found that assisted in the determination of a sufficient pool volume for a given spillway height.

Australian context

Very little research has been performed on the downstream passage of fish in Australia; however, some of the studies that have been performed have application to Six Mile Creek Dam.

A study of survivorship of fish passing through weirs with overshot (overflow) releases compared to those passing through undershot gates was performed in the Murray River (Baumgartner *et.al.* 2006). The findings were that the majority of larval fish including more than half of the Murray cod (*Maccullochella peelii*) tested died during undershot weir passage. Small-bodied native fish displayed extremely high mortality when passing through undershot weirs and adult life stages of large-bodied species were also affected by undershot weirs but to a much lesser degree.

Results for downstream passage through overshot weirs indicated that few fish died and the main welfare issues arose when water from overshot weirs fell into shallow water, where fish became physically injured when impacting the downstream weir apron. One of the recommendations of the research was that the construction of overshot release weirs with deep plunge pools would provide safer conditions for all fish species and size classes moving downstream (Baumgartner *et.al.* 2006, 2014).

Monitoring of downstream fish passage over the stepped spillway at the 37 m high Paradise Dam on the Burnett River documented fish injury and mortality caused by striking the steps during overtopping flow conditions (SunWater, 2012). Collection of small to medium sized fish that passed over the dam wall during flow events found that 81.9% of fish collected in drift nets were deceased and 94.5% of fish had serious injuries such as abrasion, scaling and head damage.

Large bodied fish species were observed striking the Paradise Dam spillway and were collected deceased during flows up to 1.3 metres over the spillway. The Queensland lungfish was the largest species to pass over the spillway and had the second highest representation of mortality and injuries compared to 15 other medium to large bodied species (SunWater, 2012).

The findings of the study were that fish mortalities were occurring during all flows over the Paradise Dam stepped spillway regardless of the flow condition. The cumulative effect of mortalities of fish passing over the spillway was considered likely to have a major impact on populations of fish in the lower Burnett River over the longer term (SunWater, 2012).

Sources of injury at spillways

Ruggles and Murray (1983) identified eight potential sources of fish injury at dam spillways in North America. Each of the causes are listed below, potential solutions are summarised to suit an Australian context below. Implications for the design of the upgraded spillway at Six Mile Creek Dam are provided in Table 3.

Abrasion against spillway

Caused by direct contact with spillway surfaces, particularly at sites with stepped spillways. Injury can be avoided by minimising the length of concrete chutes, the use of ski-jump spillways where possible, use of streamlined channels to provide a smooth contact surface and by minimising chute velocities.

Impact against base of spillway

Caused by physical impact against stilling basin floor and sills as well as energy dissipators and outlet structures. Injury can be avoided by eliminating any potential sources of direct strike during spillway fall as well as a stilling basin with sufficient depth to minimize impact on the basin floor. The location and design of flow dissipators and stilling basin nib walls should be such that fish that are washed downstream are guided around the structures with minimal risk of a direct strike.

Turbulence and shearing forces in tailwater

Caused by turbulence in the stilling basin at the base of the dam and sudden variations in velocity and pressure as the fish hits the water. Injury can be avoided by increasing the volume and depth of water in the stilling basin and by increasing the length of crest of the spillway.

Impact of fish in free fall entering a stilling basin

Injuries occur when fall velocities over spillways exceed 16m/s, which occurs at heights >13 m. Injuries can be avoided by limiting the free fall of fish to < 13 m, at higher dams use ogee or other type of spillway to eliminate or limit the height of the free-fall portion.

Gas-bubble disease below spillways

Caused by total dissolved gas supersaturation which occurs when water cascades over a dam or waterfall and fish move from one water pressure gradient to another, the impact on fish is analogous to 'the bends' in human divers. Injuries can range from mild to fatal depending on the level of supersaturation, species, life cycle stage, condition of the fish, fish depth and the water temperature. Gas bubble disease has not been reported to occur at Australian dams and may be limited to cold-water sites where the potential for gas supersaturation is increased (author pers. obs.).

Predation above and below spillways

All waterway barriers, natural and anthropogenic, cause delays that create aggregation zones for migrating fish that increase the risk of predation by fish and piscivorous birds. In addition, fish passing over the spillway may be temporarily disoriented and unable to avoid predators. Injuries and death can be minimised by providing effective passage beyond the barrier that reduces delays and if necessary by providing shelter habitat for aggregating fish.

Reduced water quality below spillways

Caused by poor quality water being released from dams either via outlets or over the spillway. Fish injury and mortalities may be reduced by only releasing high quality water via selectable intakes and by avoiding outlet and spillway releases following events such as impoundment rollover.

Dewatering and stranding of fish within and below spillways

Caused by poorly designed multi-level spillways that hold fish during flow and do not permit fish to exit when flow ceases. Dams with large impoundments may cause fish to wash over a non-flowing crest when at full supply during events such as wind seiching. Stilling basins that do not completely drain when flow ceases also have the potential to strand and kill fish when water quality decreases. Injuries and death can be avoided by ensuring that the spillway and stilling basin are designed so that any entrapment of fish is avoided. In situations where entrapment is unavoidable, it may be necessary to provide a flow release from the dam to maintain water quality in the tailwater pool or to implement fish salvage activities according to DAF Guidelines.

6. Aquatic fauna of Six Mile Creek

Fish species

Biological and habitat surveys were completed in Six Mile Creek and in the Lake Macdonald storage by FRC Environmental (2016). A desktop assessment and expert review supported by two onsite surveys determined that 28 native and four alien or noxious species occur in Six Mile Creek.

Table 1. Fish species present in Six Mile Creek from FRC Environmental (2016),

☺ = translocated native species, ☹ = alien/noxious species.

Length size class: small = <100 mm, medium = 100 mm to <300 mm, large = 300 mm to 1000 mm.

Species	Common Name	Size as adults
<i>Ambassis agassizii</i>	Agassiz's glassfish	small
<i>Ambassis marianus</i>	estuary glassfish	small
<i>Anguilla australis</i>	southern shortfin eel	large
<i>Anguilla reinhardtii</i>	longfin eel	large
<i>Glossamia aprion</i>	mouth almighty	small
<i>Craterocephalus marjoriae</i>	silverstreak hardyhead	small
<i>Craterocephalus stercusmuscarum</i>	flyspecked hardyhead	small
<i>Gobiomorphus australis</i>	striped gudgeon	small
<i>Hypseleotris spp.</i>	common carp gudgeons	small
<i>Hypseleotris compressa</i>	empire gudgeon	small
<i>Mogurnda adspersa</i>	purple spotted gudgeon	small
<i>Philypnodon macrostomus</i>	dwarf flathead gudgeon	small
<i>Philypnodon grandiceps</i>	flathead gudgeon	small
<i>Melanotaenia duboulayi</i>	crimson spotted rainbowfish	small
<i>Maccullochella mariensis</i>	Mary River cod	large
<i>Macquaria novemaculeata</i>	Australian bass	medium
<i>Macquaria ambigua</i>	yellow belly☺	medium
<i>Tandanus tandanus</i>	eel tailed catfish	medium
<i>Neosilurus hyrtlai</i>	Hyrtl's tandan	small
<i>Pseudomugil signifer</i>	Pacific blue eye	small
<i>Retropinna semoni</i>	Australian smelt	small
<i>Nematalosa erebi</i>	bony bream	medium
<i>Neoceratodus forsteri</i>	Queensland lungfish	large
<i>Trachystoma petardi</i>	pinkeye mullet	large
<i>Mugil cephalus</i>	sea mullet	large
<i>Notesthes robusta</i>	bullrout	medium
<i>Leiopotherapon unicolor</i>	spangled perch	medium
<i>Scleropages leichardti</i>	southern saratoga☺	large
<i>Gambusia holbrooki</i>	eastern Gambusia☹	small
<i>Xiphophorus maculatus</i>	platy☹	small
<i>Xiphophorus hellerii</i>	swordtail☹	small
<i>Poecilia reticulata</i>	guppy☹	small

Fish passing downstream over Six Mile Creek Dam will consist of larval life stages up to large fish such as Mary River cod and lungfish greater than 1 m in length.

Turtle species

A desktop assessment and expert consultation by FRC Environmental (2016) indicated that six native turtle species were present in Six Mile Creek (Table 2) and that no introduced turtle species are known to occur or likely to occur. Surveys determined that the upstream zone had the highest diversity and abundance of turtles and that the saw shelled turtle was the most abundant species.

Table 2. Turtle species present in Six Mile Creek from FRC Environmental (2016)

<i>Species</i>	Common Name
<i>Chelodina expansa</i>	broad shelled river turtle
<i>Chelodina longicollis</i>	eastern long necked
<i>Emydura macquarii krefftii</i>	Krefft's River turtle
<i>Wollumbinia latisternum</i>	saw shelled turtle
<i>Elusor macrurus</i>	Mary River turtle
<i>Elseya albagula</i>	white throated snapping turtle

Impoundment infrastructure has the potential to cause injury and death of turtles that aggregate at the site. Falls from spillways and abutments can cause shell fracture injuries, gated structures may cause crush injuries, and stepped spillways may cause injury during flow events and trap turtles when flow ceases (Latta, 2009). Screens, which prevent trash entering and blocking water, release intakes on the upstream side of impoundment infrastructures can trap large numbers of turtles and cause their death (Limpus, 2008).

Other aquatic fauna such as crustaceans, platypus and water rats may also be affected by passage over the spillway wall at Six Mile Creek Dam. However, little is known in regards to spillway passage of these species. It is likely that any works to minimise impact on fish and turtles will be of similar benefit to other aquatic fauna.

7. Design for the spillway upgrade at Six Mile Creek Dam

Reference to the spillway upgrade in this section refers to Drawing Set 60451967 - 101 to 122 that were developed by AECOM for Seqwater, provides concept designs for the upgrade works. The entire spillway is a trapezoidal shaped labyrinth design with a three cycle arrangement on a low flow section and a five cycle arrangement on a high flow section. The spillway crest is rounded on top with a vertical upstream face and a sloped downstream face set on a 1:12 grade.

The high flow spillway is to be 5.1 m wide on the left bank and 76.8 m wide on the right bank. The level of the spillway is set at RL 97.1 m, which is 0.4 m lower than the modelled 1:100 year AEP flood height. A 44 m wide low flow section that is set at RL 95.4 m with two 5 m wide notches set at RL 95.32 is located between the high flow spillways and across the main channel section of Six Mile Creek. A slab set at RL 89.5 extends along the base of the entire spillway and a secondary floor is set at RL 86.0 m below the low flow spillway section only.

An outlet tower is located on the left abutment of the dam; the intake will incorporate a trash screen and selectable baulks. Releases from the outlet tower will be restricted to low volumes required for environmental purposes under the Mary Basin Resource Operational Plan.

8. Implications for downstream passage at Six Mile Creek Dam

Some of the potential injuries associated with passage over spillways identified in Section 5 have implications for passage over Lake Macdonald Dam. Table 3 below provides a summary of the likelihood of injury.

Table 3. Causes of fish injury and potential to occur at Six Mile Creek Dam.

Cause of injury	Issue at Lake Macdonald spillway?	Comments
Abrasion against spillway	Possible	Spillway crest & vertical walls during shallow flows
Impact with spillway base	Likely	Vertical drop creates high potential for striking
Turbulence in tailwater	Likely	Vertical drop creates high potential for turbulence
Free-fall to stilling basin	Unlikely	Low height of spillway crest reduces potential
Gas bubble disease	Unlikely	Not known as an issue in Australia
Predation	Likely	High potential at all waterway barriers
Reduced water quality	Possible	Avoidable with good design & management
Dewatering and stranding	Possible	Avoidable with good design & management

The causes of injury that are listed in Table 3 as possible or likely to occur at Six Mile Creek Dam are expanded upon below:

Abrasion against spillway

Potential exists for fauna passing over the spillway to strike the spillway crest and vertical surfaces of the wall during low overtopping flows. As shown in Figure 2 there are numerous spillway crest designs available. Investigations into whether the proposed spillway crest shape is the most suitable for minimising the potential for abrasion injury should be considered.

Reducing impact injury

No data could be found that provides guidance for the optimum water depth for a stilling basin relative to spillway height. However, State code 18: Constructing or raising waterway barrier works in fish habitats issued by Department of Infrastructure, Local Government and Planning (DILGP) indicates that a stilling basin depth of 30% of drop may be acceptable. The split-level stilling basin arrangement proposed for the upgraded Lake Macdonald spillway makes a 30% depth an achievable and likely to be suitable for the site.

To achieve a plunge pool depth of 30% from the spillway level of RL 95.32 m to RL 89.5 m the stilling basin nib wall must extend to at least RL 91.3 m. The next stilling pool has a floor set at RL 86.0 m; the nib wall must extend to at least RL 87.6 m. The drawings indicate that the commence to flow tailwater level is approximately RL 85.4 m and the stream bed is approximately RL 84.0 m. In order to achieve a pool depth of 30% the tailwater level at commence to overtop for the dam must be a minimum of RL 85.1 m. Table 4 below provides the level details summarised for consideration in further design development.

The concept designs provided by AECOM indicate that the stilling basin has a flat floor in the centre with sides that slope upwards across the pool width. There is potential for fish that pass over the spillway to strike the shallower sloping surfaces. All areas downstream of the low flow spillway must have a depth in the stilling basin that are equal to or deeper than that specified in Table 4.

Table 4. Levels used to calculate the nib wall heights to achieve a plunge pool 30% of the spillway height.

Spillway level (RL in m)	Still basin floor level (RL in m)	Differential (m)	Height for 30% depth (RL in m)
95.32	89.5	5.82	91.3
91.3	86.0	5.3	87.6
87.6	84.0	3.6	85.1

The stilling basin nib walls have the potential to cause injury to fish that strike them during overtopping flows; particularly at locations where the spillway is close to the nib wall as shown in Figure 4. Modelling of the flow patterns in both of the stilling basins using a technique such as 3D Computational Fluid Dynamics (3D CFD) will provide details to inform an improved wall arrangement.

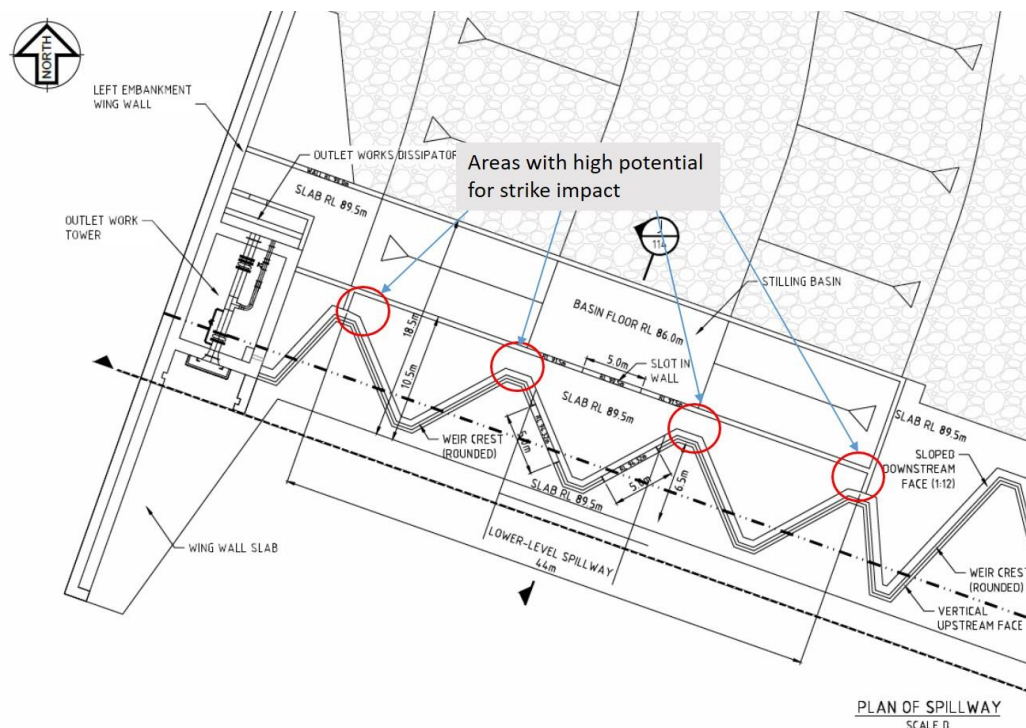


Figure 4. Low flow section of labyrinth spillway showing areas with high potential for strike (from AECOM Drawing 60451967 - 113).

Turbulence and shearing forces in tailwater

No data could be found that provides guidance for the maximum level of turbulence in a stilling basin that would prevent injury to fish. The pool volume in the first stilling basin is reduced by the cycles of the trapezoid. The turbulence levels in the stilling basin may be excessive particularly during high overtopping flows. Modelling of the turbulence levels in both of the stilling basins using 3D CFD may provide details on the level of turbulence that will occur and inform an improved design volume or arrangement for the stilling basins. Options to reduce turbulence will also reduce likelihood of injury due to shear forces.

Predation above and below spillways

The most effective way to minimise predation at waterway barriers is to maximise fish passage efficiency under all conditions both in an upstream and downstream direction. The labyrinth design will release high volumes of flow with low depth over the spillway; ongoing design should seek to facilitate downstream passage via a dedicated sluice or fishway.

Reduced water quality below spillways

The concept designs for the dam upgrade provided by AECOM indicates that the intake for downstream environmental releases from the dam will incorporate selectable baulks. Active management of the baulks in order to always ensure that surface quality water is being released downstream is paramount in maintaining suitable water quality.

Dewatering and stranding of fish within and below spillways

The arrangement of the stilling basins shown in the concept designs for the dam upgrade provided by AECOM may have the potential to trap fish that have passed over the spillway after flows have ceased. However, at this early stage it is difficult to identify potential issues with dewatering and stranding of fish. Further design of the stilling basin should consider means to ensure that the stilling pools are free draining and that fish and turtles are able to safely exit as the water levels fall.

Other potential impacts

The outlet structure to be used to provide environmental water has the potential to cause fish and turtle injury or death. The primary focus of the proposed trash screen should be as a primary screen prevent damage caused by large floating debris. A secondary screen sufficient to prevent intake of fish as small as 20 mm in length is necessary. Entrainment of fish and turtles can be prevented by providing a screen with sufficiently large surface area to ensure velocities at the screen are sufficiently low.

The level of the high flow spillway is set so that overtopping only occurs at flow approaching the 1:100 year AEP event. Under this flow condition, the tailwater level is predicted to be at approximately RL 91.1 m. The potential for fish or turtles to strike objects downstream that may cause injury should be assessed during further development of the design for the upgraded dam.

9. Conclusion

The concept designs developed for the Six Mile Creek Dam upgrade have already considered some of the potential issues with safe downstream passage of aquatic fauna. Further development of the design requires close attention to ensure that:

- the spillway crest shape is the most suitable profile;
- the stilling basin depth is increased to provide sufficient plunge pool depth;
- turbulence in the stilling basin is minimised during all flows;
- sources of direct strike impact for fauna are minimised;
- the potential for predation is minimised by reducing fish aggregations;
- only surface quality water is release from the dam outlet;
- the potential for dewatering and stranding of fauna when flows cease is minimised;
- the potential for entrainment of fauna within the intake structure is minimised.

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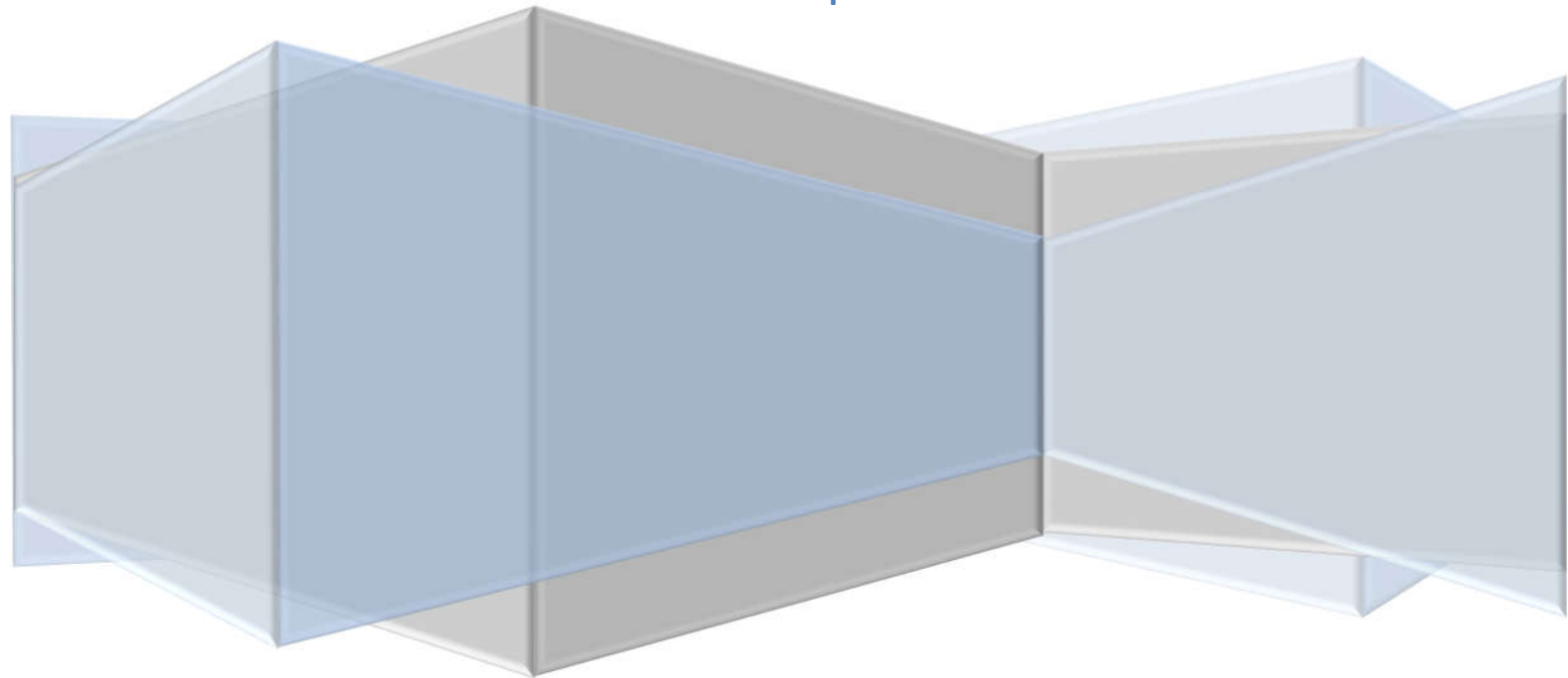


**Addendum to Potential impacts of
downstream passage of fauna over a
labyrinth spillway at
Lake Macdonald
Six Mile Creek**

A. P. Berghuis

January 2019

**Aquatic Biopassage Services
for Seqwater**



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Background

Seqwater is undertaking a Dam Safety Upgrade for Lake Macdonald to bring the structure into compliance with current industry guidelines and the requirements of the Water Supply (Safety and Reliability) Act 2008. The upgrade will preserve the storage at its current capacity and height but the spillway configuration will be changed to a labyrinth design. Aquatic Biopassage Services has been retained by Seqwater to provide technical input on the spillway design with respect to downstream passage of aquatic fauna.

A literature review by Berghuis (2017) failed to identify any labyrinth type spillway designs that specifically addressed safe downstream passage for aquatic fauna. The original labyrinth design for Six Mile Creek Dam incorporated a vertical drop to a mid-level stilling basin that then dropped into another pool and into the tailwater.

Early concept designs developed for the spillway upgrade had already considered some of the potential issues with safe downstream passage of aquatic fauna. Aspects identified for further development of the most suitable spillway profile shape for downstream passage in Berghuis (2017) are:

- the spillway crest shape is the most suitable profile;
- the stilling basin depth is increased to provide sufficient plunge pool depth;
- turbulence in the stilling basin is minimised during all flows;
- sources of abrasion and direct strike impact for fauna are minimised;
- the potential for dewatering and stranding of fauna when flows cease is minimised.

Spillway Development

Seqwater has been working with AECOM and Aquatic Biopassage Services to develop solutions to minimise fauna injury in the spillway and stilling basin design. The initial concept design for the labyrinth spillway is shown in Figure 1.

Crest Shape

The crest shape selected for the proposed labyrinth spillway was a quarter round shape, which results in a rounded upstream crest and aeration behind the spilling flows to allow a free fall plunge. For fish passage, this arrangement leads to a smooth, rounded approach surface to the spillway crest as well as minimisation or avoidance of an abrasion source downstream of the crest on the vertical drop as is shown in Figure 2. However it should be noted that in low spillway overtopping flows, aeration may be ineffective in separating the spilling flow from the downstream vertical face of the spillway.

The design for downstream plunge pool walls is for rounded upstream crests to minimise sharp upstream edges, this is not shown in the early concept designs in Figure 1 and 2.

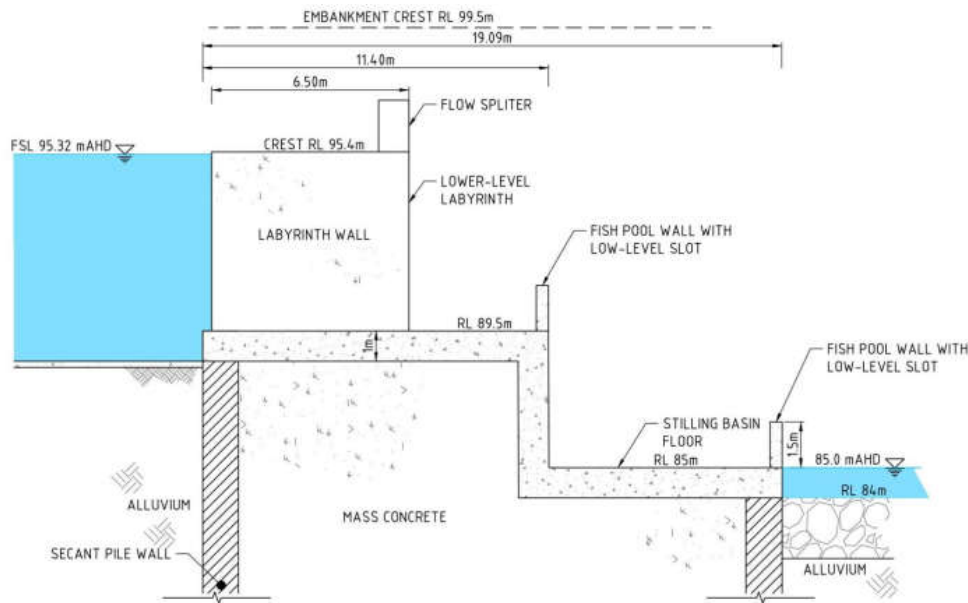


Figure 1. Six Mile Creek Dam –Concept design of the original layout of the labyrinth spillway.
(Provided by AECOM)

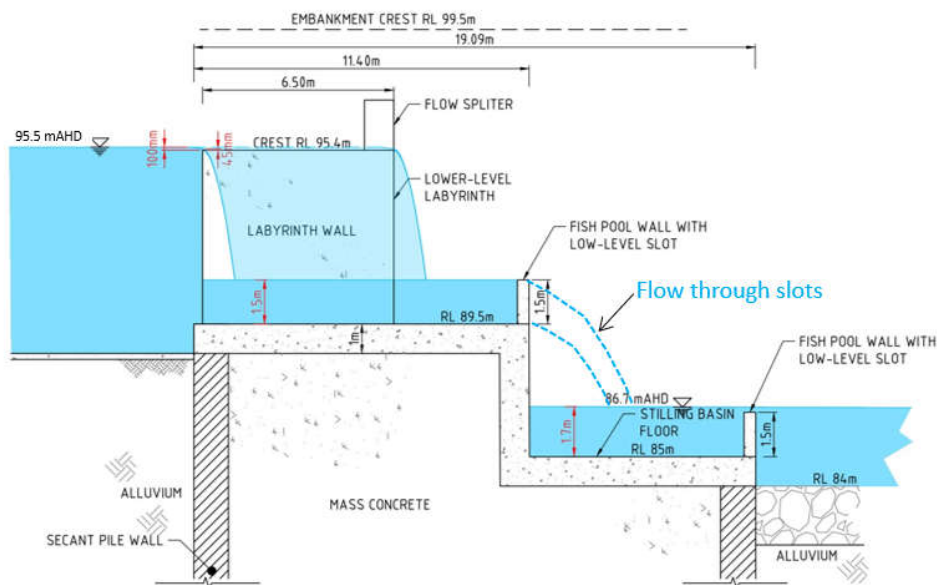


Figure 2. Conceptual water profiles for the original layout of the labyrinth spillway crest and plunge pools.
(Provided by AECOM)

Spillway Modelling

Computational Fluid Dynamic (CFD) modelling of spillway flow conditions at various rates of overtopping has been performed by AECOM in association with design development. CFD modelling was used to simulate flows through the labyrinth spillway and gave visual outputs to assess the efficacy of the spillway plunge pools, turbulence and likelihood of direct strikes.

For reference, Figure 3 shows a 3D sketch of the concept design labyrinth spillway used as a starting point for spillway modelling.

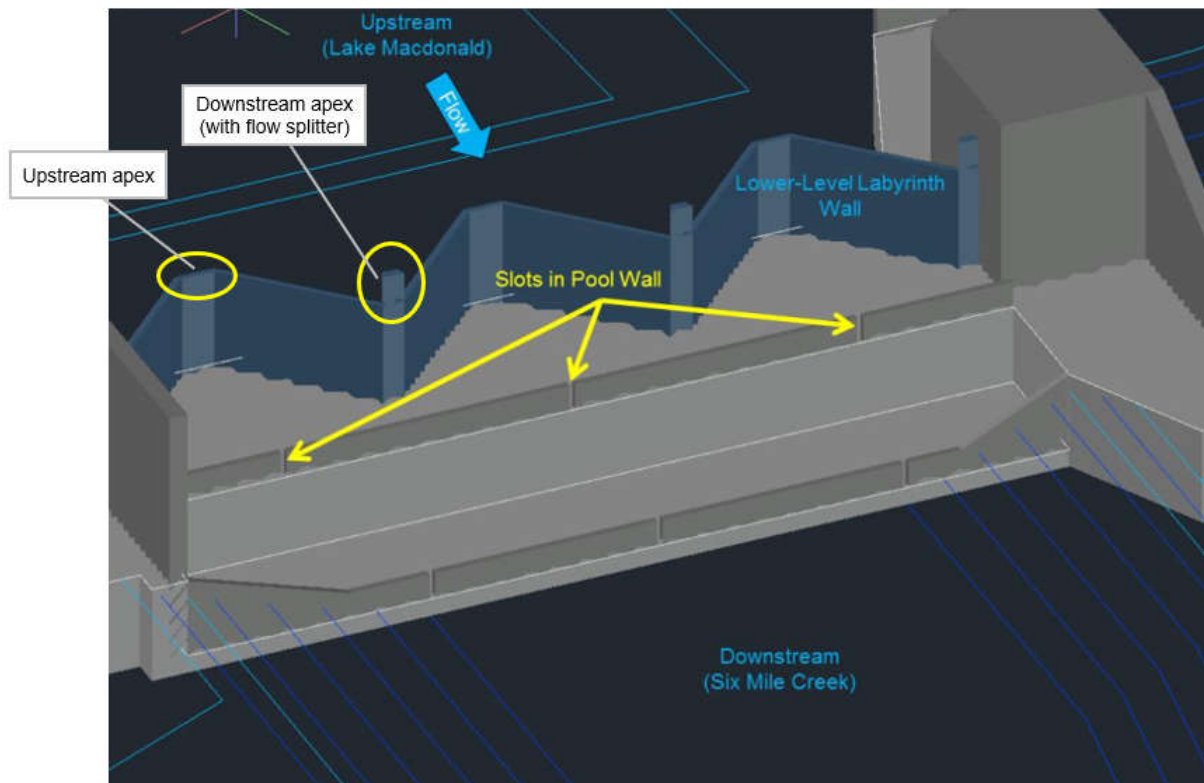


Figure 3. 3D sketch of concept design labyrinth spillway and plunge pools (Configuration 1)
(Provided by AECOM)

Modelling tests were run as an iterative process and led to a number of configurations being run, which were numbered as 1, 2, 4, 5 & 6. For each configuration, various reservoir heads (spillway overtopping flows) were modelled to understand performance changes with flow. Configuration 1 was the starting point concept design (Figure 1 and Figure 3). For intermediate configurations, a reference reservoir head of 600 mm was used to speed up the development of modelling results.

The following comments are provided regarding the modelling tests for each configuration:

Configuration 1: Original layout (upper pool depth = 1.5m; lower pool depth = 1.5m):

- The 100 mm spillway overtopping flow had the potential for vertical flow from the spillway to cause abrasion for fish passing along the spillway wall.
- At overtopping flows of 300 mm and 600 mm, flows at the upstream apex of each labyrinth trapezoid cycle fall vertically against the spillway wall, with potential for abrasion.
- At overtopping flows of 300 mm and 600 mm high velocity areas where the flow jet hits the stilling basin floor and dissipator wall may have caused strike injury.
- At the 600 mm overtopping depth, flow patterns within the stilling basin indicated a highly turbulent condition that may have injured and disoriented fish.

Configuration 2: Increased upper pool wall height (to 2m), lowered second floor (RL 84m), sloped pool walls (upper pool depth = 2.0m; lower pool depth = 1.5m).

The modelling results for 600 mm overtopping flow indicated:

- Modification to the stilling basin wall reduced the potential impact of the plunging flow where the spillway is at an acute angle to the flow.
- In areas where the water column descended vertically, there was high velocity and most likely highly turbulent flow in the stilling basin at the base of the spillway.

Configuration 4: Further increased upper pool depth (to 2.5m), lowered top floor (by 1m), extended bottom floor downstream (by 3m) (upper pool depth = 2.5m; lower pool depth = 1.5m)

Tested at 600 mm overtopping flow only:

- A deeper upper pool reduced turbulence but continued to represent issues with striking on spillway pool walls.

Configuration 5: Sensitivity configuration to check outcomes of no intermediate pool – i.e. single drop from labyrinth spillway into a deep pool, with a tall downstream end sill and free draining to creek (single pool depth = 4.5m).

The modelling results for 600 mm overtopping flow indicated:

- A higher fall between spillway crest to plunge pool surface, but with a deeper plunge pool and fewer hard surface locations for fish strike.
- Velocities in tailwater pool are generally lower apart from in localised areas along the basin floor at higher overtopping flows.
- Clear reduction in flow velocities as water enters the dissipator pool.
- Flow jet continues to have high velocities in upstream apex of the spillway cycle.
- Eliminates the risk for fish stranding by providing a floor level similar to the creek bed level and maintains connectivity with the creek in no flow.

Configuration 6: Sensitivity configuration to check outcomes of more pools with lower fall heights – multiple small drops into pools (five pools, all with pool depth = 1.5 m).

The modelling results for 600 mm overtopping flow indicated:

- Configuration was ruled out due to minimal benefit on the jet impinging on floors.
- Multiple drops increased potential for strike on end sill walls and added complexity with drainage and fish stranding risk.

Final Configuration for development

Configuration 5, with a single pool arrangement, has been selected as the final plunge pool design to move forward to detailed design. A cross section of this configuration is provided in Figure 4. The CFD modelling produced by AECOM for the latest iteration of the Configuration 5 plunge pool design indicates favourable conditions for flow over the acute angle sections of the spillway. Issues with high velocity and potential for abrasion are eliminated for the lower range of flows and reduced to

acceptable levels for higher flows up to 1.5m (1:30 AEP) spillway overtopping events. The outputs for flow scenarios with overtopping rates from 0.3m to 1.5m are provided in Appendix A (Figures 1-4).

Flows over the upstream apex section continue to present potential issues with spillway abrasion at the 300 mm overtopping flow and potential for injury during flows of 1.0m overtopping and above. The issue does not appear to be related to the plunge pool design but rather to an effect known as nappe interference, which is described in Falvey (2003) as an effect caused by the flow over the acute angle crest influencing the flow from the upstream apex section of the crest. Further development of the plunge pool arrangement is unlikely to improve the impact of nappe interference downstream of the crest, within the range of flows where it may be an issue for fish.

Further development of the Configuration 5 design has retained the single drop with the floor set at RL 84.0 m AHD (approximate creek bed level) and a lower sloped nib wall at the downstream end. The single drop configuration will lead to a higher vertical fall compared to the double plunge pool configurations. The maximum fall is estimated to be 10.32 m into a 1.0 m deep pool at commence to flow.

The tailwater level in Six Mile Creek rises rapidly during flow and by the time a 100 mm overtopping flow occurs the fall scenario is lessened to a 7.92 m fall into a 3.4 m deep tailwater pool. Table 1 below provides the range of flows up to the 1:100 AEP with the predicted overtopping levels, plunge pool depth, fall height from headwater surface to tailwater surface and pool depth as a percentage of fall height. In all flow cases over 100 mm overtopping, the maximum fall height is greater than the 30% spillway drop to plunge pool ratio recommended as a starting point by Berghuis (2017). Furthermore, none of the fall heights exceed the predicted fish injury threshold of 13 m, as outlined in Ruggles and Murray (1983).

Total Outflow	Reservoir Head	Pool Depth	Fall Height (FSL to tailwater surface)	Pool Depth as a Percentage of Fall Height
m ³ /s	mAHD	m	m	%
0	0.00	1.00	10.32	9.69
7	0.10	3.40	7.92	42.93
14	0.20	3.95	7.37	53.60
21	0.30	4.28	7.04	60.80
28	0.40	4.50	6.82	65.98
41	0.50	4.85	6.47	74.96
55	0.60	5.12	6.20	82.58
70	0.70	5.33	5.99	88.98
84	0.80	5.50	5.82	94.50
102	0.90	5.67	5.65	100.35
122*	1.00	5.83	5.49	106.19
141	1.10	5.96	5.36	111.19
161*	1.20	6.10	5.22	116.86
183	1.30	6.28	5.04	124.60
206*	1.40	6.47	4.85	133.40
230	1.50	6.62	4.70	140.85
254*	1.60	6.77	4.55	148.79
278	1.70	6.89	4.43	155.53
306*	1.80	7.03	4.29	163.87

Table 1. Range of flows up to 1:100 AEP with overtopping levels, plunge pool depth and fall height.

* represents ~1:5 AEP, ~1:10 AEP, ~1:20 AEP, ~1:50 AEP and ~1:100 AEP events respectively (AECOM data).

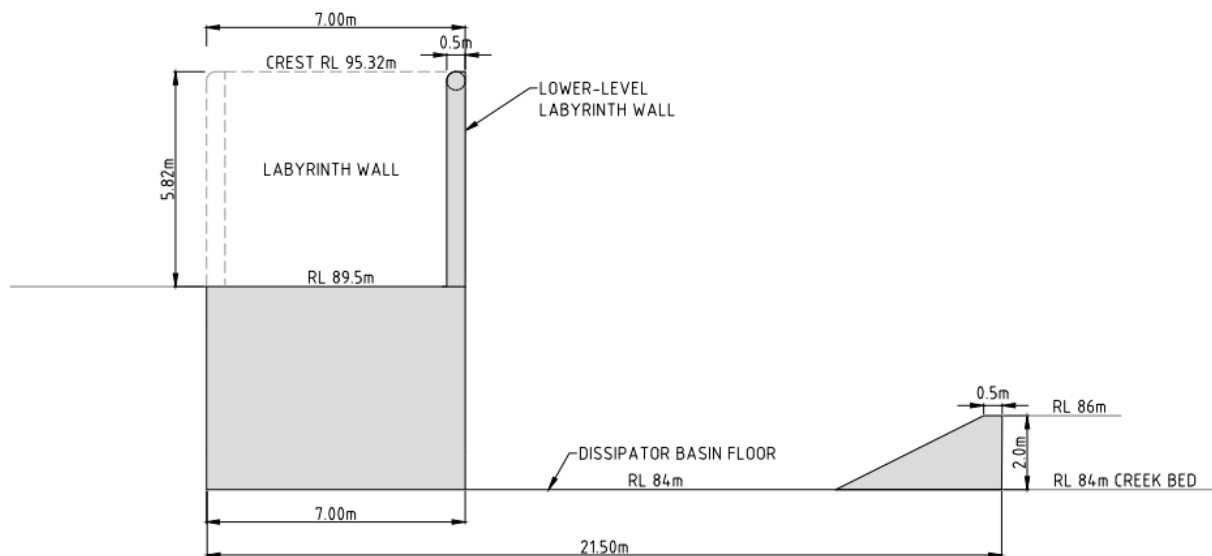


Figure 4. Cross-section of single pool labyrinth arrangement (Configuration 5)

Conclusion

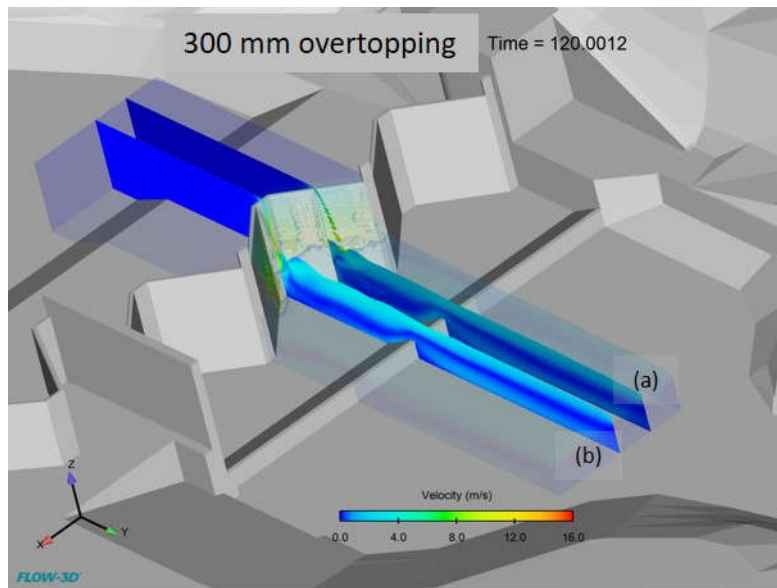
The design process leading to the development of Configuration 5 has addressed the majority of the issues with the original spillway design that were identified in Berghuis (2017) and is supported as the most suitable to take forward to detailed design. The only matter that may continue to represent issues with fish injury or survival of fish occurs at the upstream apex sections of the spillway. The majority of each spillway cycle is set at an acute angle and upstream apex sections only represent a small proportion of the overall spillway. As demonstrated by the CFD model result in Appendix A Figure 5 the impact in the stilling basin is localised. Despite this fact there is potential for fish to be injured as they pass over the upstream apex sections of the spillway cycle and in a creek system that includes large Mary River cod and Queensland lungfish it is imperative that injury be minimised.

A physical model of the spillway incorporating the Configuration 5 plunge pool design is currently being developed at the University of NSW hydraulics laboratory and tests will be performed in early February 2019. It is recommended that the physical model be utilised to develop final solutions to the nappe interference issue at the upstream apex and to continue to develop the design to minimise spillway injuries to the greatest extent possible.

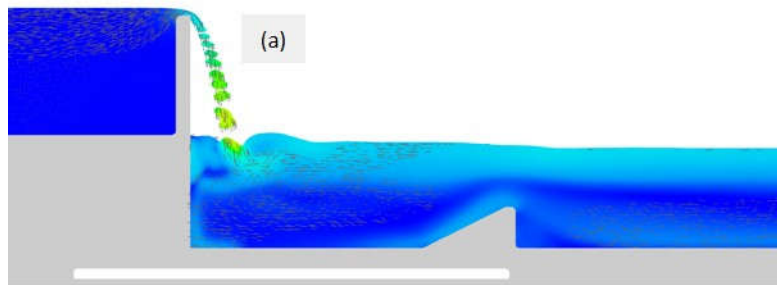
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Appendix A CFD Model Runs for Configuration 5



Time = 120.0012



Time = 120.0012

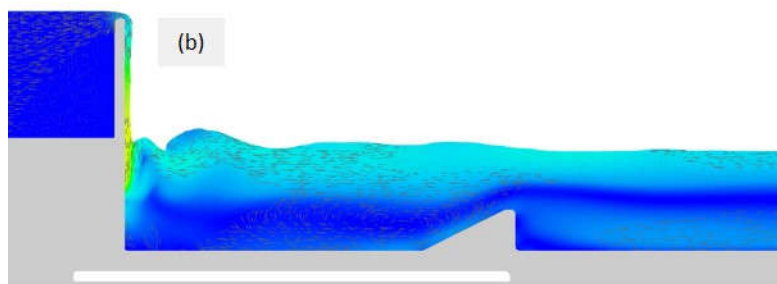
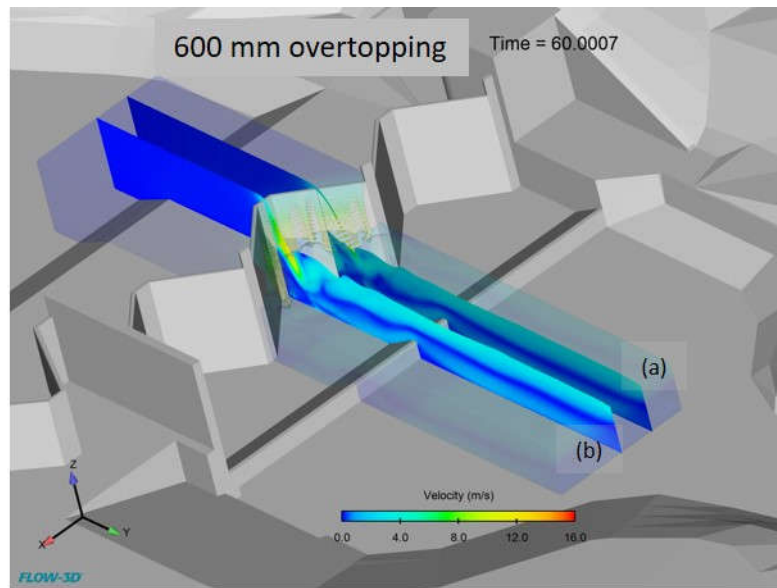
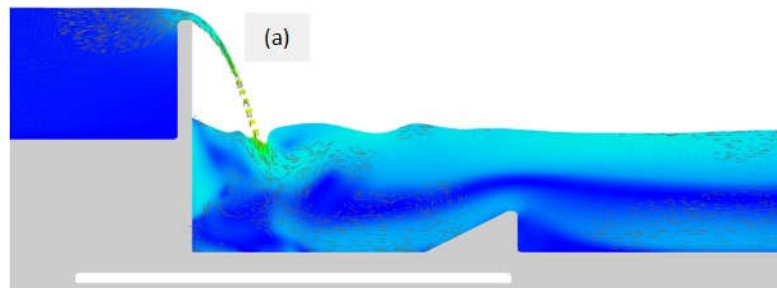


Figure 1. 300mm overtopping CFD model run slices through spillway section at an acute angle (a) and upstream apex section (b).



Time = 60.0007



Time = 60.0007

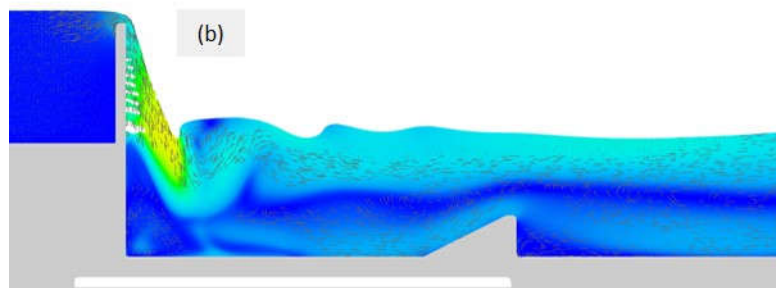
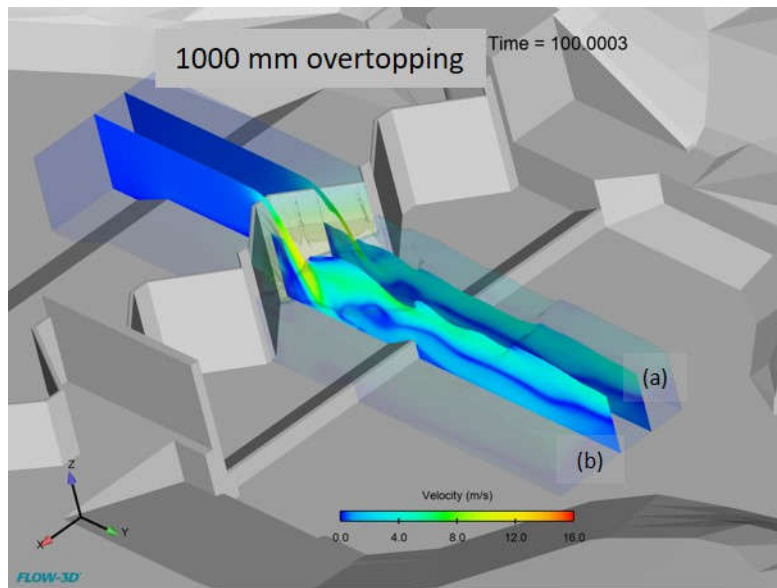
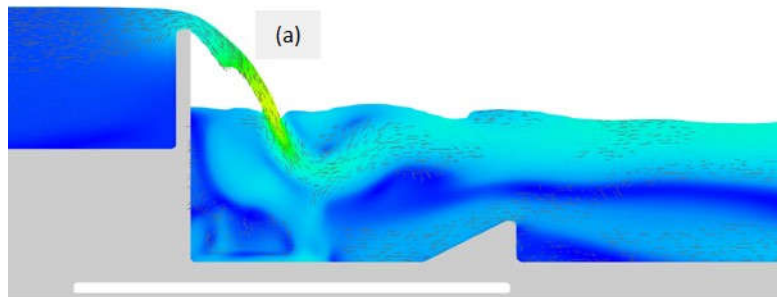


Figure 2. 600mm overtopping CFD model run slices through spillway section at an acute angle (a) and upstream apex section (b).



Time = 100.0003



Time = 100.0003

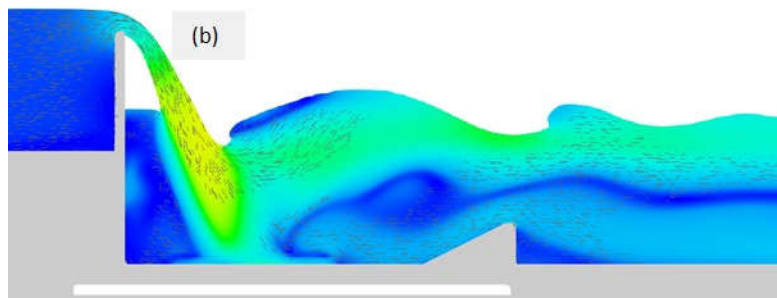
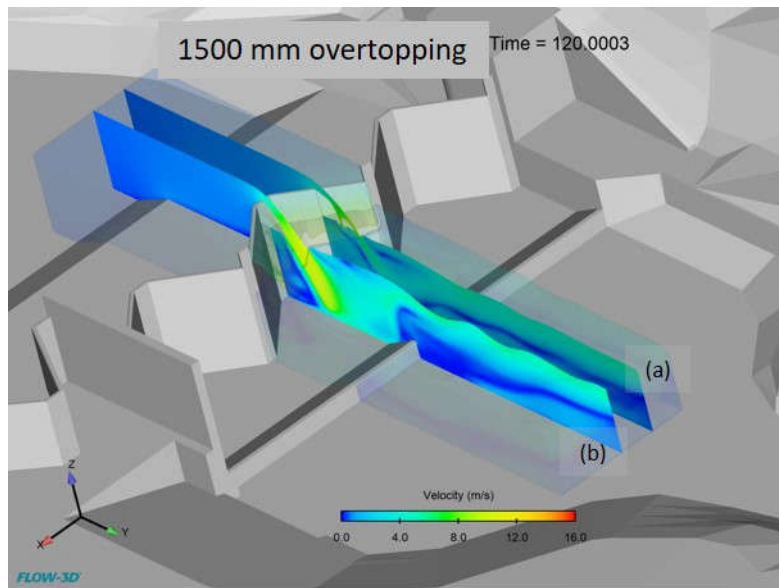
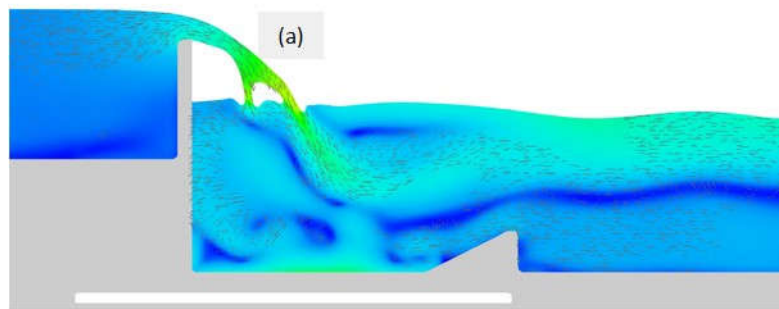


Figure 3. 1000mm overtopping CFD model run slices through spillway section at an acute angle (a) and upstream apex section (b).



Time = 120.0003



Time = 120.0003

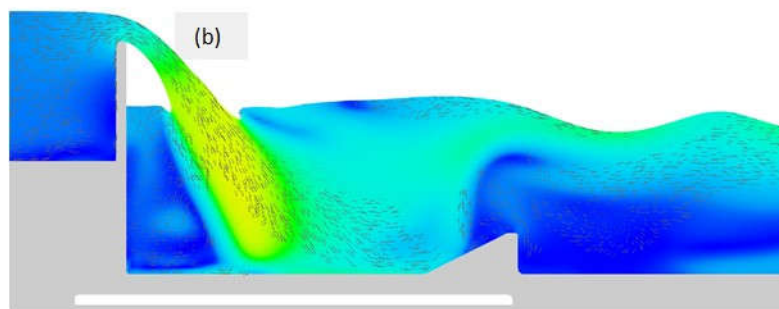


Figure 4. 1500mm overtopping CFD model run slices through spillway section at an acute angle (a) and upstream apex section (b).

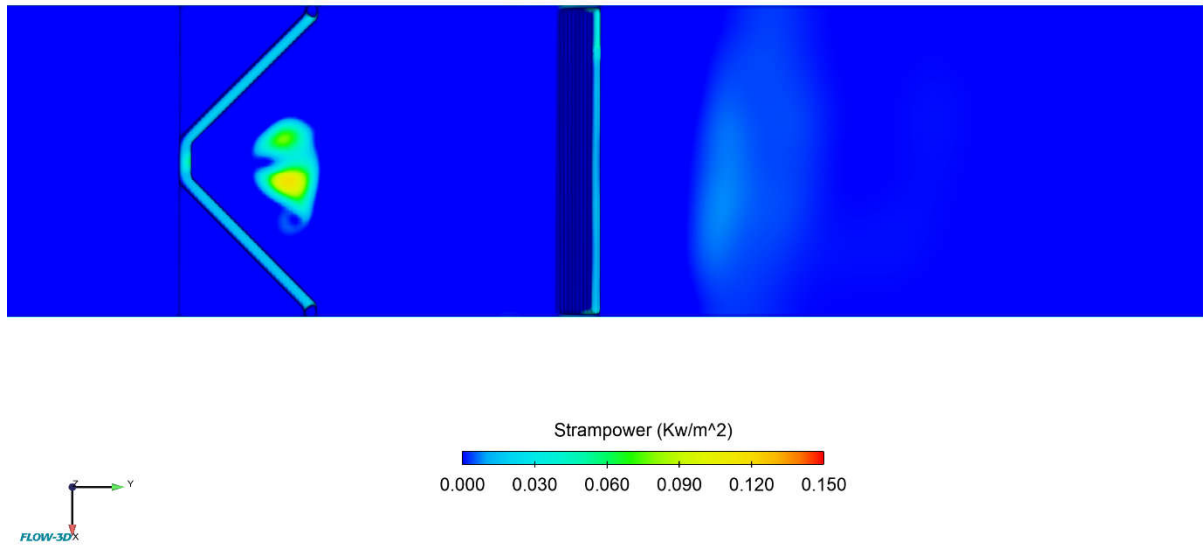


Figure 5. Plan view of CFD model run at 600 mm overtopping flow; showing impact on stilling basin floor caused by flows over the upstream apex section of spillway.

Memorandum

To	Seqwater	Page	1
CC			
Subject	Lake Macdonald (Six Mile Creek Dam) Evaluation of Labyrinth and Ogee Options for the Lower Level Spillway		
From	AECOM		

1.0 Purpose

The purpose of this document is to evaluate the labyrinth and ogee options for the lower-level spillway and recommend a preferred option to take forward in Detailed Design. The memorandum presents a comparison of the options in terms of hydraulic performance, costs, erosion protection requirements, certainty of performance and downstream fish passage.

AECOM is recommending to adopt the ogee crest for the lower level spillway in combination with an upper level labyrinth spillway as the preferred option and are seeking endorsement from Seqwater with this approach.

2.0 Design Criteria

The spillway is to meet the following design criteria:

1. Achieve AFC requirements:
 - a. Pass the PMPF (equivalent to the 1:10,000,00 AEP) below dam crest level, with
 - b. Provision of freeboard based on a risk approach.
2. Match or improve on Council's current 1:100 AEP flood levels (upstream and downstream):
 - a. Peak discharge less than 325 m³/s.
 - b. Maximum reservoir level of RL 97.2 mAHD.
3. Protect the creek and floodplain to avoid erosion for flows up to and including the PMPF.
4. Downstream fish passage:
 - a. To be provided through normal spillway operations.
 - b. Limit injury/fatality to fish passing over the spillway up to 1:100 AEP flood event.
 - c. Preferably, pass the entire 1:100 AEP flood over the main (lower-level) spillway.
 - d. The spillway plunge pool / basin should not strand fauna when spillway flows cease.

3.0 Design Constraints

The following are constraints that impact how the design criteria are achieved with some of these being competing objectives:

1. Spillway Sizing:
 - a. Balance of spillway hydraulic efficiency:

- i. Increase hydraulic efficiency for the higher AEP floods to minimise spillway length and maximise freeboard.
 - ii. Limit hydraulic efficiency for the 1:100 AEP flood so that downstream flooding is not increased.
 - b. Maximise pool depth for fish landing.
 - c. Maximise tailwater for when the upper-level labyrinth begins to overtop for energy dissipation (7.6m drop with limited length of downstream concrete slab).
2. Spillway Alignment:
 - a. The existing embankment/spillway needs to be used as a working platform for spillway construction and to manage flows during the works. This restricts the overall spillway layout to having the same alignment as the existing spillway for the low level spillway and then a different alignment for the upper level spillway to align with the right embankment.
3. Energy Dissipation:
 - a. Avoid downstream erosion for flows up to and including the PMPF with a small dissipator basin. This includes limiting velocities acting on the creek bed and creek bank downstream of the spillway.
 - b. Limit the length (upstream to downstream) of spillway and dissipator basin due to cost of mass concrete secant pile foundation cells while still meeting the structural stability requirements. This applies to both the lower and upper level spillways.
4. Turbulence:
 - a. Ideally, maximise turbulence in the basin for energy dissipation.
 - b. Minimise turbulence in basin for downstream fish passage (conflicts with 4a).
5. Limit flow velocities acting on basin floor (for fish).

4.0 History of the Spillway Design Development

An extensive options evaluation process was undertaken to manage the dam safety risks at Lake Macdonald (Six Mile Creek) Dam. Initial option studies focussed on potential dam safety upgrade measure to the existing structure and decommissioning the dam. However a key conclusion of these early studies was that a new dam was the most cost effective solution to managing the dam safety risks with the existing structure. Initial concepts for a new dam considered a conventional mass gravity ogee crest structure founded on the bedrock at the site using open excavations through the creek bed and associated flood plain. However the construction risks associated with this concept were considered to be unacceptable and new dam options comprising cellular mass concrete foundations, constructed from the existing ground surface, were developed primarily to manage the construction flood risk. However the cost of this foundation works was considerable and a labyrinth spillway crest structure was developed to manage the spillway crest length and associated foundation costs. A conventional ogee section was considered with the cellular mass concrete foundation. However the ogee spillway crest length needed to be much longer (in the order of 50m longer) than the labyrinth concept and required extensive energy dissipation measures that consequently had a substantial cost penalty. The labyrinth spillway crest control structure was subsequently adopted based on its hydraulic efficiency, reduced spillway length and associated capital cost.

The 2014 concept design consisted of a dual-level labyrinth spillway. The lower-level labyrinth had three cycles that were 12m deep, making the labyrinth efficient and limiting the overall spillway length. The dissipator basin was a small concrete lined channel, downstream of the foundation cells and founded on the creek's alluvial soils. As geotechnical investigations progressed, it was decided that the dissipator basin needed to be founded on the mass concrete spillway structure based upon concerns related to the weak and potentially liquefiable alluvial soils.

Bringing the dissipator basin onto the mass concrete structure lead to the 2016 concept, that included a lower-level labyrinth spillway with cycle depths of 6.5m, shortened to maximise the dissipator length

(to just 8m). Shortening the cycle depth was selected over extending the dissipator basin downstream due to the high cost of increasing the size of the mass concrete spillway structure, noting that there was ongoing focus on managing the total construction cost. Due to the relatively high tailwater at the site and the nature of labyrinth spillway overflows, it was thought that a short dissipator basin could work, and erosion protection lining (e.g. large riprap) would be able to handle the residual energy entering Six Mile Creek immediately downstream of the spillway. Shortening the cycle depth decreased spillway efficiency, but the newly developed concept avoided major increases to spillway construction cost.

The 2016 concept for the lower-level spillway was a 49.5m long three-cycle labyrinth capable of passing the 1:100 AEP flood event prior to spilling of the upper-level labyrinth spillway, which had a crest elevation at RL 97.1 mAHD. This concept was carried over into the detailed design study, at which time provision of safe downstream passage for fish was of increasing concern and focus given the commencement of the Regulatory Approvals process and engagement with DAFF. Initial indications were that the hydraulic performance of the labyrinth spillway was not well received by Regulators due to concerns with fish injury or mortality for a straight drop spillway, such as the proposed labyrinth. Evaluating the hydraulic conditions began with CFD modelling to gain a better understanding of flow velocities and potential impacts on fish with the dissipator floor and end walls. The concept of a partial ogee section with high level labyrinth spillway was developed as potentially a technically viable spillway alternative to the full length labyrinth spillway. The ogee section of the spillway of equal crest length was identified as being less efficient at smaller flows, including at the 1:100 AEP event, but it was equally efficient as the lower-level labyrinth and the PMPF level due to the large magnitude of overtopping depth in relation to the rather short cycle depths (making it act more similar to a straight-line weir under high heads). Initial concerns with the partial ogee option included an undersized basin compared to what would normally be adopted for an ogee section (i.e. would need to be 16m length for a USBR Type III basin with baffle blocks). Specifically there were concerns with the risk of discharging full hydraulic energy downstream into the creek channel. At this time a full labyrinth spillway was preferred for the following reasons:

- The full labyrinth spillway was more efficient, limiting the length (and cost) of the lower-level spillway (required to pass the 1:100 AEP flood event).
- The full labyrinth would provide some degree of energy dissipation on the short dissipator basin.

The original labyrinth spillway concept included a fish landing pool immediately downstream of the main labyrinth, followed by a second drop to the basin floor (near creek level). The upper landing pool was incorporated to limit drop height for fish with the goal of limiting velocities acting upon the floor slab, which was of increased concern upon the Queensland government's release of *State Development Assessment Provisions* (SDAP) Module 5 in 2016 which indicated that straight drop weirs were not acceptable.

The hydrology for the site was updated in 2018 by Seqwater. The revised hydrology resulted in a decrease in peak inflows and less inflow volume compared to what was used for the basis for the 2016 Concept Design. This reduced the peak water levels for the adopted spillway concept in the order of 0.4m, effectively providing additional freeboard; this is discussed further in Section 5.0.

CFD and physical hydraulic modelling commenced in late 2018, and this modelling showed that the upper landing pool wall needed to be relatively tall ($\geq 2\text{m}$) to maximise the upper landing pool depth. Concerns arose from the modelling regarding fish strikes on the basin floor and pool walls and hydraulic performance during large flood events (after 'rooster-tails' from water striking the pool wall were observed in the physical model). AECOM were then advised that fish passage needed to be considered up to the 1:100 AEP event, rather than say a 1:20 AEP (which has been the criteria for other recent dam projects), which led to increasing concern about performance of the stepped pool concept and the potential for fish strikes.

Multiple adjustments were made to the CFD model layout, looking at increasing pool depth or limiting drop height (these are trade-offs). As a sensitivity run, a single-drop labyrinth was modelled to consider the maximum depth for a plunge pool, recognising that it would also result in the largest drop height (11.32m from spillway crest RL 95.32 to basin floor RL 84 mAHD). CFD results indicated relatively high flow velocities near the basin floor immediately downstream of the upstream labyrinth

apexes, but low velocities elsewhere along the basin floor. Although the single-drop option had the largest drop height, it became the preferred option because the secondary drop was removed (considered less stressful for fish), the upper pool was removed (source of potential fish strikes), and the possibility of fish stranding was eliminated (basin floor below creek level, with basin connection to creek for fish exit).

If multiple concepts and layouts for the landing pools for the lower labyrinth had not been developed and evaluated with CFD modelling, then the concept of an 11.32m straight-drop spillway would potentially have received resistance by the Regulators and it is considered unlikely would have become a preferred option. Despite initial preferences to minimise drop heights from a downstream fish passage perspective, the single maximum drop height ended up being the preferred option for the labyrinth with this primarily being a result of the high tailwater for Lake Macdonald.

The first configuration tested in the physical model was the 3-cycle inverted labyrinth per the 2016 concept (with the fish landing pool/step), noting this occurred while the CFD modelling for a single-drop labyrinth was still taking place. Striking of jets on the pool wall was observed, providing further support for the single-drop layout.

The step in the basin was then removed from the physical model, and a single-drop spillway configuration was installed. The labyrinth arrangement was rotated 180 degrees to a conventional labyrinth profile, with the goal of increasing efficiency. Otherwise the geometry of the labyrinth was unchanged from the original 2016 concept.

Hydraulic conditions for the original labyrinth layout were very turbulent within the basin resulting in energy dissipation, as was the goal. However, the turbulent conditions were thought to be potentially harmful for fish, and the convergence of jets in the upstream labyrinth apexes resulted in jet thickening and minimal diffusion of the jet prior to striking the basin floor. Minimal diffusion of the jet resulted in relatively large flow velocities (on the order of 15 m/s) acting near the basin floor, leading to concern about fish passing over the upstream labyrinth apexes. It was evident that separating the jets as much as possible would limit the jet thickness and thereby limit velocities acting on the basin floor by:

1. Preventing intersection of jets coming over mirroring labyrinth walls (by increasing the upstream apex length and thereby separating diagonal walls), and
2. Flattening the angle of the diagonal labyrinth walls to limit the combining of jets so that a smaller percentage of the spillway crest led to intersection of the jets and hence reduced the percentage of the spillway that would be of concern for fish passage.

In order to accomplish the above, a two-cycle labyrinth with large upstream apexes was required. This helped limit velocities on the basin floor and reduced the area that may be harmful for fish passage (albeit, fish passage over the corners of upstream apexes could still be harmful for floods greater than say 1:20 AEP). The downsides to such a configuration were:

1. Reduced efficiency of the labyrinth spillway (less crest length for 2-cycle compared to 3-cycle).
2. The large apexes and flat wall angles made the labyrinth act more like a straight-line weir, resulting in less turbulence in the basin and sending more energy downstream into the creek.

While the revised labyrinth concept was considered an improvement for downstream fish passage, the appealing hydraulic performance benefits of the original three-cycle labyrinth weir were largely removed (decrease in spillway efficiency and loss of energy dissipation with the basin).

Some of the revised lower-level labyrinth configurations (particularly for the two cycle labyrinth) also created a transient boil(s) in the creek channel immediately downstream of the end sill, on the left side. This was attributed to the right-to-left spillway approach direction in the reservoir, which seemed to interact with the left-ward pointing diagonal labyrinth walls and caused water to reflect off the left abutment wall and intersect flows coming over adjacent portions of the labyrinth. The transient boil(s) was observed changing position over time, shifting from left to right and was rather unpredictable. It seemed that certain combinations of the labyrinth wall angle with the right-to-left reservoir approach resulted in this phenomenon, and it was clear that potential impact on protecting the creek bed would need to be evaluated further to protect against potential transient pressures caused by the boil.

The competing objectives of hydraulic performance and downstream fish passage (particularly in regards to turbulence and energy dissipation) was leading to a labyrinth layout that was less than

optimal in hydraulic performance and although it improved the downstream fish passage there were still areas of concern at the converging jets at the upstream labyrinth apexes.

Therefore, with much of the benefit removed from the full labyrinth concept, a partial ogee spillway became an increasing appealing option, especially because ogees are typically preferred for fish passage. In addition, the performance of an ogee spillway is much more predictable in terms of hydraulic performance. Based on this, further physical modelling of the ogee option was conducted to assess its hydraulic performance in comparison to the labyrinth option, in particular the risk of erosion to the alluvial channel downstream of the spillway.

A 2m end sill for the ogee was designed to be of similar geometry to a roller-bucket, but without the circular profile that creates a large back-roller. A strong back-roller that re-circulates within the basin would likely be harmful for fish, as fish could become trapped and tossed around in the roller. The linear-sloped end sill that was modelled proved to be successful in lifting the high flow velocities off the creek bed, and subsequently allowed fish to be 'flushed' through the basin rather quickly within the water jet.

In comparing the labyrinth and ogee options, the following were the key items that needed to be considered:

1. Hydraulic performance.
2. Construction cost.
3. Potential for erosion downstream / requirements for protecting the creek from erosion.
4. Certainty in performance.
5. Fish passage.

These items are discussed in the following sections.

5.0 Hydraulic Performance

For Extreme flood events, the efficiency of each full labyrinth configuration decreases significantly due to upstream submergence of the apexes and the increased zone of jet interference. At the spillway design flood (PMPF) the lower level labyrinth was assessed as essentially no more efficient than an ogee spillway. However, it was still appealing because it limited the required length of the lower spillway so that it could pass the 1:100 AEP without increasing the upstream flood level, compared to the existing spillway. In other words, an ogee spillway needs to be longer than a labyrinth spillway (for the lower spillway) to pass the 1:100 AEP within the design requirements.

To compare the ogee and labyrinth options for the low-level spillway a 49.5m width ogee (equivalent to the labyrinth width) and a 59m width ogee were assessed. A comparison of theoretical rating curves for the main (lower-level) spillway option is provided in Figure 1. The rating curves show that:

1. The 49.5m ogee is less efficient than a labyrinth spillway of equal length at the 1:100 AEP flood level.
2. The 49.5m ogee becomes equally as efficient as a labyrinth of equal length near dam crest.
3. A 59m ogee is required to match the 1:100 AEP outflow of the 49.5m labyrinth.
4. A 59m long ogee is more hydraulically efficient than a 49.5m labyrinth for Extreme flood levels (because it is 10m longer and the labyrinth loses efficiency), providing more outflow capacity for the PMPF compared to the labyrinth spillway.

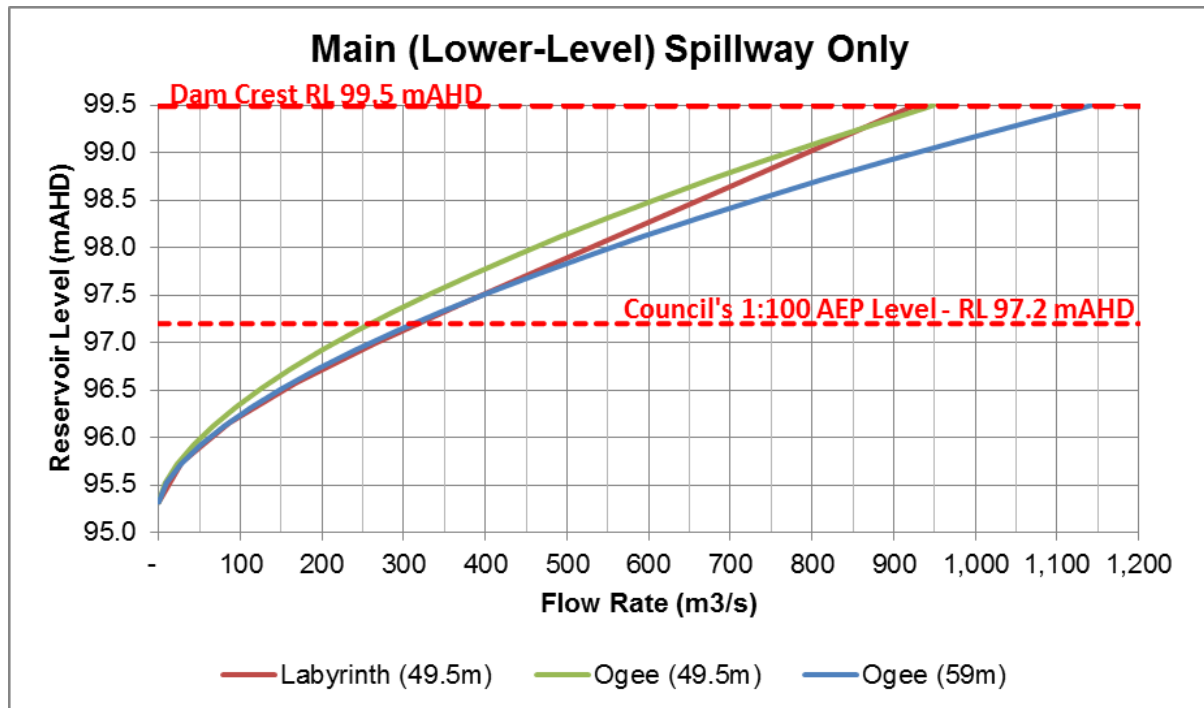


Figure 1 Comparison of ogee and labyrinth rating curves for the lower-level Spillway

Reservoir routing results are presented in Table 1 for the configurations considered.

The 59m ogee is around 10m longer than the labyrinth (lower level spillway), which provides additional outflow for the full length of spillway at the dam crest level. This means that less capacity is needed from the upper-level spillway to pass the PMPF while providing equivalent freeboard. As such, removing one cycle of the upper-level labyrinth (from 5 cycles with a length of 75m to 4 cycles with a length of 60m) was considered in the reservoir routing assessment (Table 1). It can be seen that one cycle can be removed without impacting freeboard (comparing full labyrinth layout No. 1 with ogee/labyrinth layout No. 3).

It is possible to further reduce the main spillway length, which comes at a cost of reducing freeboard. There was minimal freeboard available for 2016 Concept Design that was based upon 2009 hydrology. The 2018 hydrology update (by Seqwater) resulted in a smaller peak flowrate and less inflow volume for the PMPF (refer to Figure 2). This means that the length of the upper level spillway could be reduced from that of previous concepts. However this results in a reduction in freeboard. The 12-hr storm duration controlled based upon the 2009 hydrology, resulting in a peak reservoir inflow of 2,240 m³/s and total inflow volume of 67,000 ML. These numbers reduced to 1,780 m³/s (79%) and 46,000 ML (69%) for the 9-hr PMPF event that controls using the 2018 hydrology. For comparative purposes an assessment was made of reducing the upper level labyrinth to 2 cycles (30m length), refer Table 1. Although, there would be cost savings associated with minimizing the spillway length, it is not recommended to pursue such an option because:

1. With minimal / no freeboard, wind waves could overtop the embankment crest during Extreme flood events. This is of increased concern because cyclone events with high winds speeds are likely to produce the Extreme flood events. Wave heights during a Category 3 cyclone are estimated to be on the order of 1.4m.
2. There is inherent uncertainty in hydrologic estimates and catchment runoff modelling. In addition, hydrologic estimates for Extreme flood events will almost certainly change at some point in the future, as updates are made to data sets and methodologies. Having available freeboard will provide a buffer in case hydrologic estimates increase in the future.
3. Four (4) out of the 10 temporal patterns for the 9-hr PMP rainfall event indicate that the dam will overtop for Layout No. 4 (where the upper labyrinth is reduced to 30m in length). The PMPF lake level is taken as the median value based on all 10 temporal patterns, which sits just below the

dam crest level. However, an alternative temporal pattern could result in dam overtopping for the shortened spillway option (No. 4 in Table 1).

4. If tailwater is higher than what the current rating curve suggests (similar to the URS 2014 rating), then submergence of the lower level spillway will begin to affect outflow capacity. This would decrease the spillway capacity, potentially reducing available freeboard and the ability to pass the PMPF below dam crest level. A reduction in efficiency is expected to be of limited concern for an ogee spillway (based upon modelling completed to date). However, such large events have not been observed at the site, and as such the models have not be calibrated to Extreme events, and tailwater levels could be higher than expected due to heavily vegetated areas downstream of the spillway.

Table 1 Reservoir Routing Results

No.	Lower Level Spillway	Upper Level Spillway	Peak Total Discharge (m ³ /s)		Peak Reservoir RL (mAHD)	
			1:100 AEP	PMPF	1:100 AEP	PMPF
1	Labyrinth (49.5m 2-cycle)	Labyrinth (75m 5-cycle)	309	1545	97.16	99.16
2	Ogee (59m)		308	1605	97.19	99.06
3		1557		99.15		
4		Labyrinth (30m 2-cycle)		1468		99.45

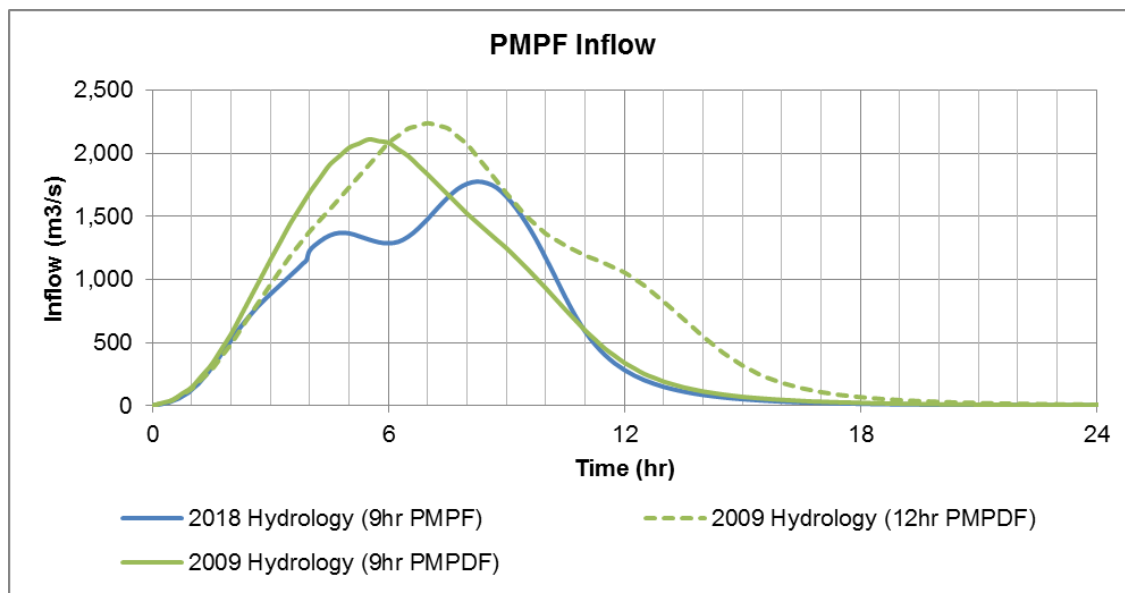


Figure 2 Comparison of inflow hydrographs from 2009 and 2018 hydrologic studies (hydrographs for controlling storm duration and temporal pattern shown)

5.1 Layouts

Layouts for the labyrinth (49.5m) and ogee (59m) options are provided as Figure 3 and Figure 4, respectively. They consist of the following:

- Low Level Labyrinth Spillway Option:
 - Low level spillway:

- 49.5m 2-cycle labyrinth.
 - 6.5m cycle depth.
- 22m long dissipator basin, sized to maintain overtopping jets within the basin.
- The upper level spillway is a 5-cycle labyrinth (15m per cycle: $L = 75\text{m}$).
- Low Level Ogee Spillway:
 - 59m ogee for the low level spillway.
 - 19.5m long dissipator, sized based on designs for roller bucket basins.
 - The upper level spillway is a 4-cycle labyrinth (15m per cycle: $L = 60\text{m}$).

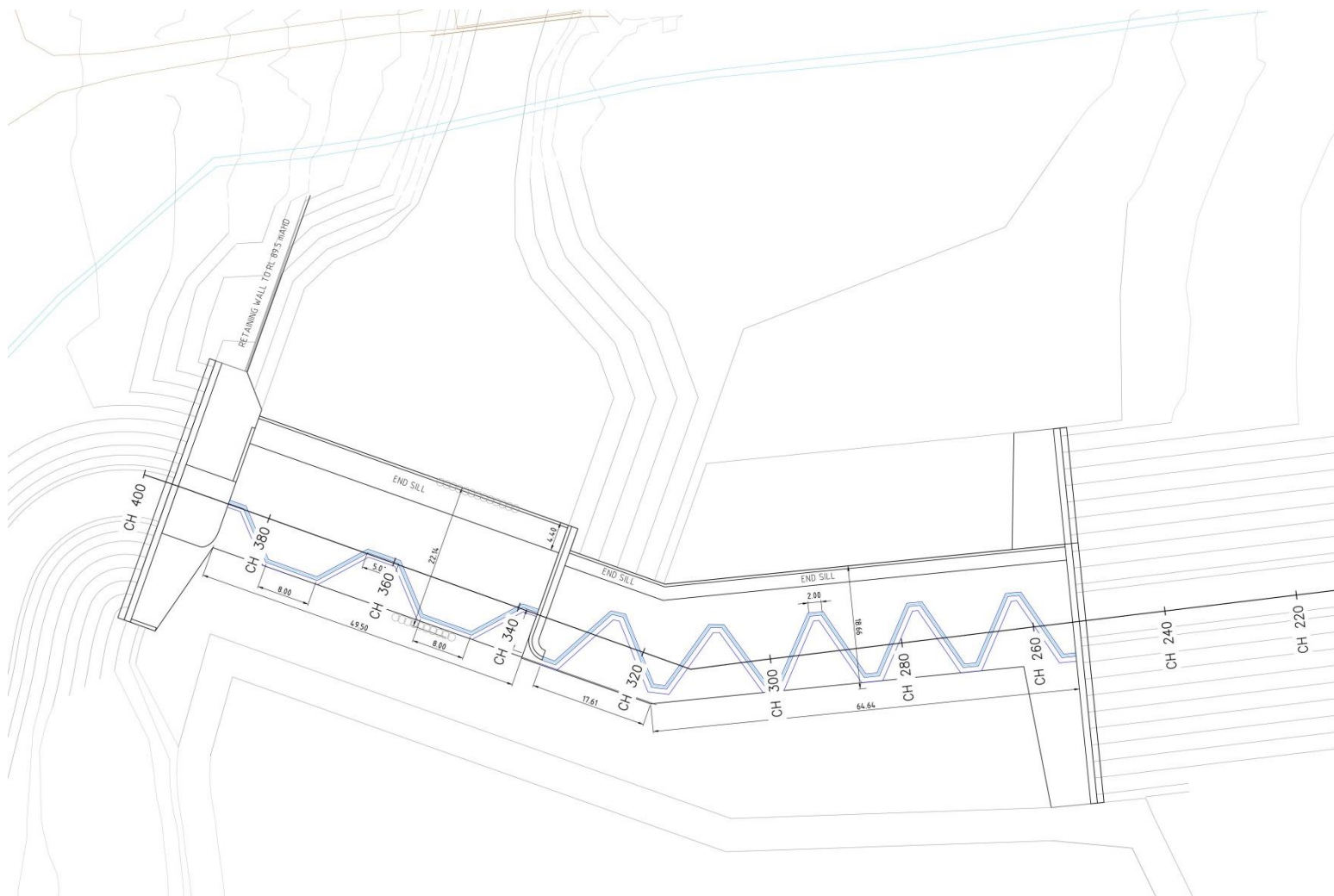


Figure 3 Draft layout for the 49.5m labyrinth low level spillway option

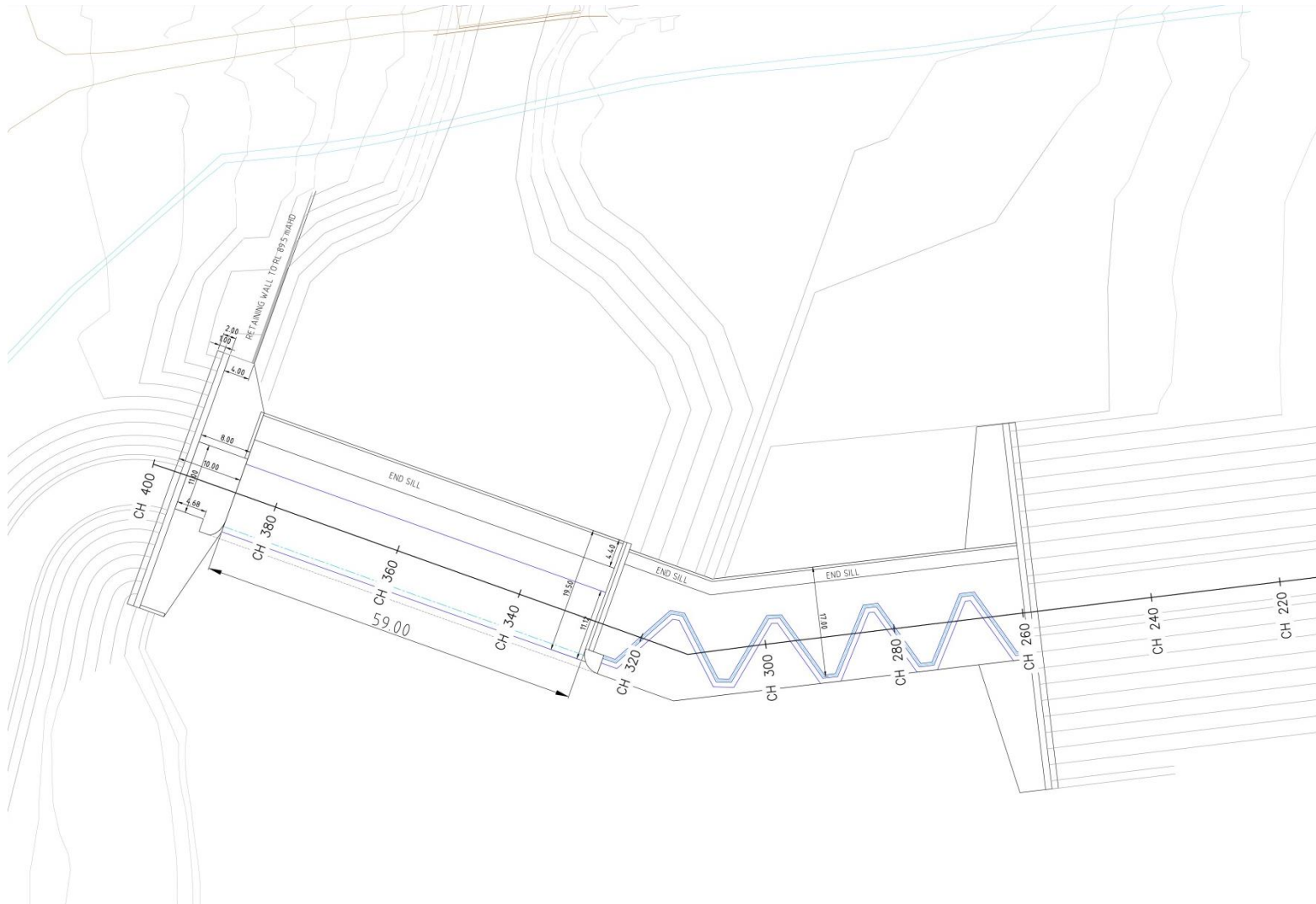


Figure 4 Draft layout for the 59m ogee low level spillway option

6.0 Construction Costs

Cost estimates were developed for both the lower level labyrinth (49.5m) and ogee (59m) options for comparative purposes. Both options had effectively the same overall spillway width and similar extents of foundation cells and mass concrete. Therefore, the key difference was in comparing the structural labyrinth wall layout and costs against the mass concrete ogee section layout and costs. It was assessed that there was negligible difference between the two costs (within the accuracy of the cost estimates) and they should be considered the same cost for the purpose of this assessment.

7.0 Erosion Protection Considerations

7.1 Velocities in the Creek Channel

Channel velocities were measured in the physical model, downstream of the following main spillway layouts:

1. 49.5m 2-cycle labyrinth (Model Configuration #11 - as shown in Figure 3).
2. 49m ogee spillway (Model Configuration #10 – which is 10m shorter than that shown in Figure 4).

Velocities were measured along model templates, which provided reference cross-section locations so measurements could be compared between the different layouts. Velocities were measured 0.5m, 1.0m, 1.5m, 2.0m, and 4.0m off the channel bed and off the channel banks. Velocity was measured using:

1. A propeller-meter (provide one-direction velocity magnitude measurements).
2. An ADV (provide three-dimension velocity magnitude measurements, which can be used to calculate the velocity resultant's magnitude and vector direction).

Sample outputs are provided as Figure 5 and Figure 6 for velocity measurements taken 0.5m above the bed for the labyrinth and ogee layouts, respectively, under PMPF flows. PMPF velocity measurement plots for the labyrinth and ogee options are provided in Attachments 1 and 2, respectively. Each plot represents a different measurement height above the bed. Velocities are reported at prototype scale (m/s).

In the velocity plots:

- **Blue** values are 1D velocities measured with the propeller-meter.
- **Red** values are velocity resultant magnitudes measured with an ADV.
- **Grey** values are velocity resultant vector directions measured with an ADV, where 0-degree is left, 90-degrees is downstream, 180-degrees is right, and 270-degrees is upstream.

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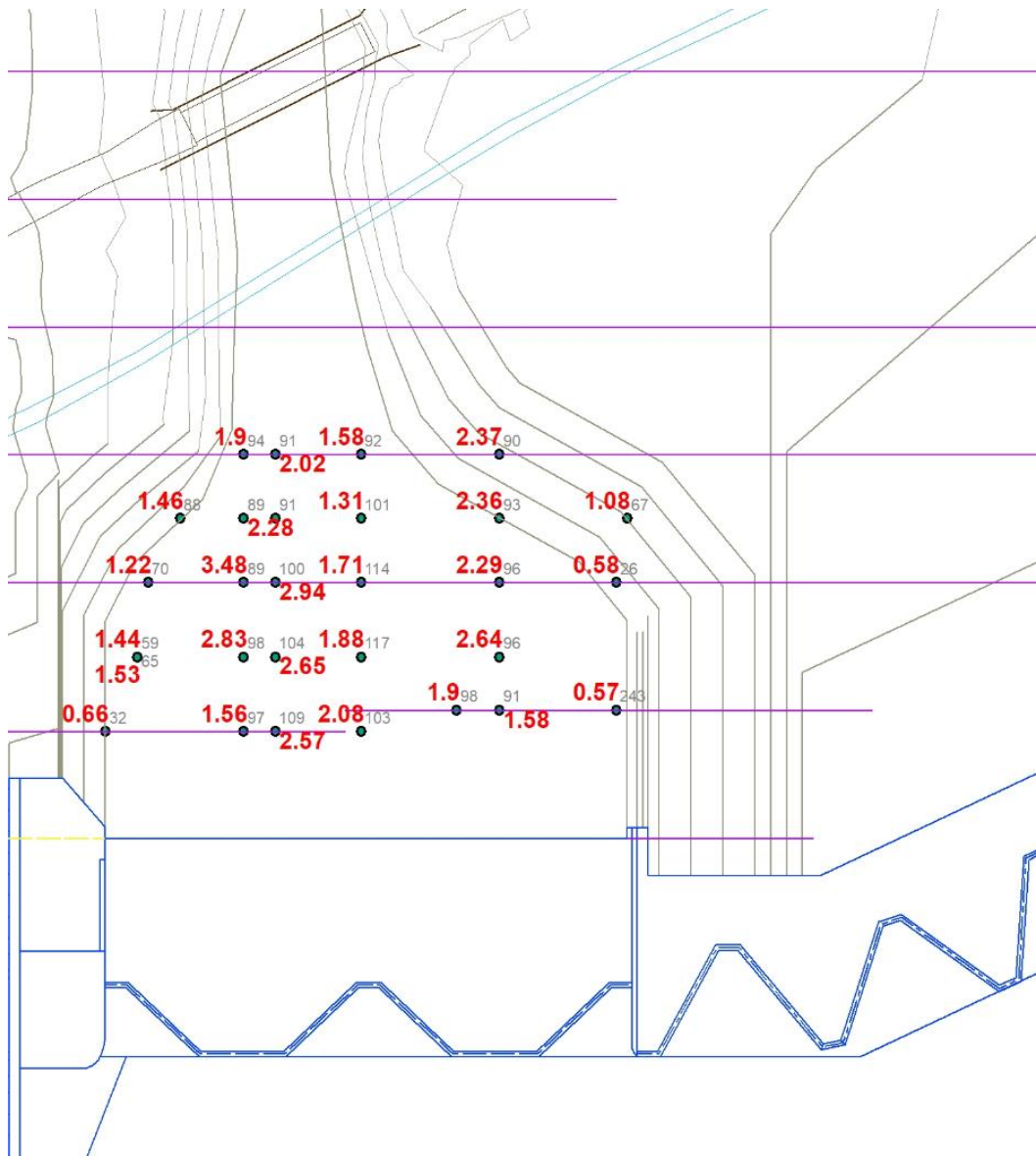


Figure 5 Flow velocity measurements taken 0.5m above the bed for the labyrinth option under PMPF flow

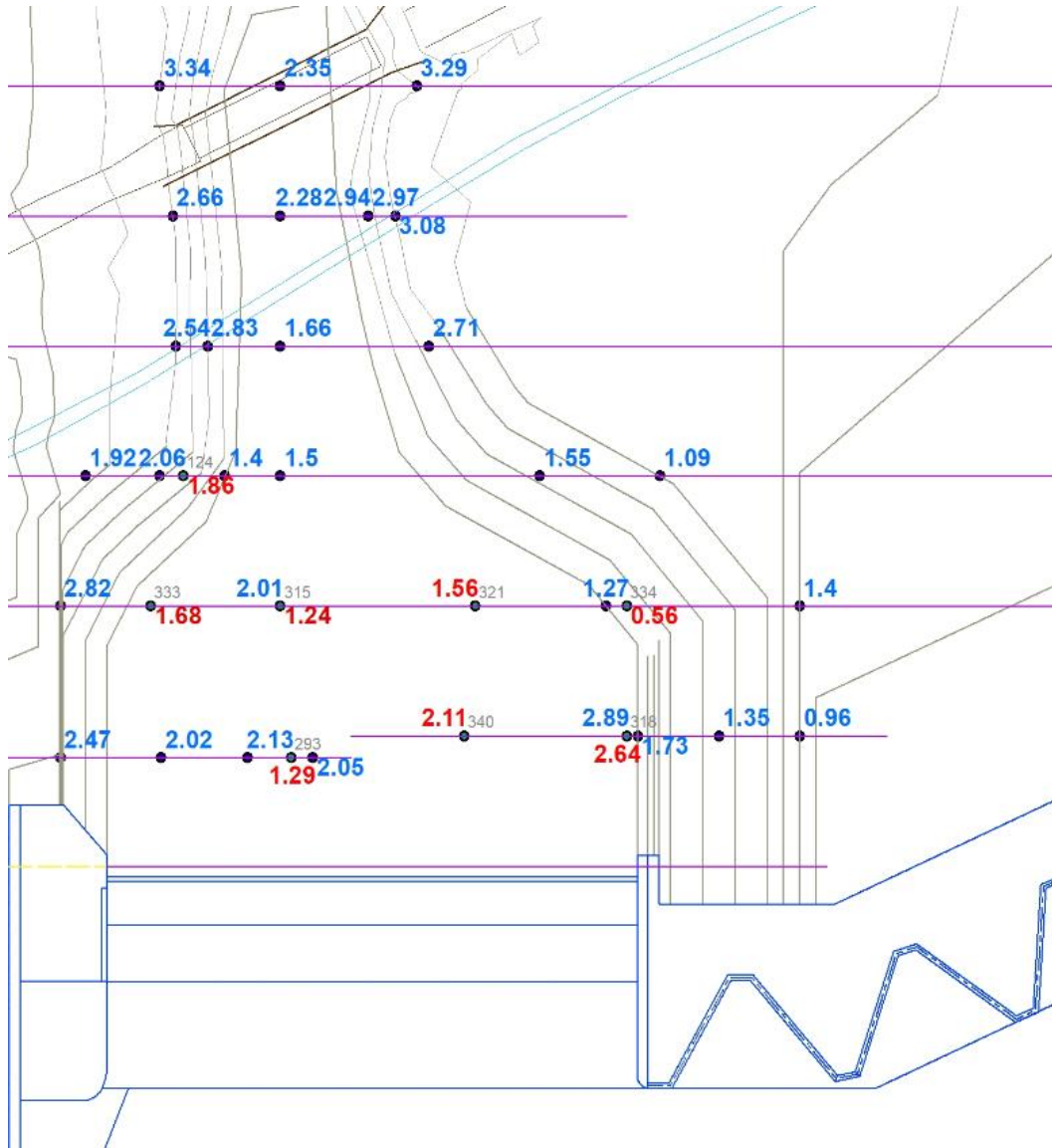


Figure 6 Flow velocity measurements taken 0.5m above the bed for the ogee option under PMPF flow

For velocity measurements in the physical model, the following have been observed:

1. For 1:100 AEP flows, measured velocities were less than 2 m/s (taken 2m above creek bed).
2. For PMPF flows:
 - a. Labyrinth spillway option:
 - i. Velocities measured 0.5m above the creek bed were generally less than 3 m/s, with one value closer to 3.5 m/s.
 - ii. Velocities measured 1.0m above the creek bed were generally less than 3 m/s, with a couple of values closer to 3.5 m/s.
 - iii. Velocities in the downstream portion of the creek (near the NPI and bridge) were on the order of 3.2 to 3.5 m/s. Measurements have only been recorded 2m above the bed at this location.
 - iv. Velocities were rather variable within a given cross-section, generally being higher downstream of upstream labyrinth apices due to concentration of flow.

- b. Ogee spillway:
- i. The ADVs vector direction measurements capture the back-roller effect and negative (upstream) flow velocities below the end sill.
 - ii. Velocities measured 0.5m above the creek bed were less than 3 m/s, except for a couple of values up to 3.3 m/s near the bridge and NPI.
 - iii. Velocities measured 1.0m above the creek bed were generally less than 2 m/s, with a few measurements up to almost 3 m/s.
 - iv. Velocities in the downstream portion of the creek (near the NPI and bridge) were generally less than 3 m/s at heights of 0.5m and 1.0m above the bed. Measurements were largest 4.0m above the bed (as expected for any configuration), where they were up to 3.2 m/s. Note that the bridge deck is about 4m above the creek bed.
 - v. Velocities were more consistent within a given cross-section, compared to the labyrinth configuration.

Overall, velocity magnitudes were similar for labyrinth and ogee options. Under PMPF flows, no velocity measurements were greater than around 3.5 m/s for either layout, and velocities were generally less than 3 m/s near the bed.

The velocities acting on the creek bed downstream of the ogee spillway were generated by a back-roller, being upstream in direction. Velocities appeared to change to a downstream direction around 30m downstream of the end sill.

7.2 Transient Pressures in the Creek Channel

Pressure transducers were installed in the creek channel to evaluate transient pressures acting on the bed and their potential impact to stability of erosion protection. Pressure transducer locations are shown in Figure 7 and Figure 8. They were installed as follows:

- Four (4) pressure transducers located around 10m downstream of the end sill.
 - Placed under the boil locations for both spillway options.
 - Pressure transducer L-LHS-1 was placed underneath where the labyrinth spillway showed a large transient boil on the left side of the channel.
 - Note that the pressure transducer L-RHS-2 had a problem with calibration and was not working correctly.
- Three (3) pressure transducers extending straight downstream in the central part of the creek channel, located approximately 18m, 26m, and 42m downstream of the end sill (distances to be confirmed with WRL).
 - Pressure transducer C-2 was placed under the standing wave formed by the boil re-entering tailwater level (for the ogee configuration, and position maintained for the labyrinth configuration).
 - Pressure transducer C-3 was placed where back-roller was thought to initiate e.g. the point of impingement on the creek bed of water coming over the boil (for the ogee configuration, and position maintained for the labyrinth configuration).
 - Pressure transducer C-4 was placed further downstream in the creek channel.

For the PMPF flows, pressure heads were plotted for both the labyrinth and ogee options. Results are presented in Figure 9 and Figure 10, respectively.

In summary, pressures measured in the channel for the labyrinth layout are significantly more transient than for the ogee configuration. This would be expected, as the labyrinth generates more turbulent conditions, whereas the ogee spillway's basin tends to direct water to the surface in a far more uniform pattern. This supports the higher variability in velocity measurements also. Transient pressures were highest closer to the end sill, and pressure fluctuations were on the order of 1 to 2m for the labyrinth, compared to around 0.5m for the ogee.

This assessment demonstrates that while the labyrinth is creating turbulence and energy dissipation within the basin, it is also send more turbulence into the creek channel immediately downstream of the dissipator basin, compared to the ogee. How this may impact stability of riprap erosion protection has yet to be assessed, although the variable heads are considered relatively minor.

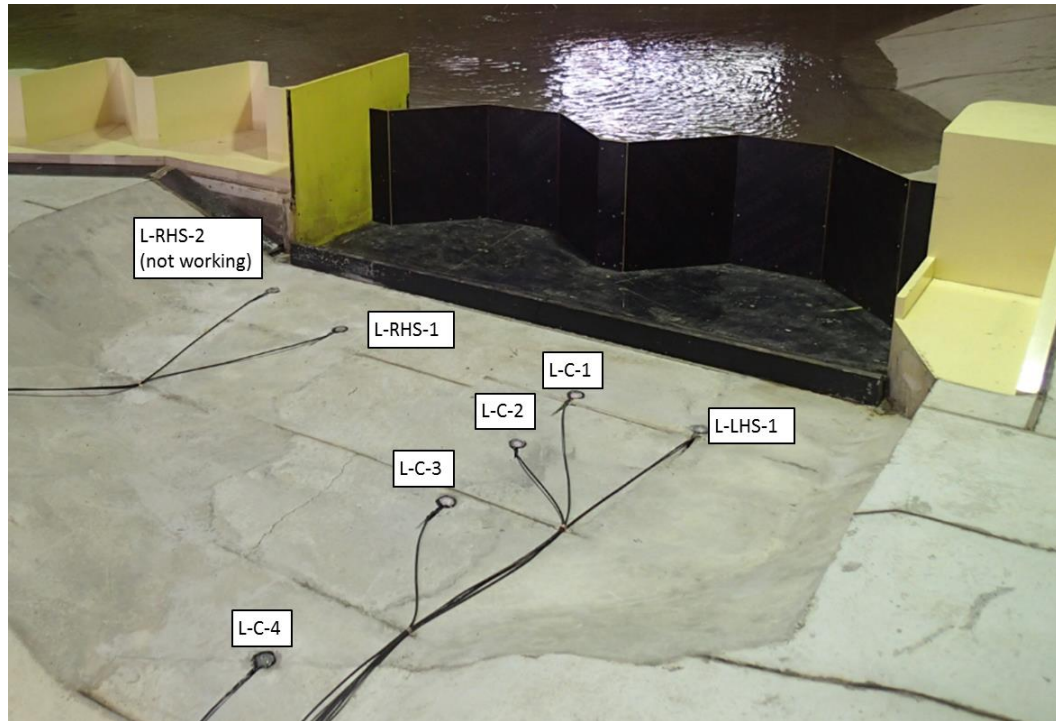


Figure 7 Pressure transducer locations for the labyrinth spillway option

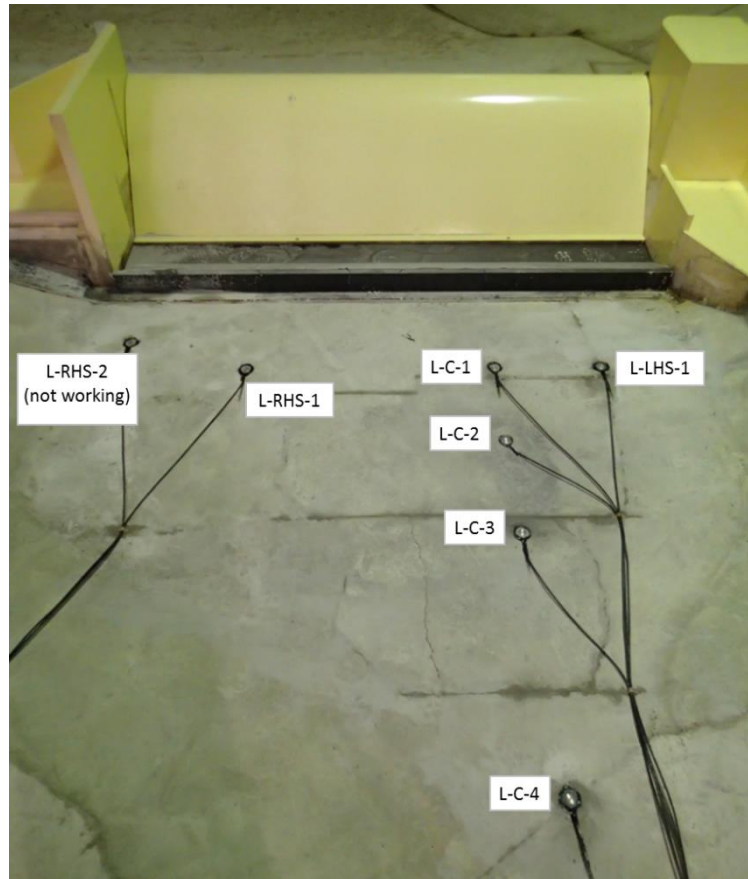


Figure 8 Pressure transducer locations for the ogee spillway option (Configuration #10)

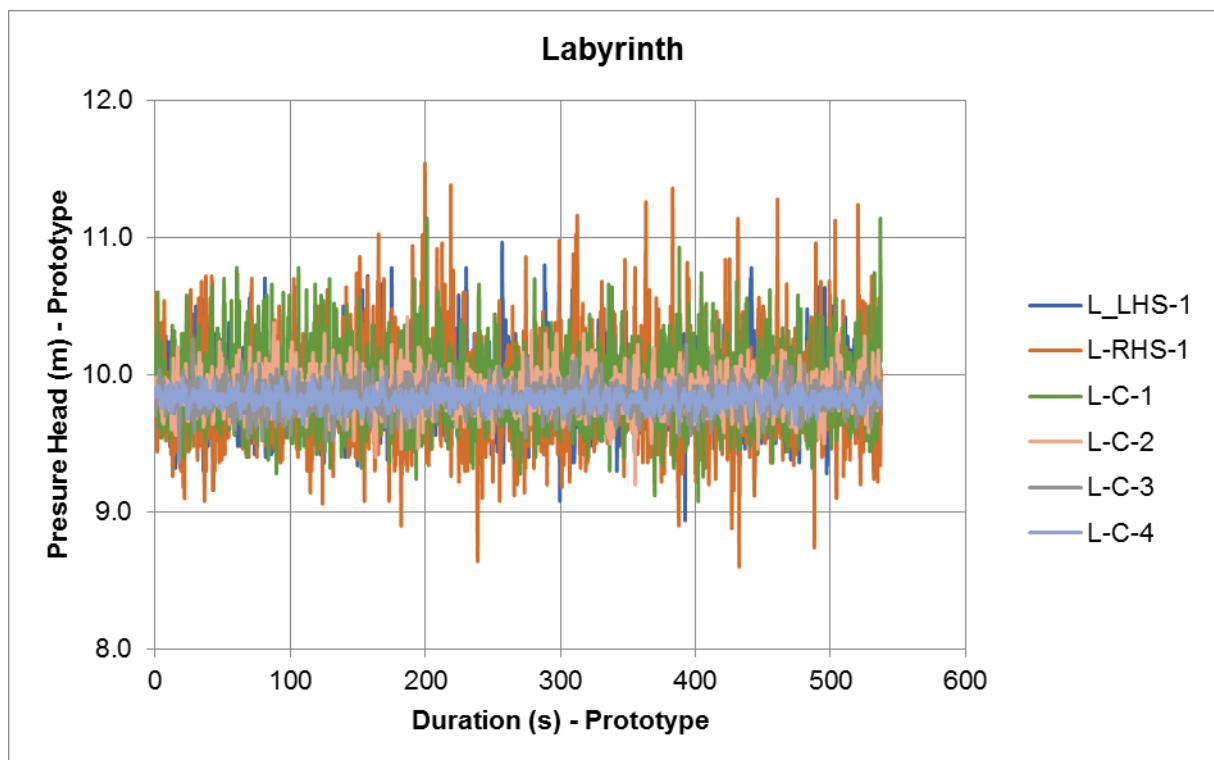


Figure 9 Pressure head for labyrinth spillway Configuration #11 under PMPF flows and normal tailwater conditions

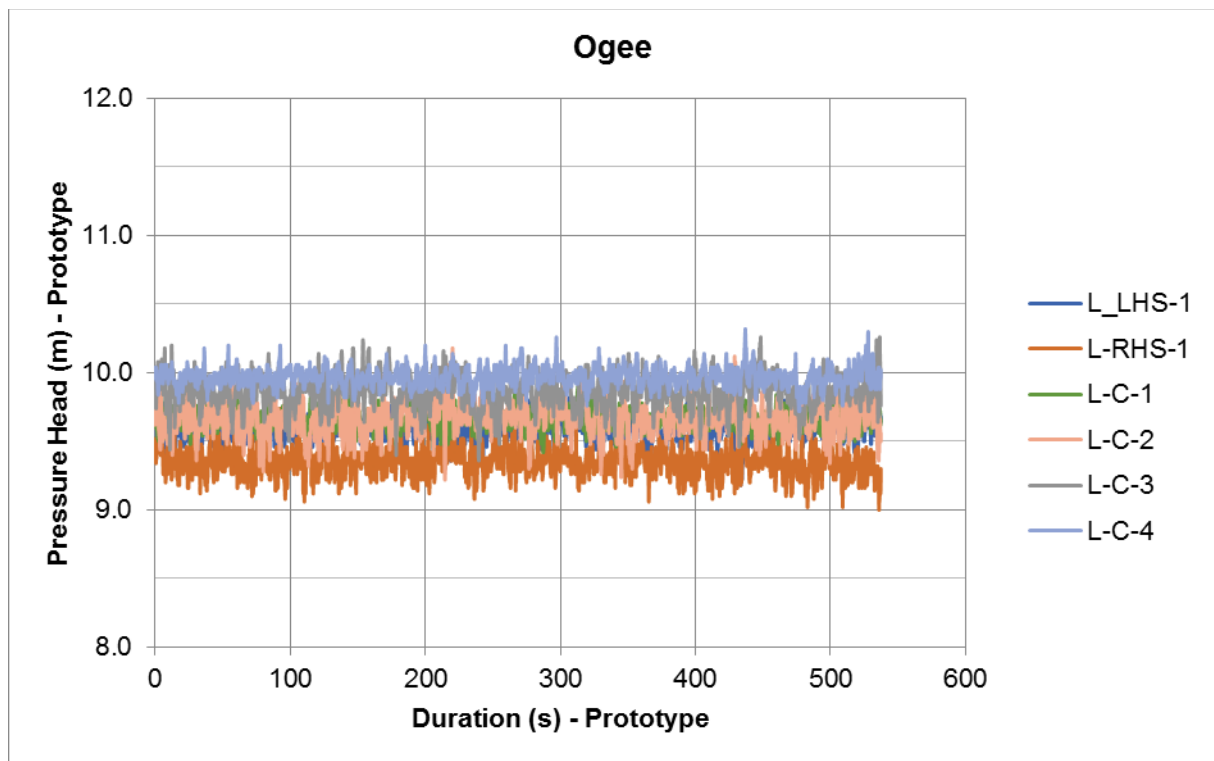


Figure 10 Pressure head for ogee spillway Configuration #10 under PMPF flows and normal tailwater conditions

8.0 Certainty in Performance

Hydraulic performance of the ogee spillway is more predictable than the labyrinth performance. The spillway rating and flow conditions entering the dissipator basin can easily be calculated based upon empirical data and past studies. Performance of roller bucket type arrangements are relatively well studied, whereas hydraulic conditions entering the creek channel downstream of the labyrinth are far more variable and less predictable.

The right-to-left reservoir approach caused unpredictable behaviour with the labyrinth spillway in the physical model. As mentioned in Section 4.0, for some configurations the labyrinth wall angle seemed to interact with the spillway approach direction, creating reflection of the overtopping jet off the left abutment wall and a transient boil that was occasionally observed to shift position over time.

The ogee spillway sends energy downstream much more uniformly than the labyrinth spillway. The labyrinth concentrates flows in the upstream apexes, making the energy variable across the dissipator basin and downstream creek channel. This leads to higher localised velocities in the downstream creek channel, whereas velocities downstream of the ogee would be much more uniform and more predictable.

Labyrinth spillways need to be vented to prevent an oscillating/collapsing nappe. Notches in the abutment walls could be designed to maintain atmospheric pressure downstream of the labyrinth walls, but it is difficult to test the performance of such vents at model scale. Some labyrinths have flow splitters to provide the aerated nappe for low flows, but they can catch debris and require additional maintenance.

There was original concern about the ogee sending all the energy downstream into the creek channel, rather than dissipating some energy within the basin. However, it is also unknown how much energy actually gets dissipated in the rather short basin for a labyrinth. The ogee spillway's end sill directs the overtopping jet high up into the water column, similar to a roller bucket. This helps to keep high velocities off the creek bed, but impacts to features nearer the water surface needs to be further

assessed (e.g. impacts to the NPI and bridge, and impacts to creek banks for floods with lower tailwater levels).

9.0 Spillway Approach Conditions

To validate the spillway approach conditions observed in the physical model, which have a follow-on effect and impact hydraulics entering the downstream creek channel, a CFD model was created and run for the 1:100 AEP and PMPF flood levels.

CFD results indicated the same right-to-left approach of the reservoir towards the spillway. So approach conditions observations in the physical model are thought to be valid. Flow lines for the spillway approach have been captured in the physical model using a dye tracer inserted at set locations. Results are yet to be provided to AECOM. They will be compared to the CFD model results for further validation of the physical model.

CFD results for the 1:100 AEP and PMPF lake levels are provided as Figure 11 and Figure 12, respectively.

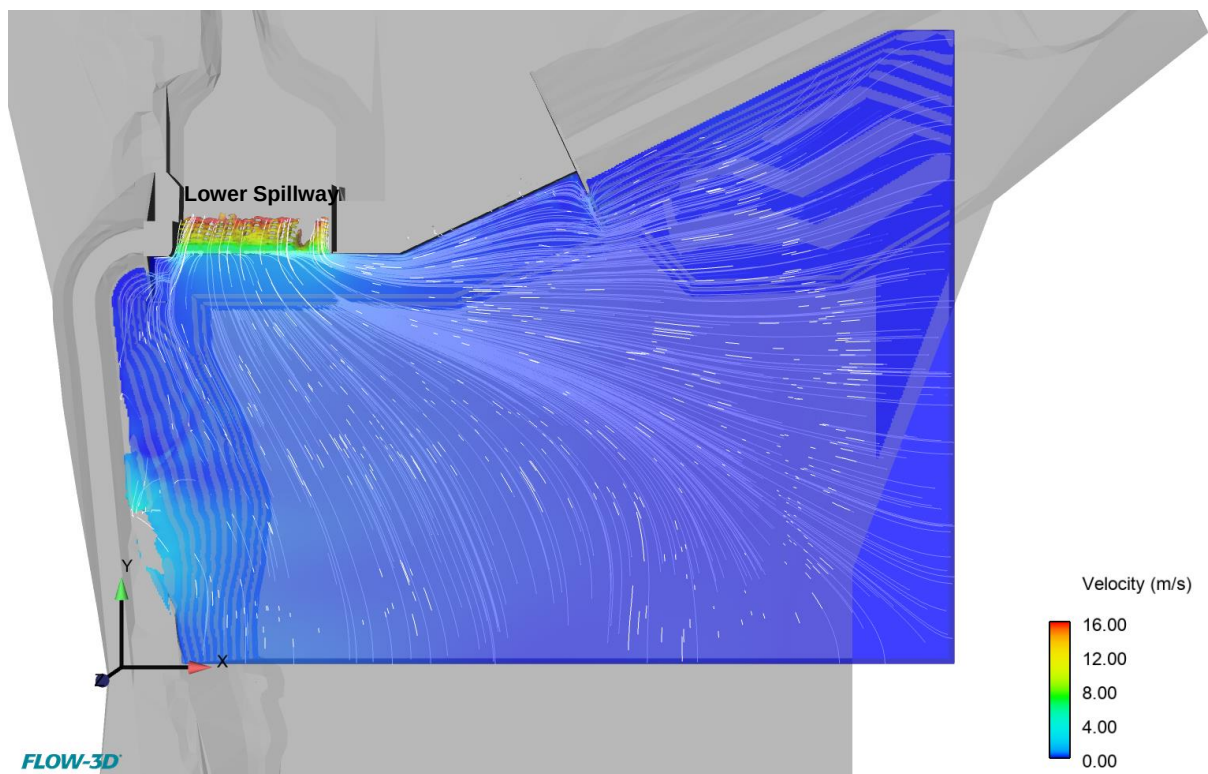


Figure 11 CFD results showing spillway approach velocities for 1:100 AEP lake level

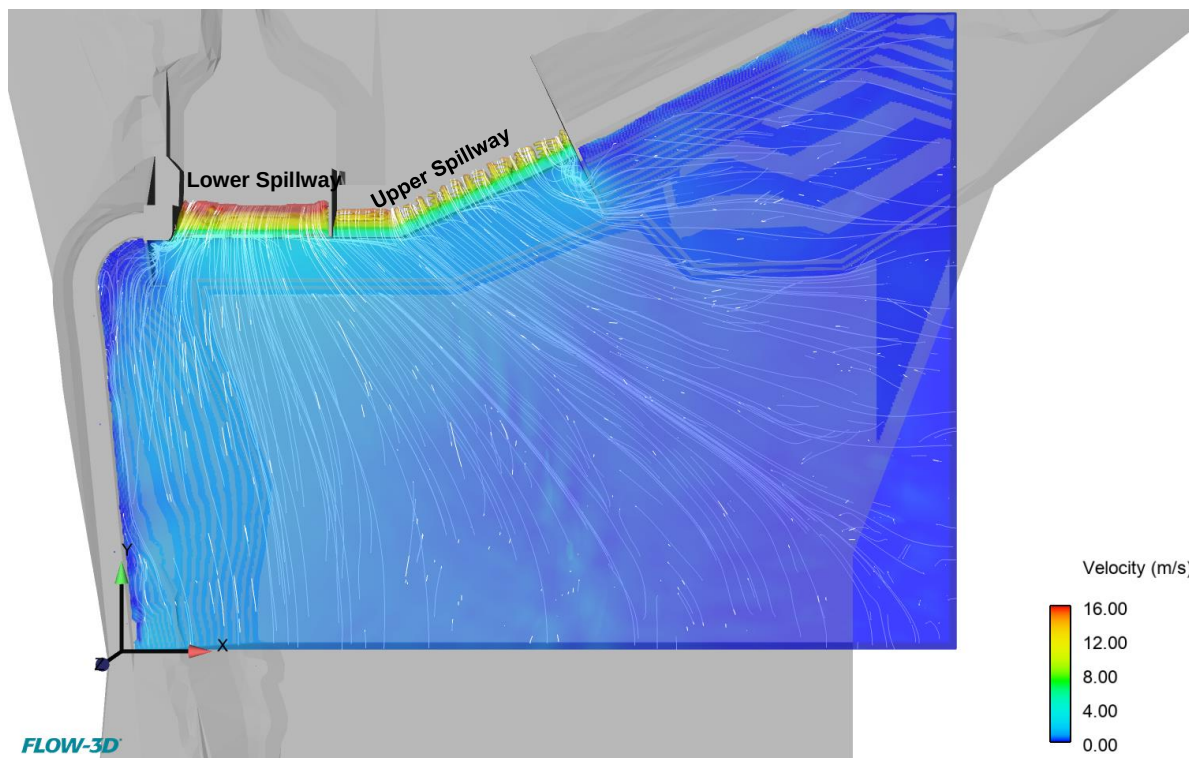


Figure 12 CFD results showing spillway approach velocities for PMPF lake level

10.0 Downstream Fish Passage

Ogee spillways are generally considered acceptable for downstream fish passage. Initial indications from state Regulators and in consultation with Seqwater's fish biology expert, Andrew Berghuis are that an ogee spillway would be preferred over a labyrinth spillway.

While the majority of the labyrinth spillway is likely suitable for downstream fish passage at the 1:100 AEP flood level, the potential for fish injury cannot be completely eliminated, as flows coming over the upstream labyrinth apex corners were shown to result in high velocities (e.g. 12 m/s acting near the dissipation basin floor). It was noted in Andrew Berghuis's report that *'the potential for fish strike against the floor in these zones is still of concern under higher flow events'*.

Both the labyrinth and ogee main spillway options were sized such that they pass the 1:100 AEP flood without overtopping of the upper level spillway. The upper spillway crest was set at RL 97.2 mAHD, which matches Noosa City Council's 1:100 AEP flood level and is not exceeded.

11.0 Comparison and Recommendations

The labyrinth and ogee options have been compared against the following items with results summarised in Table 2:

1. Hydraulic performance.
2. Construction cost.
3. Potential for erosion downstream / requirements for protecting the creek from erosion.
4. Certainty in performance.
5. Fish passage.

Table 2 Comparison of labyrinth and ogee main spillway options

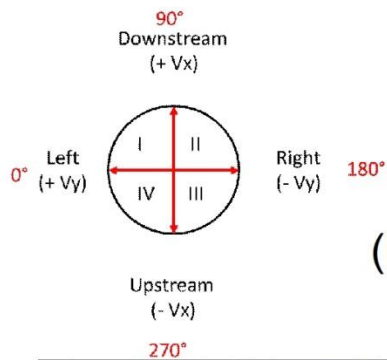
Evaluation Criteria	Labyrinth (main spillway)	Ogee (main spillway)
Hydraulic performance	- Both achieve the Council's 1:100 AEP flood criteria. - Both pass the PMPF with similar residual freeboard. - Neither overtop the upper level spillway before the 1:100 AEP flood	
Construction cost	Baseline cost.	Can match the labyrinth cost by removing one cycle of the service spillway without sacrificing freeboard.
Erosion potential / protection requirements	Velocity measurements collected to date show no major difference between the two options in terms of velocity magnitude. Velocities near the channel bed for PMPF are generally less than 3 m/s (not exceeding 3.5 m/s), which can be handled by reasonably sized riprap. The ogee option showed lower transient pressures, but overall the transient pressures for both options are considered small.	
Certainty in performance	Uncertainty associated with: - Hydraulic conditions entering the creek channel. - Concentration of flow by upstream apexes. - Transient boil on left side of creek channel - Aeration of the nappe. - Degree of injury and/or fatality to fish during downstream passage.	- Performance is more certain for an ogee spillway and the roller-bucket type end sill. - Uncertainty currently remains regarding potential impacts to higher velocities acting on infrastructure downstream near the water surface. This will be evaluated further with CFD modelling.
Fish passage	Less preferred option. Cannot eliminate the potential for injury to fish that pass over upstream apex corners.	Preferred option. Generally considered acceptable for downstream fish passage.

It is noted that one of the original main concerns with ogee option was erosion potential, but model results to date indicate that there is no higher erosion potential for the ogee option than for the labyrinth option. This will be evaluated further with CFD modelling and mobile bed testing in the physical model, and results will be aid in the design of downstream erosion protection works.

It is recommended that an ogee lower level spillway be carried forward into detailed design due to:

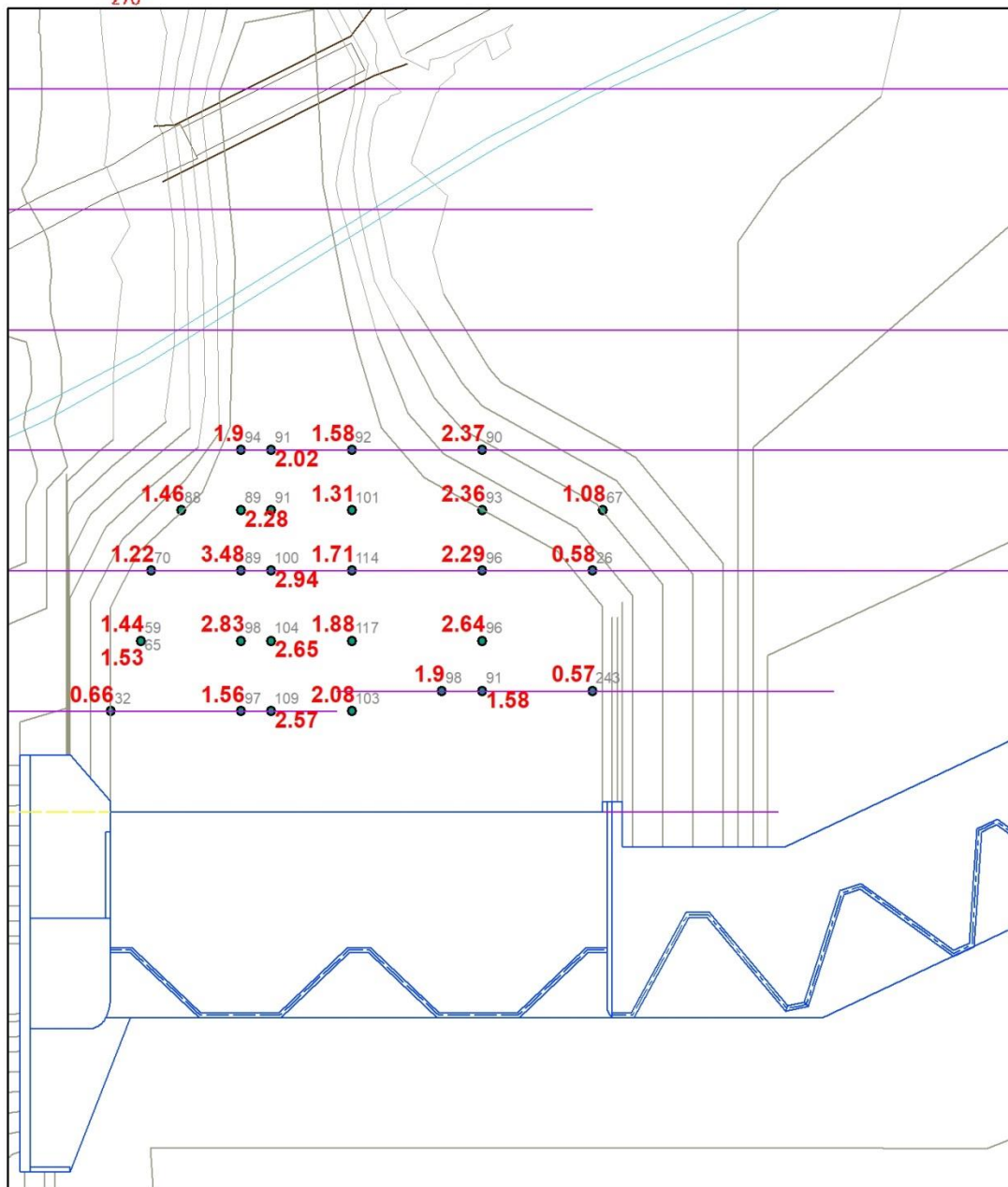
- A higher certainty in its performance. The certainty comes at no additional construction cost and the hydraulic and design criteria of the spillway are still achieved.
- An ogee spillway is preferred for downstream fish passage, which makes it more appealing from an environmental, social and Seqwater reputation perspective.

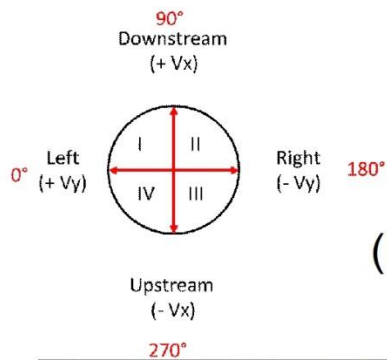
Attachment 1
Velocity Measurements



ADV Velocity Measurements Configuration #11 0.5m Above Bed

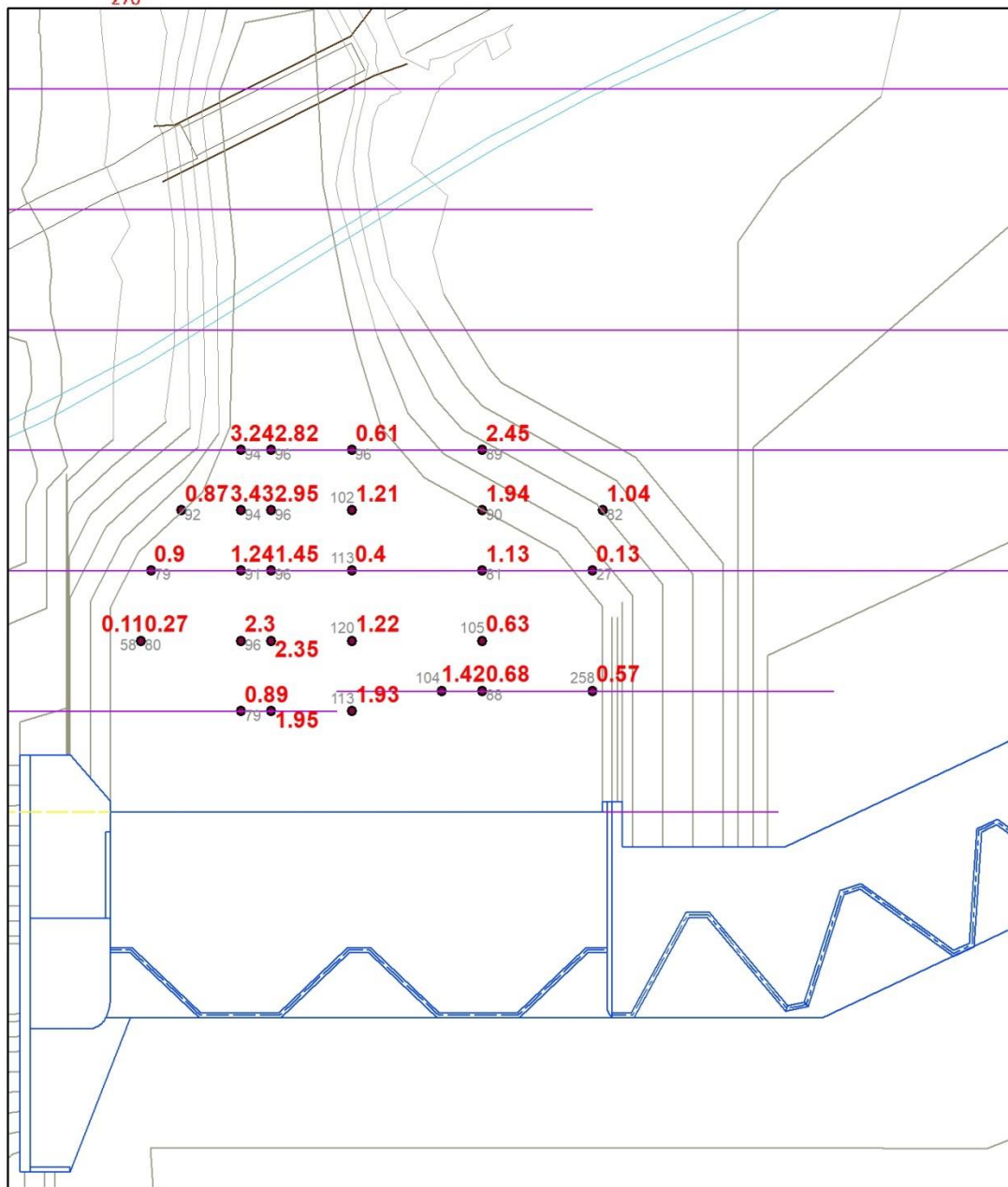
(Red = velocity in m/s, Grey = direction)

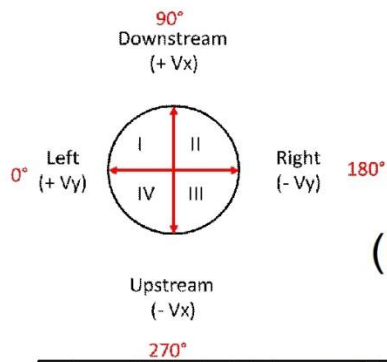




ADV Velocity Measurements Configuration #11 1.0m Above Bed

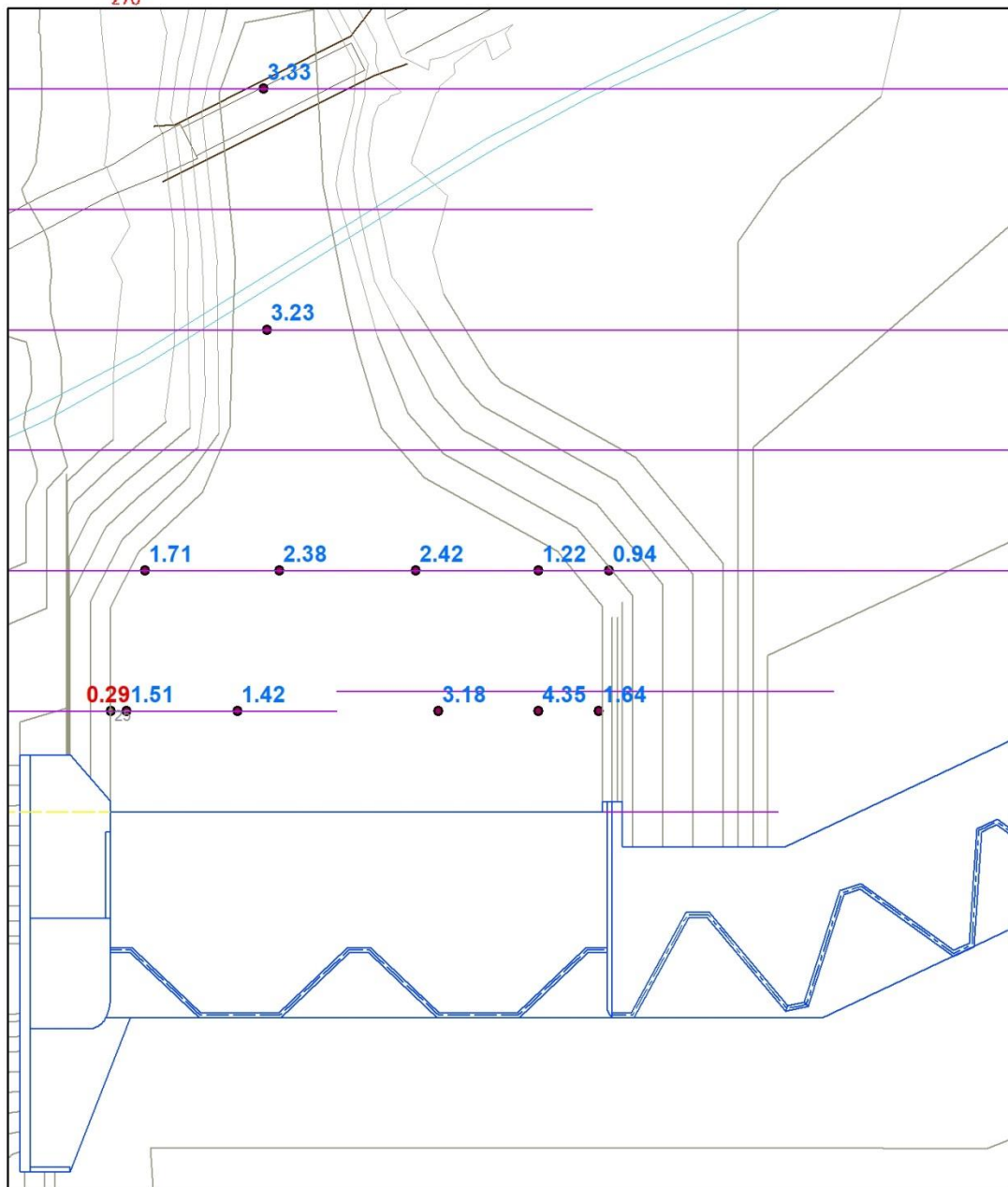
(Red = velocity in m/s, Grey = direction)



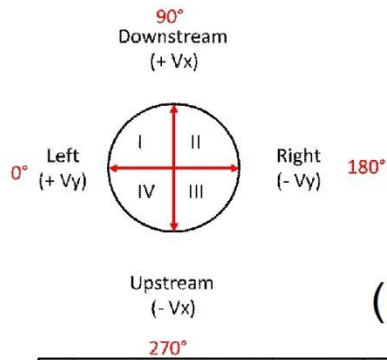


All Velocity Measurements Configuration #11 2.0m Above Bed

(Red = velocity in m/s, Grey = direction)

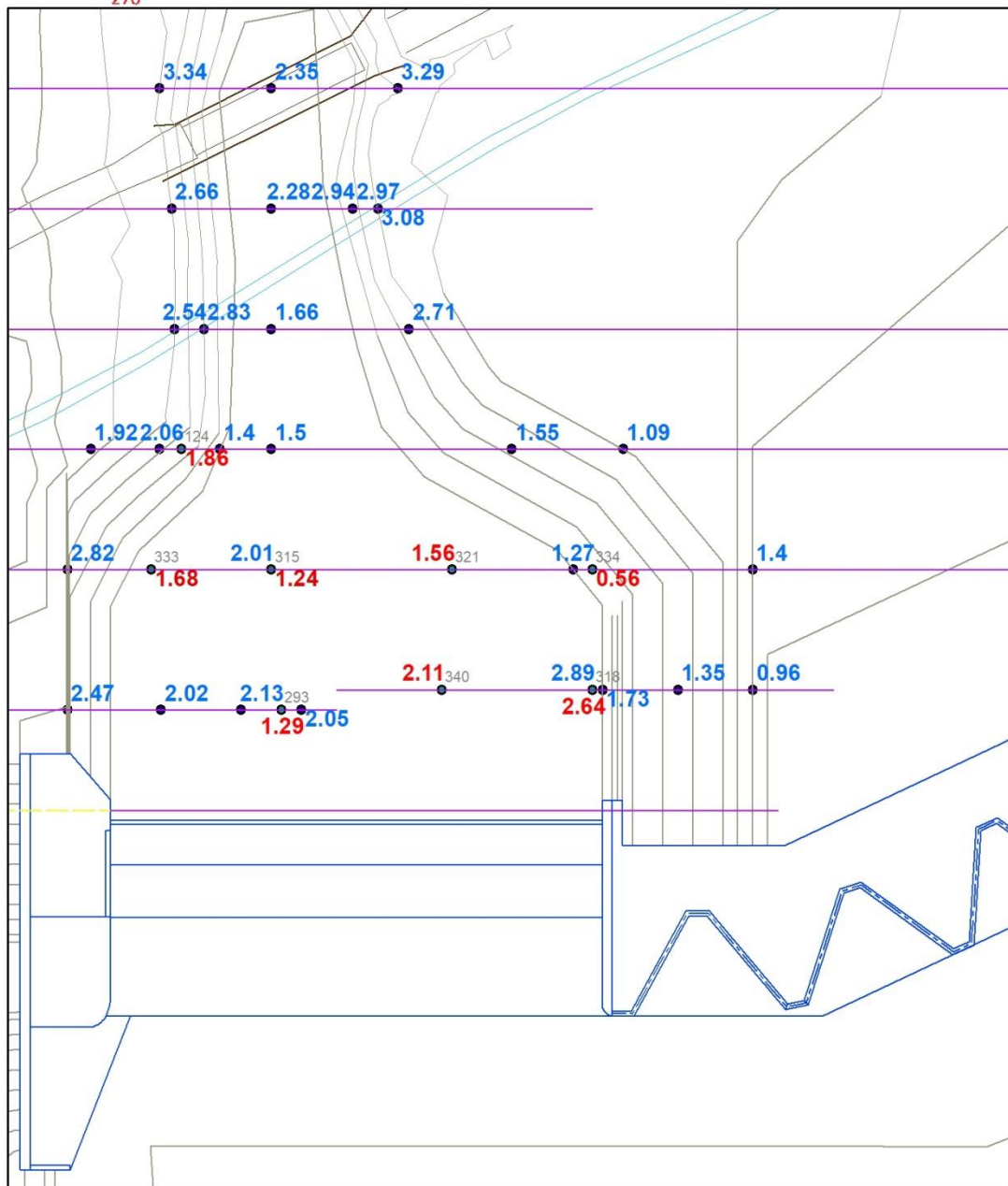


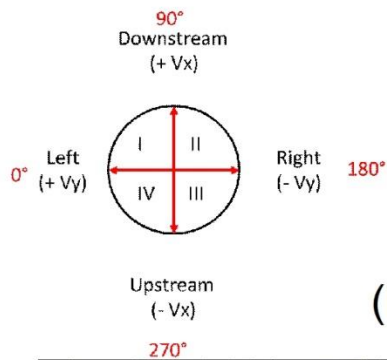
Attachment 2
Velocity Measurements
Configuration #10 (Ogee)



All Velocity Measurements Configuration #10 (Ogee) PMPF Event 0.5m Above Bed

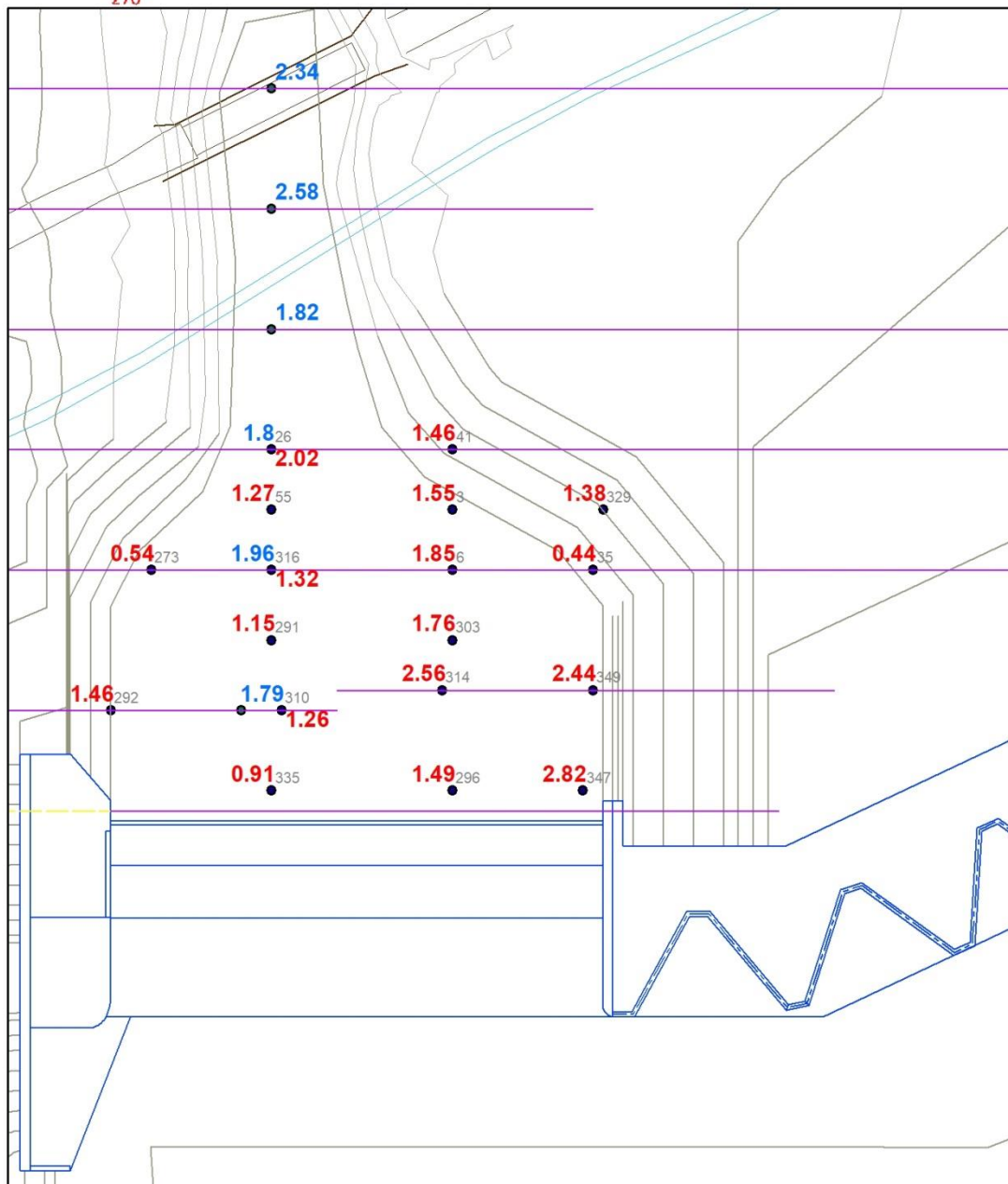
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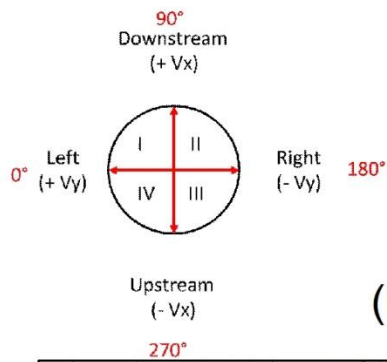




All Velocity Measurements Configuration #10 (Ogee) PMPF Event 1.0m Above Bed

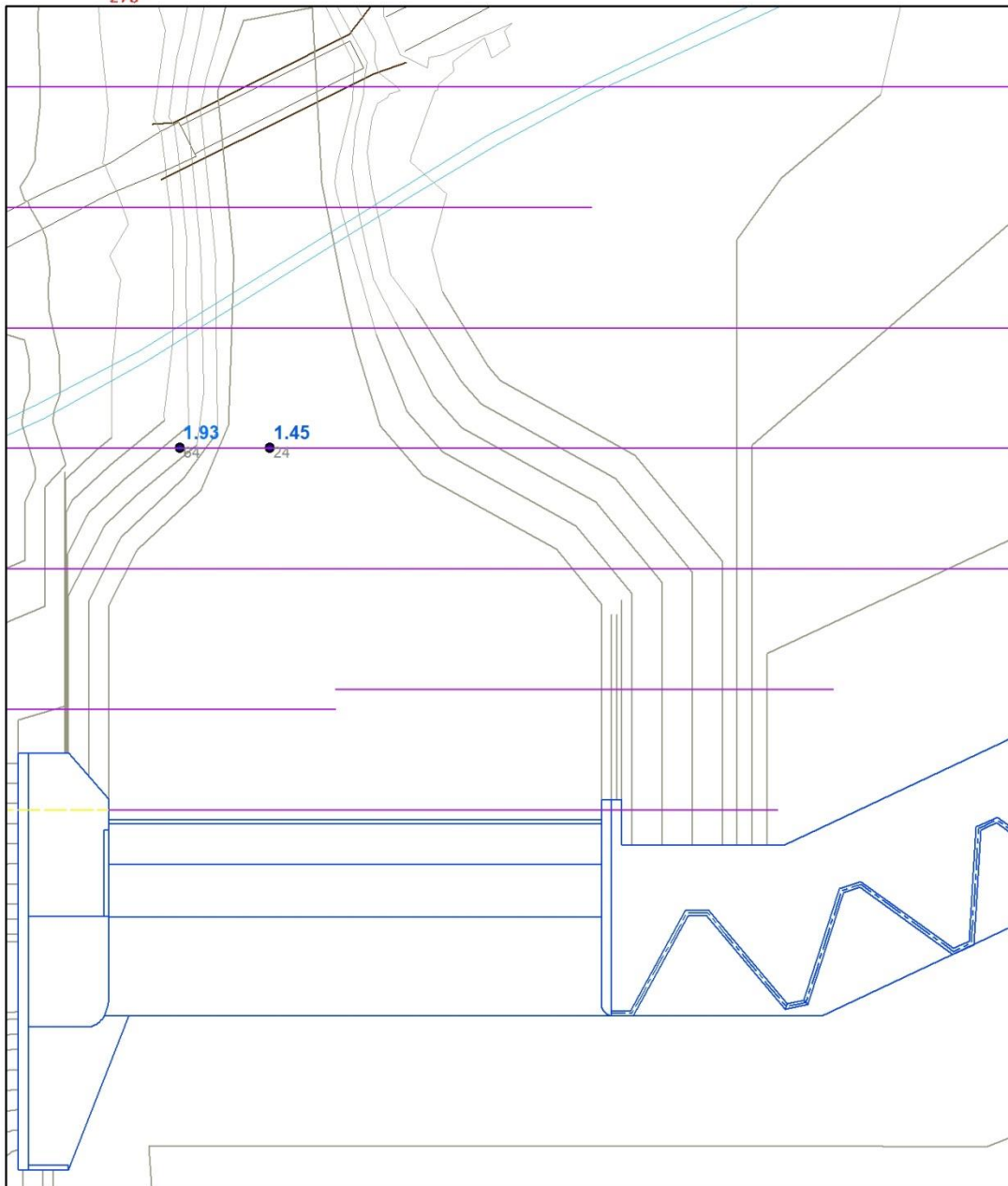
(Red = velocity in m/s, Grey = direction)

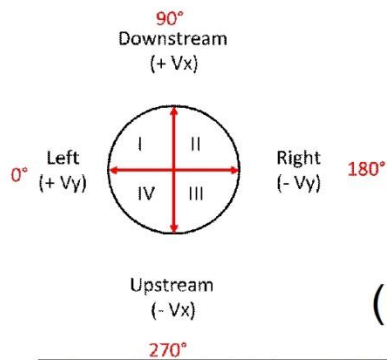




All Velocity Measurements Configuration #10 (Ogee) PMPF Event 1.5m Above Bed

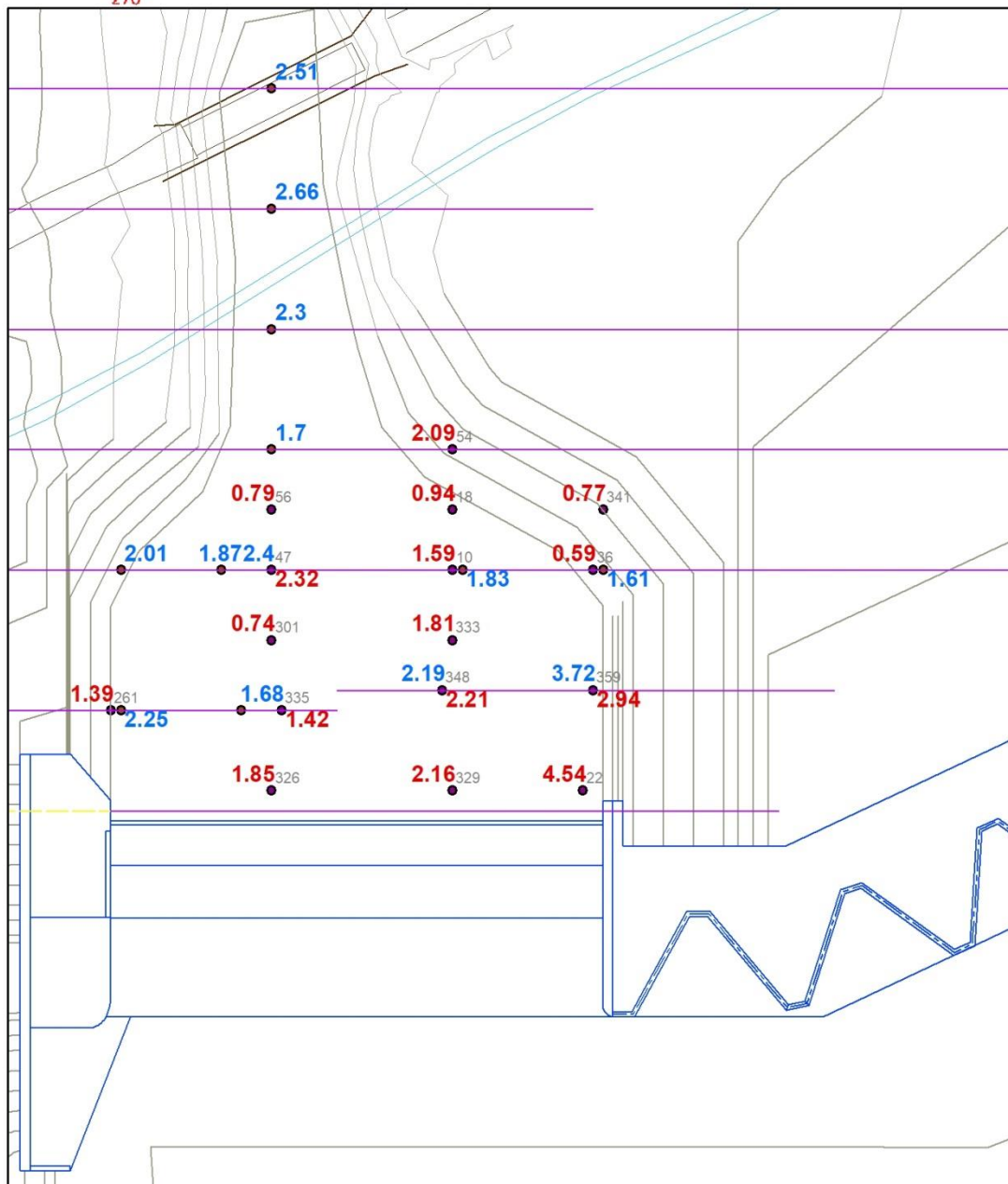
(Red = velocity in m/s, Grey = direction)

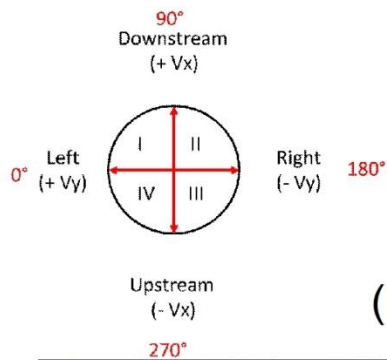




All Velocity Measurements Configuration #10 (Ogee) PMPF Event 2.0m Above Bed

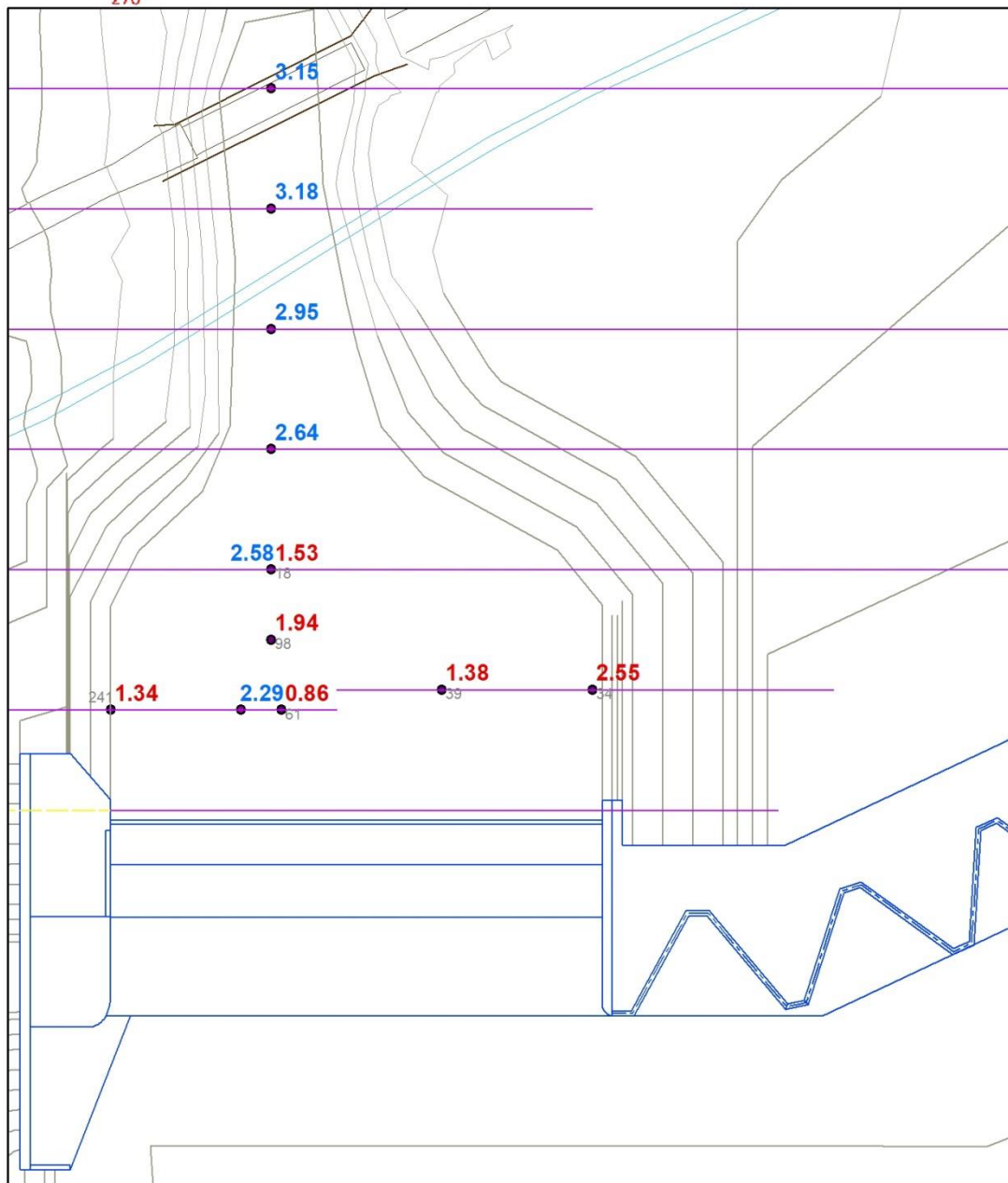
(Red = velocity in m/s, Grey = direction)





All Velocity Measurements Configuration #10 (Ogee) PMPF Event 4.0m Above Bed

(Red = velocity in m/s, Grey = direction)



Andrew Berghuis
Aquatic Biopassage Services

Website: www.aquaticbiopassage.com.au



To: Steven Cox, Environmental Approvals Coordinator (Dam Upgrades)
From: Andrew Berghuis, Principal Consultant, Aquatic Biopassage Services
Date: February 11, 2019
Re: Observations from Six Mile Creek Dam spillway physical model; 07/02/19

Background

Seqwater is undertaking a Dam Safety Upgrade for Lake Macdonald to bring the structure into compliance with current industry guidelines and the requirements of the Water Supply (Safety and Reliability) Act 2008. The upgrade will preserve the storage at its current capacity and height but the spillway configuration will be changed. Aquatic Biopassage Services has been retained by Seqwater to provide technical input on the spillway design with respect to downstream passage of aquatic fauna.

Spillway Development

Seqwater has been working with AECOM and Aquatic Biopassage Services to develop solutions to minimise fauna injury in the spillway and stilling basin design. Computational Fluid Dynamic (CFD) modelling of numerous plunge pool designs for the labyrinth type spillway at various rates of overtopping have been performed by AECOM.

Following detailed review, a single step spillway pool, designated as Configuration 5 and shown in Figure 1, appeared to provide substantial improvements in minimising fish injury. The main features of this configuration were a higher fall between spillway crest to plunge pool surface, deeper plunge pool, and fewer locations of potential hard surface strike. The single pool option also eliminates the risk of fish stranding, as it will retain water and have connectivity with the creek in no flow. Fish and turtles can exit the basin through slots in the end sill.

The only matter that continued to represent potential issues with injury or survival of fish occurred during the higher range of flows (>1.0 m overtopping). At the corners of upstream apexes of the spillway, nappe interference created a localised area of insufficient energy dissipation in the tailwater. The jet resulted in a velocity of up to 12m/s acting on the stilling basing floor as demonstrated in Figure 2.

Although the upstream apex corners only represented a small proportion of the overall spillway, there was potential for fish to be injured against the spillway basin floor at these locations.

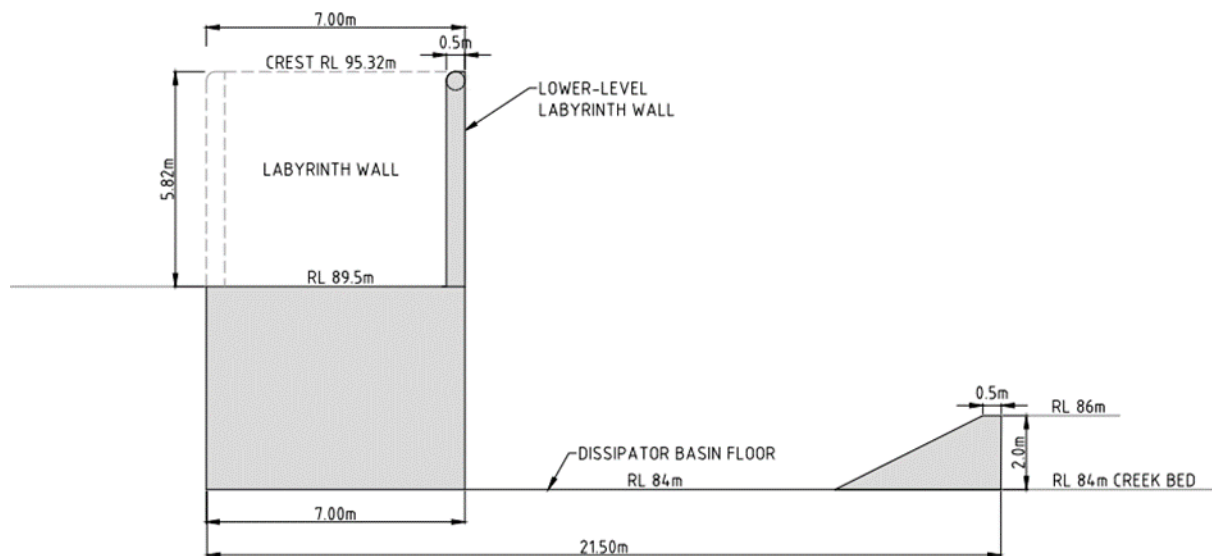


Figure 1. Cross-section of Configuration 5 single pool labyrinth arrangement.

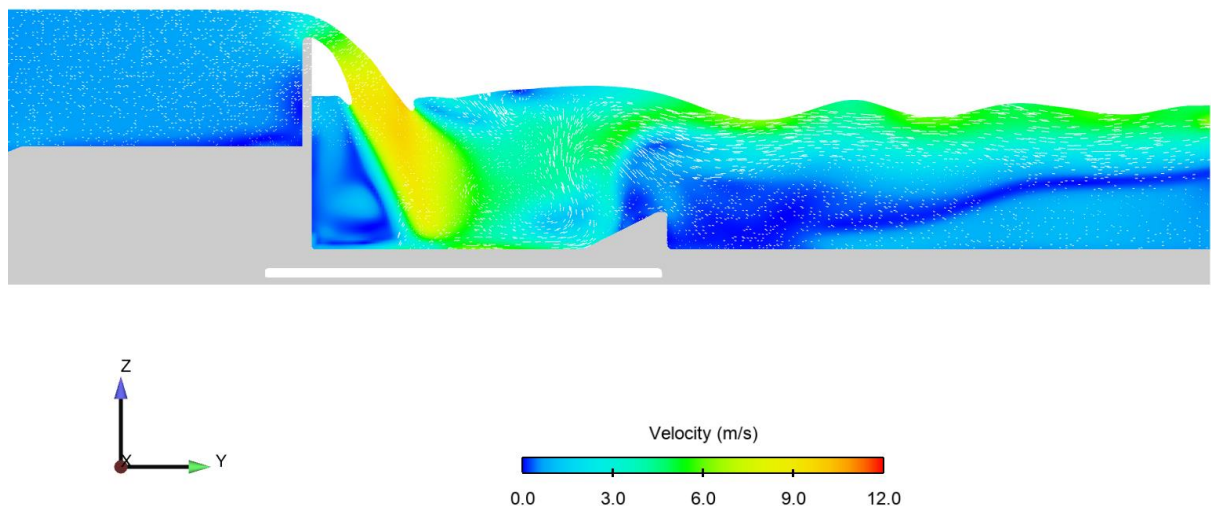


Figure 2. CFD model of Configuration 5 at 1500 mm overtopping showing slice through upstream apex section.

Physical modelling

Labyrinth spillway

A physical model of the labyrinth spillway incorporating the Configuration 5 plunge pool design was investigated at the University of NSW, Water Research Laboratory in Manly. Physical modelling confirmed that the nappe interference areas that were observed at the upstream apex in the CFD modelling resulted in a high velocity impact of up to 12m/s on the spillway floor.

Modifications to the labyrinth design were made to minimise nappe interference, which included a change from a three-cycle to two-cycle design; to widen the apex sections and reduce the angle of the upstream apex. Various configurations were trialed in the physical model, and a two-cycle spillway arrangement designated as Configuration 8 (refer Figure 3) was the preferred arrangement.

Configuration 8 provided upstream apices with a wider angle that reduced the total area of nappe interference but did not eliminate it. The area of impact is limited to four zones of approximately 2m^2 , these areas are demonstrated by the red-circled areas in Figure 3.



Figure 3. Physical model of Configuration 8 labyrinth arrangement at a prototype equivalent of 1.0m spillway overtopping, red-circled areas represent areas of high impact on basin floor.

At overtopping levels equivalent to 1.8m (1:100 AEP) and 1.0m (1:20 AEP) over the spillway crest for the full scale prototype, water velocities of the jet from upstream apices were up to 12m/s at a depth equivalent of 2m above the spillway basin floor on the full scale prototype. At an overtopping level equivalent to 0.6m, the water velocities downstream of the jet caused by the upstream apices were much lower, with velocities as low as 2m/s being recorded.

In areas outside of the impact of the upstream apices, velocities immediately above the spillway basin floor were approximately 1m/s at all flows. Evaluation of the Configuration 8 physical model is ongoing, a detailed report on the outcomes of the modelling will be produced by AECOM.

In regards to downstream fish passage over the Configuration 8 labyrinth, velocities throughout the majority of the spillway tailwater pool were relatively benign. Isolated small areas of moderate turbulence were observed immediately downstream of the jets from the upstream apices. The remainder of the tailwater pool was observed as having low turbulence and there appeared to be a very low possibility of fish entrainment within the basin overall.

In comparison to the previous labyrinth spillway configuration, there is a reduction in the area of high velocity acting on the stilling basin floor at the upstream apices with Configuration 8. The high velocity areas on the full-scale prototype have potentially been reduced to four separate zones with a diameter of approximately 2m^2 each; a small proportion relative to the entire spillway length and only for short durations of flow. For example, there is a 1% chance for 1:100 AEP flood in given year, the potential for fish injury over less than 10% of weir length for over a total of 6 hrs if the event occurs, (AECOM data).

Ogee spillway

As an alternative design to the Configuration 8 labyrinth, an Ogee type spillway crest on a slope of 55° was investigated for the main (lower) spillway (Figure 4). Evaluation of the tailwater pool conditions at overtopping levels equal to 1.6m over the spillway crest for the full-scale prototype indicated uniform water velocities up to 2m/s immediately downstream of the spillway and at a depth equivalent of 2m above the spillway basin floor on the full-scale prototype.

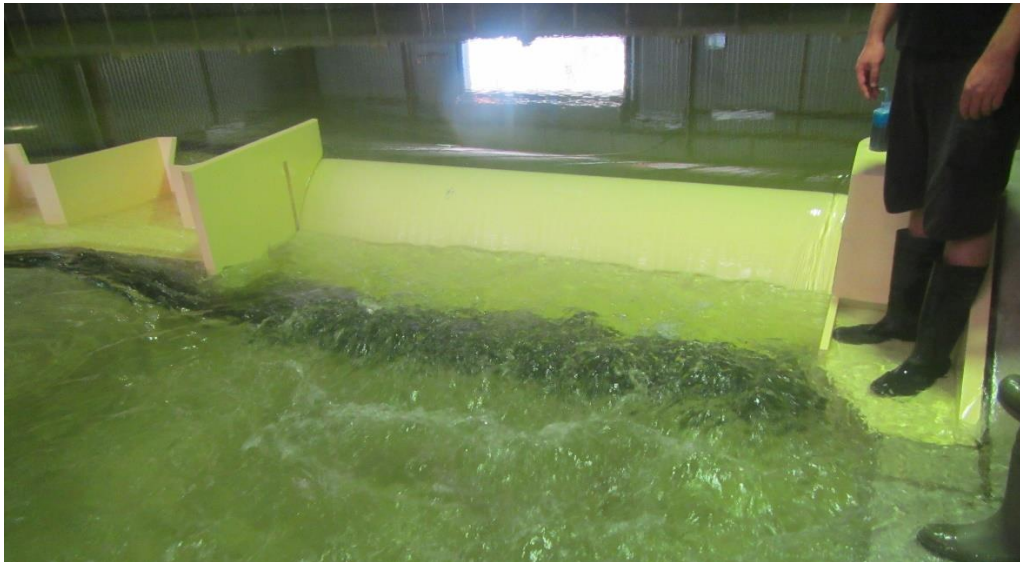


Figure 3. Physical model of Ogee spillway arrangement at a prototype equivalent of 0.8m spillway overtopping.

At the flow shown in Figure 4, a spillway water depth of 0.8m on the full-scale prototype equivalent resulted in a minimum depth of approximately 0.4m on the downstream face of the weir. At a lower flow of 0.4m, spillway depth on the prototype equivalent the minimum depth on the downstream face was 0.2m prototype equivalent. No other flow rates were evaluated on the day.

In comparison to the Configuration 8 labyrinth design, the Ogee spillway design appeared to provide very benign tailwater conditions for fish that passed downstream over the spillway crest. The most significant advantage at this site is the deep tailwater pool even at low flows.

No obvious issues that may cause fish injury in the tailwater pool were observed. A small sill on the tailwater pool floor directed flows away from the floor and towards the water surface. Water velocities at the sill appeared sufficiently low to avoid major issues with fish strike. A roller zone immediately upstream of the sill caused a reverse flow, however there were no obvious areas of high turbulence that were likely to entrain fish.

The shallow water depth observed on the downstream spillway face at moderate to low flows has the potential to cause injury due to shear forces on the spillway chute. To date no Australian studies on the survival of fish on an Ogee spillway have been performed.

At Lake Macdonald Dam the deep tailwater pool provides a cushioning effect that is likely to minimise potential for strike, however if the Ogee design is to proceed, modelling of the potential for strike must be investigated and minimised.

At a meeting following the physical modelling on the 7th February, the potential to lower a small section of the Ogee spillway by up to 0.3m was discussed as a potential solution to deepen spillway flows (i.e. low flow notch). It is recognised that there are implications associated with lowering the spillway that impact on other aspects of flow management at the site. However, it is recommended that the potential for providing a low flow spillway be investigated to determine if any amount of spillway lowering is practical and if so what benefit this would provide for downstream fish passage.

Conclusion

The combination of CFD and physical modelling has provided the opportunity to assess the labyrinth design concept in some detail with comparable results between the two hydraulic analysis methods. The majority of the labyrinth spillway provides what appears to be suitable conditions for downstream fish passage. However, localised velocities in the tailwater pool below the corners of the upstream apexes area remain excessive, particularly at moderate to high flows (e.g. 1:20 AEP to 1:100 AEP event).

The Configuration 8 design (inverted labyrinth profile) has reduced the extent of the problem areas created by the upstream apexes. Further detail including CFD modelling of a full spillway cycle for flows up to 1:100 AEP will be performed by AECOM and this will inform the actual extent of the impact on downstream fish passage. The hydraulic modelling data in conjunction with the frequency and extent of unsuitable conditions that are likely to occur will assist in the decision making process for the final design.

Due to the late inclusion of an Ogee spillway design for Lake Macdonald Dam, there is less detail to aid in the evaluation of safe downstream fish passage. Observations of the physical model indicate that conditions in the tailwater pool are likely to be favourable. The shallow nature of flow over the spillway face introduces potential for fish injury. Options to increase the water depth of the spillway face as far as practical should be investigated. Further detail including CFD modelling of a spillway section in flows up to 1:100 AEP will inform the actual extent of the impact and velocities and assist in the decision making process for the most suitable spillway design for Lake Macdonald.

Appendix 4 Addendum to IAR Appendix M – State Code 18

State code 18: Constructing or raising waterway barrier works in fish habitats

Table 18.2.2: Operational work

Performance outcomes	Acceptable outcomes	Response
All development		
PO1 There is a demonstrated need for the development and alternatives (locations and designs) which do not involve constructing or raising waterway barrier works are not viable.	No acceptable outcome is prescribed.	Complies with PO1 Seqwater needs to undertake safety upgrade works on Six Mile Creek Dam in order to meet legislative requirements for dam safety of regulated dams and meet current and future standards. The upgrade will involve rebuilding the embankments and replacing the spillway. An upgrade of Six Mile Creek Dam was identified by Seqwater's portfolio risk assessment (PRA) completed in 2013, which identified the dam: • has a societal risk just above the Australian National Committee on Large Dams (ANCOLD) defined limit of tolerability, and • does not satisfy the Queensland Guidelines on Acceptable Flood Capacity (DEWS 2013). The key failure mechanisms to be addressed by the safety upgrade are piping through the earthen embankment during flood and liquefaction of foundation materials under the spillway due to earthquake. Seqwater reviewed a range of options to manage dam safety for Six Mile Creek Dam, including: • Adoption of risk reduction strategies (such as downstream property purchase) – not feasible as such measures still fail legislative requirements. • Partial dam upgrade – not feasible due to residual safety risk associated with potentially liquefiable material within the existing spillway foundation. • Reconstructing the embankment and relocating the spillway to the right of the dam - not feasible due to poor foundation conditions. • Decommissioning the storage - not feasible due to impact on Seqwater operations, the need for a water source to meet future demand, and potential environmental impacts. • Replacing the dam with a weir - not feasible due to the need to augment water supply for the lost capacity. • New dam options (new alignment in vicinity of existing dam - not feasible due to high costs identified in response to the outcomes of geotechnical investigations. Further information on the need for the project is discussed in the Draft IAR, particularly the Executive Summary and Chapter 2 (Project Description).

Performance outcomes	Acceptable outcomes	Response
PO2 Development has a functional requirement to be located within a waterway. Ancillary elements of development occur outside the waterway. Note: Bed and banks of the waterway and any associated wetlands and riparian areas within the development site should be accurately identified on plans provided with the application, together with the location of highest astronomical tide, mean high water spring and mean low water spring tide heights if the waterway is tidal.	No acceptable outcome is prescribed.	Complies with PO2 The existing dam is for a water supply impoundment located on Six Mile Creek in the Noosa Shire. An option to decommission the dam was considered, but discounted due to the impact on Seqwater operations (bulk treated water supply), particularly the need for future water supply in the region and the consequential bring forward costs of alternative supplies. The proposed dam upgrade will largely be built and operated within the existing dam and impoundment footprint. The dam safety upgrade will not alter the existing dam full supply level (FSL), or the frequency of spilling flows downstream (hydrological or flow regime). Further information regarding options considered for the project is discussed in the Draft IAR, Chapter 2 (Project Description).
PO3 The number and extent of waterway barrier works and the spatial and temporal extent of their impacts on waterways providing for fish passage are minimised.	No acceptable outcome is prescribed.	Complies with PO3 The proposed dam safety upgrade will largely be built and operated within the existing dam and impoundment footprint. The dam safety upgrade will not alter the existing dam full supply level (FSL), or the flow regime downstream. The proposed dam will comprise a package of waterway barrier works, being the dam embankments, spillway, spillway end sill structure and erosion protection. Modifications to the dam and immediate downstream waterway will extend no further than the existing vehicle bridge across Six Mile Creek, which is approximately 70 m downstream of the existing spillway toe. The proposed dam spillway and end sill will be relatively compact and extend no further downstream than the existing dam structure. Nevertheless, modifications to channel width will be necessary to accommodate the lower spillway, which will be wider than the existing spillway channel. The proposed channel will be tapered to match the existing bank width at the existing pipeline and bridge infrastructure. Rock erosion protection will be necessary on the bed and banks downstream to the existing infrastructure. The arrangement for dam construction footprint is shown in the Draft IAR, Appendix D (Concept Design – Embankment Reconstruction Plan). It should be noted that some detailed aspects of the final dam design, such as erosion protection and channel tapering, have not yet been finalised. These aspects are not anticipated to impact fish passage any more than the proposed dam upgrade, which will be a complete barrier to fish passage. The design intent for spillway end sills and erosion protection is for these structures to prevent or minimise the chance of fish stranding by providing permanent connectivity with the static water level of Six Mile Creek. Finalised detailed design of the dam and spillway structures to confirm this design intent will be provided with the development application for waterway barrier works. During construction a temporary sheet pile coffer dam will be installed in the upstream side of the existing embankment, which is functionally required to maintain control of the level and flow path of the lowered lake during construction. A discussion on coffer dam options considered is provided in the Draft IAR, Chapter 2 (Project Description, page 2-3). The coffer dam is further discussed on page 2-23 of Chapter 2.

Performance outcomes	Acceptable outcomes	Response
		No other waterway barrier works are proposed as part of this development application. Where additional temporary measures are proposed by the construction contractor, based on further detailed consideration of the project constructability, such measures will be separately managed by the construction contractor.
PO4 For the life of the barrier, adequate fish passage must be provided and maintained at all waterway barrier works through: 1. fish way(s) that adequately provide for the movement of fish; or 2. the movement of fish is adequately provided for in another way.	For all crossings: AO4.1 Hydraulic conditions (depth, velocities and turbulence) from the downstream to the upstream limit of the structure allow for fish passage of all fish attempting to move through the crossing at all flows up to the drownout of the structure. AND	Not applicable – works are not a crossing.
	AO4.2 For the life of the crossing, the relative levels of: 1. a bed level crossing or a culvert invert 2. bed erosion protection 3. apron scour protection; and 4. the stream bed are maintained to avoid drops in elevation at their joins. AND	Not applicable – works are not a crossing.
	AO4.3 The crossing and associated erosion protection structures are installed at no steeper gradient than the waterway bed gradient. AND	Not applicable – works are not a crossing.
	AO4.4 The crossing and associated erosion protection structures are roughened throughout to approximately simulate natural bed conditions. AND	Not applicable – works are not a crossing.
	AO4.5 Design and maintenance measures are in place for the life of the crossing to keep crossings clear of blockages through a regular inspection program in order to retain fish passage through the crossing. AND	Not applicable – works are not a crossing.

Performance outcomes	Acceptable outcomes	Response
	For waterway crossings other than bridges and culverts: AO4.6 The crossing is built at or below bed level so that the surface of the crossing is no higher than the stream bed at the site. AND	Not applicable – works are not a crossing.
	AO4.7 The lowest point of the crossing is installed at the level of the lowest point of the natural stream bed (pre-construction), within the footprint of the proposed crossing. AND	Not applicable – works are not a crossing.
	AO4.8 There is a height difference between the lowest point of the crossing and the edges of the low flow section of the crossing so that water is channelled into the low flow section of the crossing. AND	Not applicable – works are not a crossing.
	AO4.9 The level of the remainder of the crossing is no higher than the lowest point of the natural stream bed outside of the low flow channel. AND	Not applicable – works are not a crossing.
	For bridges: AO4.10 Bridge support piles are not constructed within the low-flow channel and do not constrict the edges of the low-flow channel, and the number of piles in-stream are minimised. AND	Not applicable – works are not a bridge.
	AO4.11 Bridge abutments and bank revetment works do not extend into the waterway beyond the toes of the banks. AND	Not applicable – works are not a bridge.
	AO4.12 Suitable fish habitats are maintained within the low-flow channel. AND	Not applicable – works are not a bridge.
	For culverts:	Not applicable – works are not a culvert.

Performance outcomes	Acceptable outcomes	Response
	AO4.13 Culverts are only installed where the site conditions do not allow for a bridge. AND	
	AO4.14 The combined width of the culvert cell apertures are equal to 100 percent of the main channel width. AND	Not applicable – works are not a culvert.
	AO4.15 The base of the culvert incorporates a low flow channel consistent with the natural low flow channel and: 1. is buried a minimum of 300 millimetres to allow bed material to deposit and reform the natural bed on top of the culvert base; or 2. the base of the culvert is the stream bed; or 3. the base of the culvert cell and any instream scour protection is roughened throughout to approximately simulate natural bed conditions. AND	Not applicable – works are not a culvert.
	AO4.16 The outermost culvert cells incorporate roughening elements such as baffles on their bankside sidewalls. AND	Not applicable – works are not a culvert.
	AO4.17 Roughening elements are installed on the upstream wingwalls on both banks to the height of the upstream obvert or the full height of the wingwall. AND	Not applicable – works are not a culvert.
	AO4.18 Roughening elements provide a contiguous lower velocity zone (no greater than 0.3 metres/second) for at least 100 millimetres width from the wall through the length of the culvert and wingwalls. AND	Not applicable – works are not a culvert.
	AO4.19 Culvert alignment to the stream flow minimises water turbulence. AND	Not applicable – works are not a culvert.

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	AO4.20 There is sufficient light at the entrance to and through the culvert so that fish are not discouraged by a sudden darkness. AND	Not applicable – works are not a culvert.
	AO4.21 The depth of cover above the culvert is as low as structurally possible, except where culverts have an average recurrence interval (ARI) greater than 50 years. AND	Not applicable – works are not a culvert.
	AO4.22 For culvert crossings designed with a flood immunity ARI greater than 50 years, fish passage is provided up to culvert capacity.	Not applicable – works are not a culvert.
	For all other development no acceptable outcome is prescribed.	Solution Proposed Adequate fish passage is provided in line with current waterway conditions and flow regime, whereby an existing lawful structure is in place. The proposed dam safety upgrade will maintain the existing waterway conditions and will be no worse in terms of fish passage opportunity. The existing Six Mile Creek Dam does not provide for upstream fish passage and provides downstream fish passage during spillway flows. Opportunities to improve fish passage with a fishway were investigated for the proposed dam upgrade and also compared with alternatives. A discussion on the investigation and outcomes is provided in PO5 response. In summary, a fishway at Six Mile Creek Dam would provide limited benefit due to operational limitations and relatively small upstream catchment opened up. A fishway may also lead to non-compliance with General Biosecurity Obligations. An alternative fish passage improvement with greater catchment benefit is proposed in lieu of improving fish passage at Six Mile Creek Dam. This is discussed further in PO5 response.
PO5 Waterway barrier works are designed, constructed, operated and maintained to provide lateral and longitudinal fish passage for all members of the fish community, regardless of size, species, life-stage or swimming ability, and accommodating future and seasonal increases in fish biomass. Note: In order to demonstrate compliance with this performance outcome, the seasonal and flow related biomass of the fish community at the	No acceptable outcome is prescribed.	Solution Proposed As described in PO4 response – the proposed dam safety upgrade does not comply with PO5 for longitudinal passage for upstream movement. Complies with PO5 for longitudinal passage for downstream movement and lateral passage. <i>Downstream movement</i> It is proposed that downstream fish passage will be provided via spillway flows, whereby opportunities for downstream fish passage will be available as soon as a spill commences. Information relating to the safety of downstream passage is provided in PO6 response.

Performance outcomes	Acceptable outcomes	Response
location of the proposed waterway barrier works will need to be surveyed and addressed in the design of the fish way by a person suitably qualified and experienced in fish passage biology. In addition, any future increases in fish biomass should be quantified and catered for. Longitudinal fish passage refers to the movement into both permanent and temporary offstream systems, including wetlands, lagoons, floodplain etc. Fragmentation of connectivity into and out of these systems must be mitigated via adequate fish passage.		<i>Lateral movement</i> The proposed dam safety upgrade will not be a barrier to lateral fish passage as it will not impede overland flow of water. <i>Upstream movement</i> During the project design, a biopassage expert was engaged to investigate all options to provide fish passage on the upgraded Six Mile Creek Dam¹. The investigation incorporated: - the outcomes of fish community surveys undertaken by suitably qualified aquatic ecologists - the hydrology of Six Mile Creek at the existing dam site, and - proposed operational parameters that could be employed for a fishway (such as flow rates and triggers), which provide an estimate of fishway operation frequency while incorporating water security of the existing impoundment. Based on a multi-criteria analysis, the biopassage investigation determined that a simplified fish lift with automatic operation would be the most suitable option for upstream passage. The fish lift operational frequency would be based on a compromise to maintain water security, whereby the fishway would operate when there were inflows to the lake, or the dam was spilling, which would also mimic natural flow regime cues. Nonetheless, this limitation of fishway operating frequency reduces the opportunity for fish passage and the associated benefit. In addition, the need for a mechanical fishway led to reduced confidence in operational reliability based on experience in Queensland, which also reduced the perceived benefit of a fishway at Six Mile Creek Dam. Following the fish passage options assessment, Seqwater was notified in January 2018, that Mozambique tilapia (a noxious fish and restricted biosecurity matter in categories 3, 5, 6 and 7 under the <i>Biosecurity Act 2014</i>) had been observed immediately downstream of the Six Mile Creek Dam spillway. This noxious fish has not been recorded upstream of the dam. Seqwater has a General Biosecurity Obligation (GBO) under the <i>Biosecurity Act 2014</i> that, based on advice provided by the Department of Agriculture and Fisheries (DAF), cannot be removed by the conditions of a coordinated project evaluation report or a waterway barrier works development approval. Consequently, any provision of upstream fish passage at Six Mile Creek Dam must also enable Seqwater to comply with its GBO. This finding further limited the options for upstream fish passage to methods that include manual fish sorting (e.g. trap and haul or a simplified fish lift with manual operation). Seqwater has experience with manual fish sorting at Hinze Dam, and determined that there are significant constraints to effective fishway operation. These include: - the requirement for an on-going workforce to sort the fish (generally restricted to business hours) - health and safety issues, particularly manual handling of fish with spines - misidentification of fish by staff (i.e. unintentionally allowing pest fish upstream or destroying a native fish).

¹ Berghuis, A. (2018). Fish passage options for Six Mile Creek Dam, Six Mile Creek. Report to Seqwater prepared by Aquatic Biopassage Services.

Performance outcomes	Acceptable outcomes	Response
		Due to the biosecurity risk and operational constraints associated with a fishway, the proposed approach for the project is to maintain the existing waterway conditions at Six Mile Creek Dam, and instead mitigate existing fish passage impacts at an alternative location within the Mary River catchment. Seqwater proposes to improve fish passage at Gympie gauging weir, which is located just downstream of the confluence of Six Mile Creek with Mary River. The Gympie gauging weir is a relatively high priority barrier for rectification in the Mary River catchment (Marsden <i>et al.</i>, 2016²). Marsden <i>et al.</i> assessed exiting waterway barriers, including Gympie gauging weir against multiple criteria, including the hydraulic conditions and impacts on the movement of native fish species in the Mary River. There is a demonstrated need for rectification of this waterway barrier in some fashion. Seqwater proposes to improve fish passage across all flows by installing an appropriate fishway or potentially by removing the instream structure, if feasible. The gauging weir is a Seqwater asset, on which biopassage assessment and detailed design was previously undertaken for an unrelated offset project. To deliver the fish passage improvement at Gympie gauging weir, Seqwater is currently reviewing the detailed design of the proposed biopassage and environmental/planning requirements to commence procurement and construction. During this design review, options for complete removal of the instream structure will be revisited in the context of Seqwater's stream gauging requirements. Regardless of the design review outcomes, fish passage at Gympie gauging weir will be significantly improved. It is likely that a waterway barrier works development approval will be required prior to starting construction of the improved biopassage. An application will be lodged once the detailed design review has been completed. This is anticipated to be completed in mid-2019. Construction for the Gympie gauging weir biopassage is expected to be scheduled for the winter period (typically river low-flows) of 2020 or 2021.
PO6 Development is designed and operated so that all components of waterway barrier works (for example scour protection, intake and outlet structures, spillway, stilling basin, apron and dissipation structures) and all pathways of potential fish movement provide safe fish passage. Stepped spillways (including sheet pile weirs) are not acceptable. Note: Stepped spillway (including sheet pile weirs) have been associated with high mortalities and injuries to fish. Assessment of this performance outcome will include consideration of adequate tailwater depth at the toe of the spillway (for example:	No acceptable outcome is prescribed.	Complies with PO6 <i>Dam Spillway</i> As part of the dam safety upgrade, the spillway for Six Mile Creek Dam will be replaced with a design that can cater for the flood capacity that is required by dam safety guidelines. In the case of Six Mile Creek Dam, the dam must safely pass the Predicted Maximum Precipitation Flood (PMPF), which is equivalent an Annual Exceedance Probability (AEP) of 1:10,000,000. For the purposes of assessment for safe fish passage, the fisheries operational range was taken as up to the 1:100 AEP flood event. The dam safety upgrade will install a dual height spillway, such that the main (lower-level) spillway will pass all flows up to the 1:100 AEP flood event. The secondary (upper-level) spillway will pass larger flood events, which exceed the capacity of the main spillway. Seqwater has assessed the options for the dam safety upgrade since 2012 and this has included the type of spillway that would be feasible for the site. A summary of the spillway options

² Marsden, T. and Berghuis, A. (2016). Prioritising Barriers to Upstream Fish Passage, Mary River Catchment. Report to Seqwater. Fisheries Collective.

Performance outcomes	Acceptable outcomes	Response
stilling basin) at commencement to spill (for example: 30 percent of the head difference).		assessment and justification is provided in the Draft IAR (Appendix O). The preferred spillway type for Six Mile Creek Dam is a hybrid ogee and labyrinth design, where an ogee type is proposed for the main spillway, catering for flows up to the 1:100 AEP flood event, and a labyrinth type is proposed for the secondary (upper spillway). The main ogee spillway, including associated energy dissipation structures, is discussed here in response to PO6. Note that detailed design for the dam spillway has not been finalised. Detailed design drawings for the spillway and aspects described below will be provided with the development application for waterway barrier works. Spillway Design The proposed ogee spillway is shown in a concept design drawing attached. The proposed spillway consists of an ogee crest into a slope of 55° before a horizontal transition to an angled end sill. The sill provides a similar geometry to a roller-bucket, but without the circular profile that creates a large back-roller of water. A large back-roller would be a poor result for fish passage. The end sill is designed as a linear slope to lift the laminar spillway flow off the creek bed and allow aquatic fauna to be flushed through the basin. The end sill is 2 m tall, with a foundation at the bed level of the creek, as shown on Section A of the attached drawing. The end sill will be drowned out during all spillway flows where fish passage may occur. At a reservoir head of 0.1 m above spillway crest, the expected tailwater depth is approximately 3.4 m above the creek bed (i.e. 1.4 m above the end sill height) and at a reservoir head of 1.8 m (1:100 AEP) the expected tailwater depth is approximately 7.0 m. The relatively short structure (upstream-downstream direction) is necessitated by the foundation constraints at the site, whereby foundations require significant quantities of mass concrete. Spillway Hydraulics Hydraulic performance of the ogee spillway has been assessed using Computational Fluid Dynamics (CFD) modelling and physical modelling. A cross section of water velocity from CFD modelling (1:100 AEP flood event) is provided as a demonstration of the expected spillway hydraulics (attached). The CFD model shows the proposed energy dissipation approach, which is designed to lift the spilling flow into the water column of tailwater. Energy dissipation structures with high risk of direct strike are not proposed. The velocity profile also demonstrates the back-roller effect is minimal in this design. Physical modelling (1:20 scale model) of the proposed ogee spillway was undertaken in conjunction with CFD modelling. Physical model runs for several reservoir heads were observed by an experienced fisheries biologist during a site visit in February 2019. The resulting observations are summarised in the Draft IAR (Appendix O). Note that these observations were for a narrower ogee spillway (49.5 m) than proposed (59 m), however the observations remain valid as the cross-section was identical to that proposed. The ogee spillway design was observed to provide very benign tailwater conditions for fish. No obvious causes of fish injury in the tailwater pool were noted. CFD modelling was undertaken following the physical model observations, which further demonstrate the laminar flow profile through the spillway cross section and smooth transition from spillway to tailwater. The one area

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		of concern noted in physical model observations was the shallowing of water depth on the spillway face, compared with the crest depth, potentially leading to shear forces (abrasion) on the spillway chute. A low-flow notch in the ogee crest was suggested as a possible approach to alleviate this issue. This possibility has been ruled out as not feasible due to the existing Full Supply Level (FSL) and impact on hydraulics if a tiered ogee crest was used. To achieve a low-flow notch, the design would require lowering the impoundment FSL by 200-300 mm, which leads to a loss of 7 – 10% water capacity. A low-flow notch of up to 50 mm may be possible, but this is not expected provide a beneficial depth for fish passage. A such, a low-flow notch is not proposed in the ogee spillway design. The potential for abrasion on fish moving downstream is considered to be acceptable and also comparable to similar sloped spillway structures, including the current spillway, where there is no history of observed fish injury due to abrasion. This potential impact can be also be minimised through technical specifications for construction, with respect to concrete finishes for low roughness. Spillway Stranding The proposed ogee spillway is relatively simple in terms of energy dissipation or tailwater control. Only the end sill structure is proposed downstream of the ogee, as discussed in spillway design. There is no need for tailwater control at Six Mile Creek because the tailwater comes up rapidly and drowns out the end sill. The end sill is necessarily continuous across the width of the spillway, to provide the function of lifting spillway flows off the downstream creek bed. Drainage slots cannot be accommodated within the end sill. Nevertheless, the base of the ogee profile will be at the elevation of the creek bed and a drainage channel to the right (east) side of the ogee spillway will be provided. This arrangement will maintain continual connectivity between the base of the spillway and the downstream creek, which has a depth of approximately 1 m on cease to flow conditions. The environmental flow outlet (described below), will discharge from the outlet tower on the left (west) side of the to the ogee spillway, which subsequently drains to Six Mile Creek from the drainage channel on the right side. This arrangement will allow for maintenance of water quality through water exchange, as required. <i>Outlet structures</i> The dam outlet structure will incorporate two intake pipes for releases from the impoundment – for environmental flows and for emergency release. The Water Treatment Plant inlet is an existing structure, not related to the dam upgrade, and is not considered here. Detailed design for the dam's outlet structure has not been finalised. Detailed design drawings for the outlet structure will be provided with the development application for waterway barrier works. Environmental flow outlet The environmental flow outlet will not provide for fish passage. The purpose of this release is to meet downstream flow requirements of Seqwater's water licence. Intake pipework will be screened to prevent fish ingress or entrainment. The design intent is to provide a screen aperture small enough to avoid fish injury, mortality and entrapment. This will entail a fine screen

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		with a slot velocity no greater than 1.5 m/s and an approach velocity no greater than 0.1 m/s (NSW Department of Primary Industries, 2012³). Emergency release outlet The emergency release pipe intake will not provide for fish passage. The purpose of this release will be for emergency drawdown of the impoundment where a dam safety issue is detected. An example of this is if an earthquake occurs and causes deformation of the dam embankment and structural stability is in question. The ability for a dam owner to reduce water level to assess dam safety and make the structure safe is a standard inclusion in new dams, and so this feature is required for the dam safety upgrade of Six Mile Creek Dam. It's likely that emergency drawdown via the emergency release outlet will not be required for the life of the dam. For the emergency release, the intake pipework will be coarse screened for debris, but it is not feasible to exclude fish based on the criteria for approach and slot velocity described above. This is due to the high flows required to meet dam safety guidelines for emergency drawdown (e.g. 1 m diameter pipe, releasing around 2.8 m³/s). Notwithstanding, the emergency release is not to be used for operation or maintenance. Maintenance of emergency release pipework/fittings (e.g. valves) will be undertaken with upstream bulkheads in place to prevent inflows from the lake. Operational releases from the dam will be made using the screened environmental flow pipework, which will be capable of releasing up to 16 ML/day.
PO7 The drownout characteristics of the waterway barrier works and the frequency, timing and duration of drownout conditions will provide adequate fish passage for the fish community and biomass moving past the barrier. Note: Determining adequacy of fish passage will involve consideration of passage achieved during drownout and during other hydraulic conditions and the relative frequencies of these conditions among other things.	No acceptable outcome is prescribed.	Not applicable – The proposed dam will not drownout. Spillway flows, up to the maximum predicted flood, will not provide hydraulic conditions suitable for upstream fish passage.
PO8 Development does not increase the risk of mortality, disease or injury, or compromise the health, productivity, marketability or suitability for human consumption of fisheries resources, having regard to (but not limited to):	No acceptable outcome is prescribed.	Complies with PO8, incorporating implementation of mitigation measures. Operation of the upgraded Six Mile Creek Dam will be consistent with operation of the current dam and no changes to water quality are anticipated during operation once the refilled lake settles. Safe fish passage in relation to the design of structures is discussed in responses to PO5 and PO6.

³ NSW Department of Primary Industries (2012). Development of fish screening criteria for water diversions in the Murray-Darling Basin. Cronulla: NSW Department of Primary industries and Murray-Darling Basin Authority.

Approach velocity is defined as velocity of water flowing perpendicular to, and in front of, the screen face. Typically taken as 8 cm in front of the screen.

Slot velocity refers to the velocity as water passes through the screen.

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1. biotic and abiotic conditions, such as water and sediment quality 2. substances that are toxic to plants or toxic to or cumulative within fish 3. design of structures 4. impacts on reproductive success 5. effect on fish energy reserves 6. whether fish may be physically damaged, injured, killed, trapped or stranded 7. fish passage and access to habitat generally; and 8. the impacts of pest fish and other relevant pest species. Note: A fish salvage plan may be required to demonstrate compliance with the performance outcome and may form a condition of any approval. Permits or other authorities may be required under the <i>Fisheries Act 1994</i> for the use of regulated fishing apparatus and to possess fisheries resources.		The upgrade dam will not increase the risks associated with fish passage and access to habitat, as there will be no change in that regard when compared with the existing dam. Seqwater will require the implementation of a Construction Environmental Management Plan (CEMP) that includes management measures for potentially hazardous substances (e.g. fuels and oils). All materials used in the construction of the dam will be suitable for use in waterways and in accordance with Australian Standards. No change in operation of the upgraded dam is expected compared to the existing situation, with regard to hazardous substances. During construction, the water level in Lake Macdonald will be lowered to enable works to occur safely. This will reduce the habitat available to fish upstream of Six Mile Creek Dam for a period of up to 24 months. If not managed appropriately, the lowering of the lake could result in fish being injured or stranded. In order to manage potential impacts associated with the lowering of Lake Macdonald, a lowering management plan has been developed in consultation with regulatory agencies and recognised experts. The management plan is provided in the Draft IAR, Appendix C. The proposed approach to the Project is to build the upgraded dam generally within the existing dam footprint to minimise potential impacts, including disturbance of fish breeding habitat. Hydrological conditions that trigger breeding events will also be broadly similar during and after construction, as there will be minimal flood attenuation by both the temporary coffer dam and the upgraded dam (similar to the existing dam). Mozambique tilapia (a noxious fish under the <i>Biosecurity Act 2014</i>) have been observed immediately downstream of the existing dam, but have not been recorded upstream. The upgraded dam will act as a barrier to upstream movement of tilapia, with no upstream passage provided. During construction, biosecurity management will be implemented as part of the CEMP and lake lowering management plan to manage the risk of tilapia moving upstream if the temporary coffer dam is drowned out.
PO9 Development: 1. avoids non-essential hardening or unnatural modification of the main channel of the waterway 2. retains natural fish habitat and features such as rock outcrops and boulders, wherever possible 3. avoids channelisation (i.e. straightening) of meandering waterways or where channels need to be significantly modified, simulates natural watercourses and habitat features (for example, by including meanders, pools, riffles, shaded and open sections, deep and shallow	No acceptable outcome is prescribed.	Complies with PO9 1. As described in response to PO3, erosion protection and some localised channel modification will be necessary immediately downstream of the proposed dam spillway. These modifications will be located within the existing disturbance footprint and will have minimal impact on fish passage as the dam will prevent upstream passage. These channel modifications will be essential to protecting the integrity of the dam and the waterway channel immediately downstream. Rock protection is anticipated to be used for erosion protection purposes. No other modification of upstream or downstream waterways is proposed. 2. Natural fish habitat features will be retained wherever possible. Seqwater will also investigate opportunities to improve fish habitat in Lake Macdonald with the lowered lake. 3. No channel modification will be undertaken, other than that described in point 1 above. The project will largely be built within the existing dam footprint.

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sections and different types of substrata); and 4. avoids construction during times of elevated flows.		4. Construction is expected to occur over one, possibly two, wet seasons. In order to complete the dam safety upgrade in a timely period, construction will continue over summer months. Planning and management for elevated flows will include appropriate monitoring of weather and responses for given conditions. The construction site will be planned and prepared in a manner to safely dewater an elevated flow and with contingency plans for return to construction when flows ease.
PO10 Where waterway barrier works will modify water levels or flow characteristics of the waterway, existing up and downstream structures are upgraded to provide adequate fish passage in accordance with the new levels or flow characteristics.	No acceptable outcome is prescribed.	Not applicable The proposed dam safety upgrade will not modify water levels or flow characteristics of the upstream/downstream waterways compared with the existing situation.
PO11 Sufficient water exchange and flow is maintained and provided to sustain and where necessary restore, water quality and the health and condition of fisheries resources, ecological functions and fish passage.	No acceptable outcome is prescribed.	Complies with PO11 The upgraded dam will pass water over the spillway at the same elevation as the existing dam. During operation, environmental flows will be implemented per Seqwater's existing water licence to impound water of Six Mile Creek. Environmental flows will be released to the toe of the spillway in the upgraded dam (upstream of the spillway end sill), such that water exchange will be provided in the most upstream part of barrier. During construction, a low flow channel will be maintained through the existing spillway area, which will provide spilling flows similar to the existing conditions.
PO12 Development likely to cause drainage or disturbance to acid sulfate soils, prevents the release of contaminants and impacts on fisheries resources and fish habitats. Note: Management of acid sulfate soil is consistent with the current Queensland acid sulfate soil technical manual: Soil Management Guidelines V4.0, Department of Science, Information Technology, Innovation and the Arts, 2014.	No acceptable outcome is prescribed.	Complies with PO12 Acid Sulfate Soils are not present at the site of Six Mile Creek Dam, based on investigations undertaken for the Draft IAR (Appendix H).
PO13 Construction avoids direct and indirect disturbance, or where avoidance is not possible, minimises direct and indirect disturbance to beds, banks and vegetation adjacent to the permanent development footprint.	No acceptable outcome is prescribed.	Complies with PO13 The proposed dam upgrade will largely be built within the existing dam footprint (i.e. a highly disturbed area) and the construction footprint will be minimised as much as possible. Direct disturbance to the natural bed and banks of Six Mile Creek, areas not previously affected by the current Six Mile Creek Dam, is not anticipated. Direct disturbance of the bed in Lake Macdonald will be confined to the areas immediately adjacent to the existing embankments and spillway. Direct disturbance of the banks of Lake Macdonald will be restricted to existing areas of disturbance. Indirect disturbance will be minimised through the implementation of a Construction Environmental Management Plan and Erosion and Sediment Control Plan.

Performance outcomes	Acceptable outcomes	Response
PO14 After completion of in-stream works, disturbed areas of the bed and banks of the waterway outside the permanent development footprint are returned to their original profile and stabilised to promote regeneration of natural fish habitats. Note: Monitoring of the success of fish habitat regeneration, within and adjacent to the work site, is likely to be conditioned as part of any development approval.	No acceptable outcome is prescribed.	Complies with PO14 The construction footprint for the proposed dam upgrade will be minimised as much as possible to limit disturbance. Where disturbance is unavoidable, the original profile will be re-established and stabilised after construction works are completed. As noted in PO9, there will be some modification of the waterway channel immediately downstream of the dam spillway to incorporate the new spillway structure width and to minimise erosion.
PO15 The natural substrate of the waterway bed is retained or reconstructed so that the post-construction substrate is comparable to the natural substrate; for example in terms of size and consistency.	No acceptable outcome is prescribed.	Complies with PO15 The proposed dam upgrade will largely be built within the existing dam footprint and the construction footprint will be minimised as much as possible to limit disturbance in the waterway. In general, where the natural substrate is disturbed, the material will be retained and replaced if possible or be reconstructed to be comparable to the current substrate. As noted in PO9, there will be some modification of the waterway channel immediately downstream of the dam spillway and erosion protection measures (i.e. rock) will be placed on the waterway bed in these areas.
PO16 Development does not adversely impact on community access to tidal land and waterways.	No acceptable outcome is prescribed.	Not applicable – the waterway is not tidal.
PO17 Development does not adversely impact on community access to fisheries resources and fish habitats including recreational and indigenous fishing access. Note: In some cases, compensation for impact on fisheries access, operations and/or productivity may be necessary. The Guideline on fisheries adjustment provides advice for proponents on relevant fisheries adjustment processes and is available by request from the Department of Agriculture and Fisheries.	No acceptable outcome is prescribed.	Does not comply with PO16 on a temporary basis Seqwater proposes to close Lake Macdonald to public access during construction works for the dam upgrade (approximately two years). The closure will have a temporary impact on community access to recreational fishing in the lake, but is required as safe access and safe use cannot be guaranteed. Community access will be restored on project completion and subject to water quality monitoring and compliance with recreational water quality indicators.
PO18 Development does not adversely impact on commercial fishing access and linkages between a commercial fishery and infrastructure, services and facilities. Note: In some cases, compensation for impact on fisheries access, operations	No acceptable outcome is prescribed.	Not applicable – there are no commercial fishery activities in the project area.

Performance outcomes	Acceptable outcomes	Response
and/or productivity may be necessary. The Guideline on fisheries adjustment provides advice for proponents on relevant fisheries adjustment processes and is available by request from the Department of Agriculture and Fisheries.		
Development involving fish ways		
PO19 Having regard to the hydrology of the site and fish movement characteristics, the fish way is capable of operating, and will operate: - for as long as the waterway barrier work is in position; and - whenever there are inflows into the impoundment or waterway, release out of the impoundment and during overtopping events; and - when the impoundment is above dead storage level.	AO19.1 For the life of the waterway barrier works, the lower operational range of the fish way is at least: 0.5 metres below minimum headwater drawdown level; and 0.5 metres below minimum tail water level at the site.	Not applicable – no fishway proposed. Please refer to PO5 for explanation and further information.
PO20 For the life of the waterway barrier works, the hydrology of the development allows for adequate fish movement.	AO20.1 The lower operational range of the fish way is at least: 0.5 metres below minimum headwater drawdown level; and 0.5 metres below minimum tail water level at the site.	Not applicable – no fishway proposed.
PO21 Fish way maximises fish movement by providing: - continuous attraction flows at the fish way entrance under all flow conditions within the fish way's operating range - additional means of fish attraction are included in the fish way design if appropriate - attraction flow velocities are sufficient and variable to attract the whole fish community, and expected future and seasonal biomass - adequate holding chamber capacity for the expected fish biomass in any lock, lift, trap and transfer type fish ways - adequate exit conditions for downstream fish passage; and - for future adjustments in capacity or operation that may be needed once in place.	No acceptable outcome is prescribed.	Not applicable – no fishway proposed.

Performance outcomes	Acceptable outcomes	Response
PO22 Fish ways are designed so that: 1. water intakes, outlets, screens and other structures do not cause entrainment, injury or mortality to fish 2. appropriate light levels are maintained at entrances, exits and throughout the fish way to ensure successful use by fish 3. fish attracted to the spillway or outlet flows are able to access the fish way without having to swim back downstream 4. fish are able to exit upstream and downstream fish ways at a water levels over the full range of tailwater and headwater levels 5. exits are located to avoid fish being washed back over the spillway during overtopping 6. adequate hydraulic conditions and minimum water depth for fish passage is maintained throughout the fish way 7. predation on fish using the fish way is avoided 8. rubbish and debris do not impede fish passage or cause blockages or damage the fish way 9. delays in fish movement are avoided when fish are undertaking upstream spawning migrations; and 10. delays in fish movement are avoided immediately after times when there have been flows in the system but no fish passage in the rising hydrograph.	No acceptable outcome is prescribed.	Not applicable – no fishway proposed.
PO23 All water releases are directed through the fish way as a priority over the outlet works.	No acceptable outcome is prescribed.	Not applicable – no fishway proposed.
PO24 All flows and releases initiate and terminate adjacent to the fish way or are directed parallel to the fish way entrance and all flows are transferred to the fish way as soon as possible during a flow recession. Note: Flows and releases include but are not limited to spillway overtopping and	No acceptable outcome is prescribed.	Not applicable – no fishway proposed.

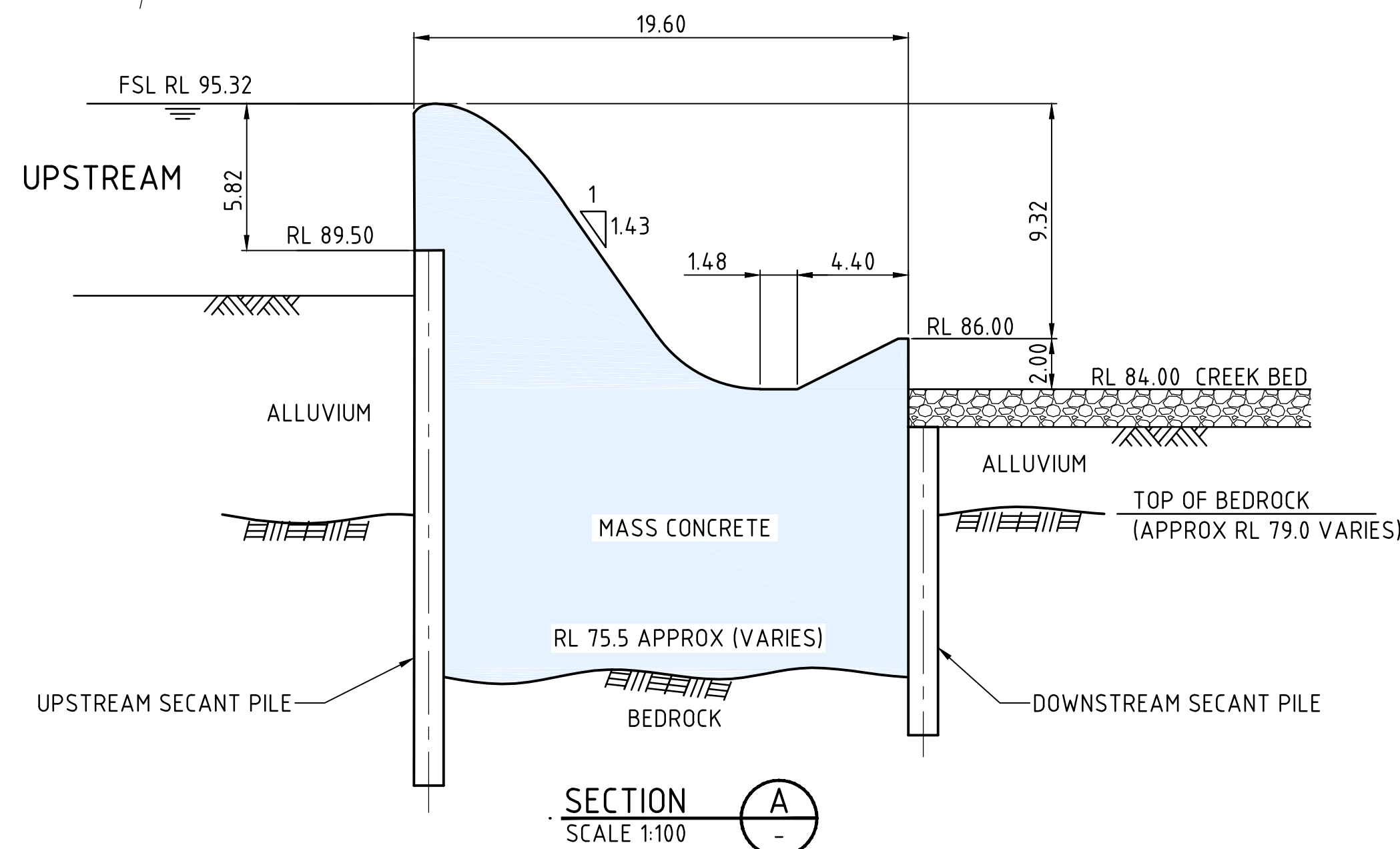
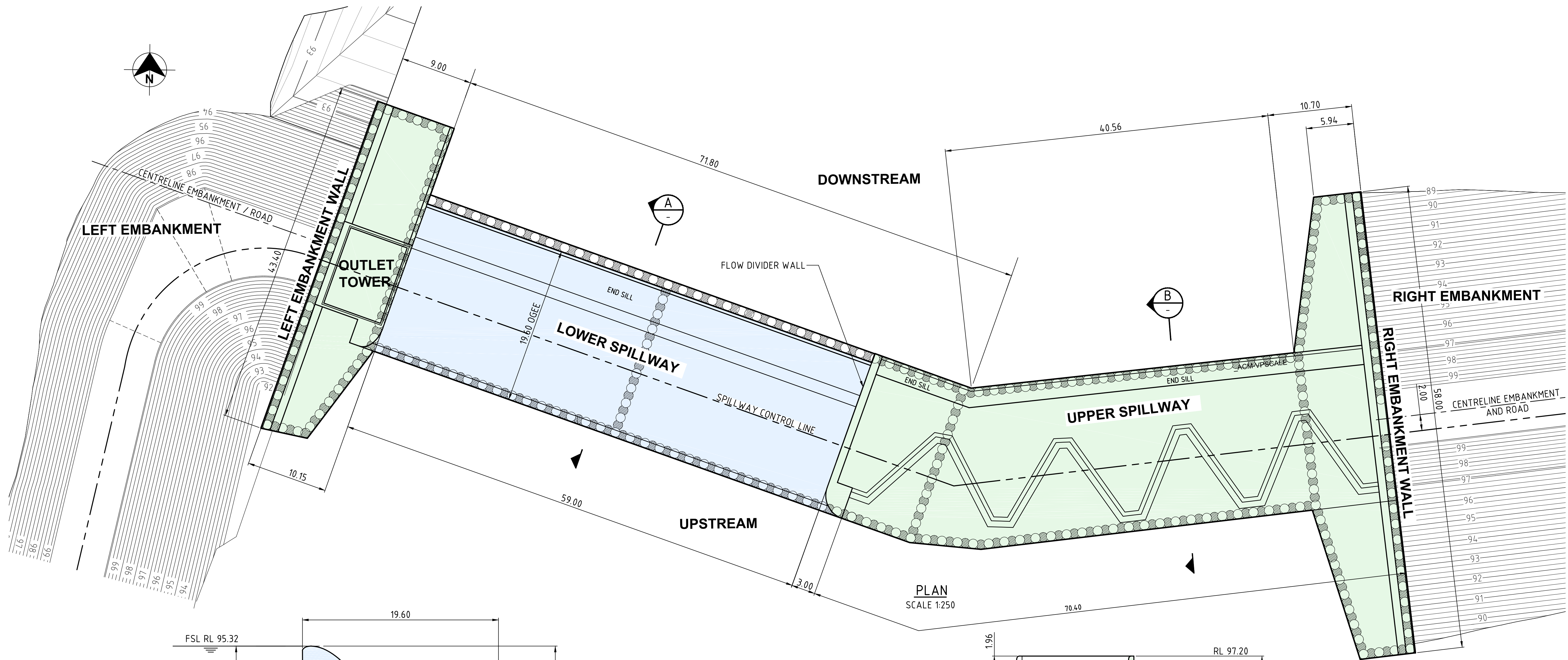
Performance outcomes	Acceptable outcomes	Response
outlet flows. Such flows must not compete with fish way attraction flows or reduce the operation of a fish way.		
PO25 Mechanisms are in place to ensure that operational issues in fish ways are promptly rectified for the life of the fish way including but not limited to: 1. all components are designed to be durable, reliable and adequately protected from damage during high flow and flood events 2. all components can be replaced; and 3. a contingency plan ensures provision of alternate adequate fish passage during the fish way re-instatement process. Note: Fish way downtime greater than 14 consecutive calendar days is likely to have a significant impact to fisheries resources.	No acceptable outcome is prescribed.	Not applicable – no fishway proposed.
PO26 Development provides for: 1. installation of monitoring equipment (such as traps and lifting equipment); and 2. access for monitoring, maintenance and operational purposes.	No acceptable outcome is prescribed.	Not applicable – no fishway proposed.
PO27 Water supply for the fish ways and attraction flows are sourced from surface quality water or equivalent water quality.	No acceptable outcome is prescribed.	Not applicable – no fishway proposed.
PO28 Tailwater control structures such as a gauging weir, rock bar or stream crossings are fitted with a fish way or designed to provide fish passage.	No acceptable outcome is prescribed.	Not applicable – no fishway proposed.
Development involving floodgates		
PO29 Floodgates are designed and operated: 1. to provide hydraulic conditions adequate for fish passage over an adequate duration of the tidal cycle; and 2. as tidally activated, automatic floodgates.	No acceptable outcome is prescribed.	Not applicable
PO30 The invert of the floodgate is at bed level.	No acceptable outcome is prescribed.	Not applicable

Performance outcomes	Acceptable outcomes	Response
PO31 The operation of the floodgate will not result in adverse impacts on water quality that may harm fish or fish habitat.	No acceptable outcome is prescribed.	Not applicable
Temporary waterway barrier works		
PO32 The temporary waterway barrier works will exist only for a specified temporary period and provide for adequate fish movement.	AO32.1 The temporary waterway barrier work: - is a partial barrier, or - does not constrict the area or flows of a low flow channel. AND one of the following acceptable outcomes apply: AO32.2 The temporary structure is only in place outside of known fish spawning or migration periods. OR AO32.3 The barrier is opened periodically every five days for at least 48 hours to allow fish movement and water exchange. OR AO32.4 Fish movement is provided for via a stream diversion.	Complies with PO32 The proposed dam safety upgrade will include a temporary sheet pile coffer dam for the period of construction, which is anticipated to be about 24 months. The temporary coffer dam will control the lake level and allow for flows through a low flow channel when inflows from the catchment occur. This will be similar to the existing dam and will allow for downstream passage when flows occur.
PO33 Temporary barriers are removed at the end of their design life, so that full movement for fish is reinstated and the bed and banks are returned to their original profile and stability.	No acceptable outcome is prescribed.	Partial compliance with PO33 The temporary sheet pile coffer dam will be removed or made redundant following construction of the dam safety upgrade. Nonetheless, the dam will be reinstated, and so movement of fish will be restricted per the responses provided for permanent waterway barrier works.
PO34 Where there are species, at the site of the temporary waterway barrier works that require downstream movement during works, provisions are made to allow those species to move downstream.	No acceptable outcome is prescribed.	Partial compliance with PO34 The temporary sheet pile coffer dam will allow for downstream passage through a low flow channel, when suitable flows occur in the catchment. This scenario will be in line with the existing dam conditions and flow regime and is expected to have no additional impact on fish passage opportunities while the temporary barrier is in place.
PO35 The condition and value of aquatic macrophytes and other fish habitats is maintained.	No acceptable outcome is prescribed.	Complies with PO35 The temporary sheet pile coffer dam will be installed in the upstream embankment of the existing dam and so the footprint of disturbance is minimised. Lake lowering will occur to facilitate construction, which will temporarily limit habitat access for fish in the lake. Aquatic macrophytes will also be impacted by the lake lowering, however this is generally experienced in the lake environment where water levels can fluctuate by several metres over time.

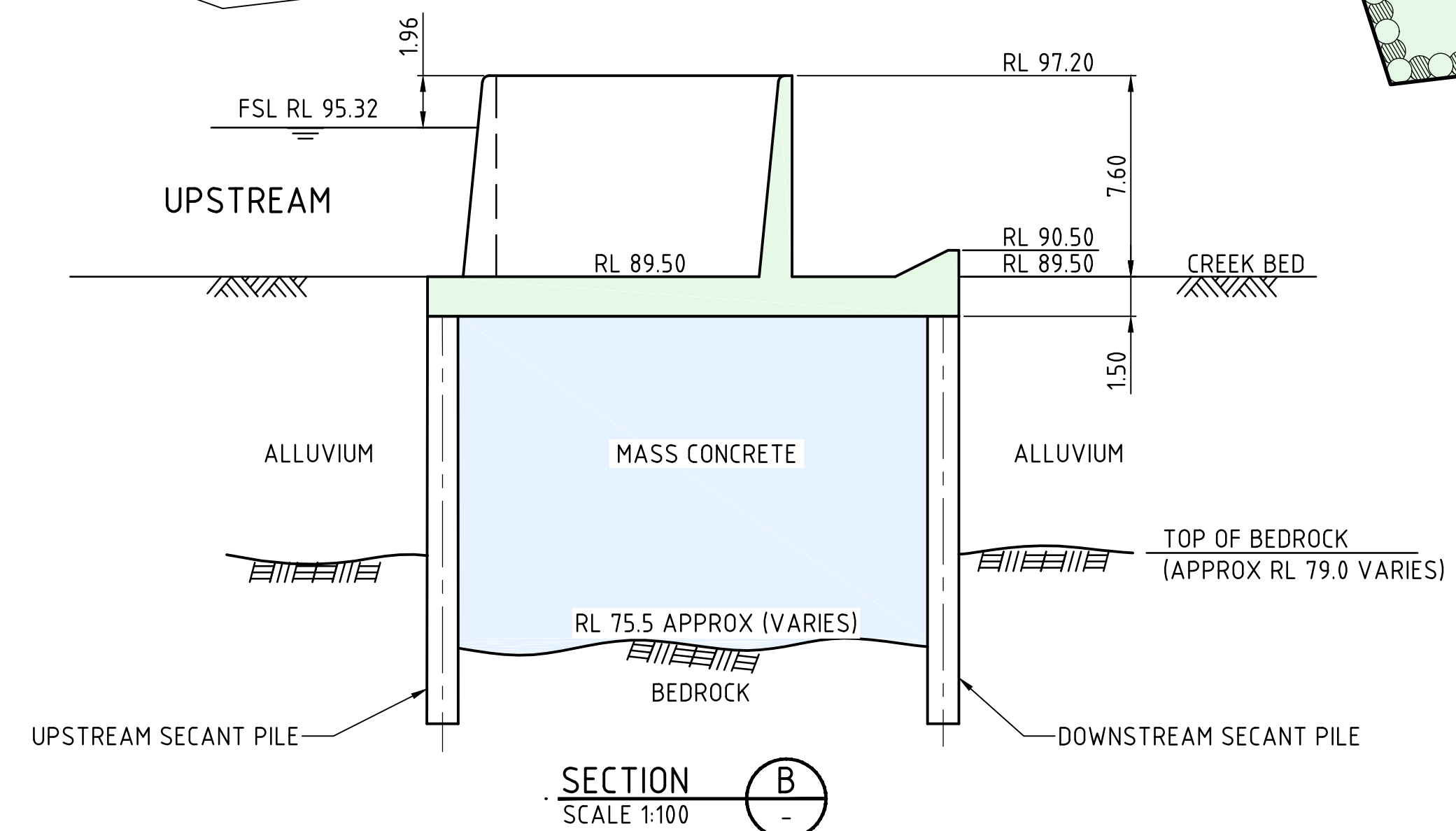
Performance outcomes	Acceptable outcomes	Response
		The limiting of access to aquatic habitat will be temporary for the construction period and habitat access will be reinstated following Project completion and refilling of the lake. Direct disturbance of aquatic habitat in the lake is expected to be minimal, largely restricted to access for aquatic fauna translocation, and Seqwater will remediate any direct disturbance areas to match or improve fish habitat at those locations. Seqwater also recognises that there will be a loss of fisheries productivity for a period of time following Project completion and reinstating recreational access, due to the translocation of previously stocked fish and the change in supporting aquatic communities. It is expected that reinstatement of the full supply level will regenerate aquatic communities such as macrophytes and small bodied fish, which will remain in the lowered lake. Seqwater has also engaged with the local fish stocking group and intends to collaborate and co-fund stocking activities for two years following the Project.
Temporary waterway barrier works-Matters of State Environmental Significance		
PO36 Development: 1. avoids impacts on matters of state environmental significance; or 2. minimises and mitigates impacts on matters of state environmental significance after demonstrating avoidance is not reasonably possible; and 3. provides an offset if, after demonstrating all reasonable avoidance, minimisation and mitigation measures are undertaken, the development results in an acceptable significant residual impact on a matter of state environmental significance. Statutory note: For Brisbane core port land, an offset may only be applied to development on land identified as E1 Conservation/Buffer, E2 Open Space or Buffer/Investigation in the Brisbane Port LUP precinct plan. For the Brisbane Port LUP, see www.portbris.com.au. Note: For the purpose of this code, the matters of state environmental significance assessed are marine plants, waterways that provide for fish passage and declared fish habitat areas. Guidance for determining if the development will have a significant residual impact on the matter of state environmental significance is provided in	No acceptable outcome is prescribed.	Complies with PO36 The development will impact the relevant MSES, being the area of waterway providing for fish passage. Due to the nature of the works, avoidance of this MSES is not possible though impacts have been minimised to the greatest extent possible by the adoption of various construction methodologies and consideration of fish passage in the dam upgrade design. The potential impacts of the upgraded dam spillway are discussed throughout responses to this code, but particularly PO4 to PO6. Opportunities to improve fish passage with the dam safety upgrade were investigated, as discussed in responses to PO4 and PO5. A fishway at Six Mile Creek Dam was found to have limited benefit and potential for biosecurity impacts. Seqwater has proposed an alternative opportunity to improve fish passage in the Mary River catchment. Based on an impact assessment of the proposed dam safety upgrade on fisheries waterways, Seqwater considers that impacts are unavoidable, but the Project design has minimised or mitigated the impacts compared with the existing waterway conditions. Seqwater considers that the Six Mile Creek Dam safety upgrade will result in no significant residual impact on fisheries waterways.

Performance outcomes	Acceptable outcomes	Response
the Significant Residual Impact Guideline, Department of State Development, Infrastructure and Planning, 2014. Where the significant residual impact is considered an acceptable impact on the matter of state environmental significance under the Environmental Offsets framework and an offset is considered appropriate, the offset should be delivered in accordance with the <i>Environmental Offsets Act 2014</i> .		

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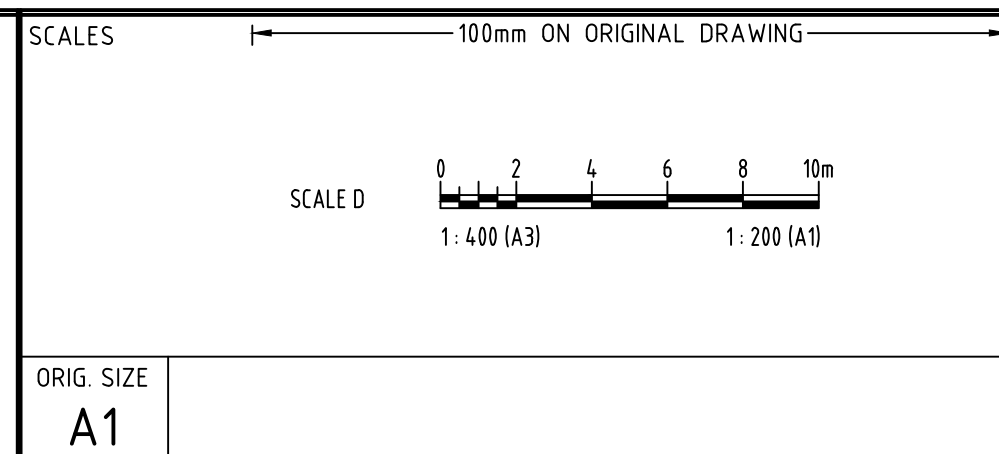


TYPICAL UPPER SPILLWAY LABYRINTH WEIR SECTION

NOT FOR CONSTRUCTION

AECOM

AECOM Australia Pty Ltd A.B.N. 20 093 846 925
AECOM JOB NUMBER: 60585926



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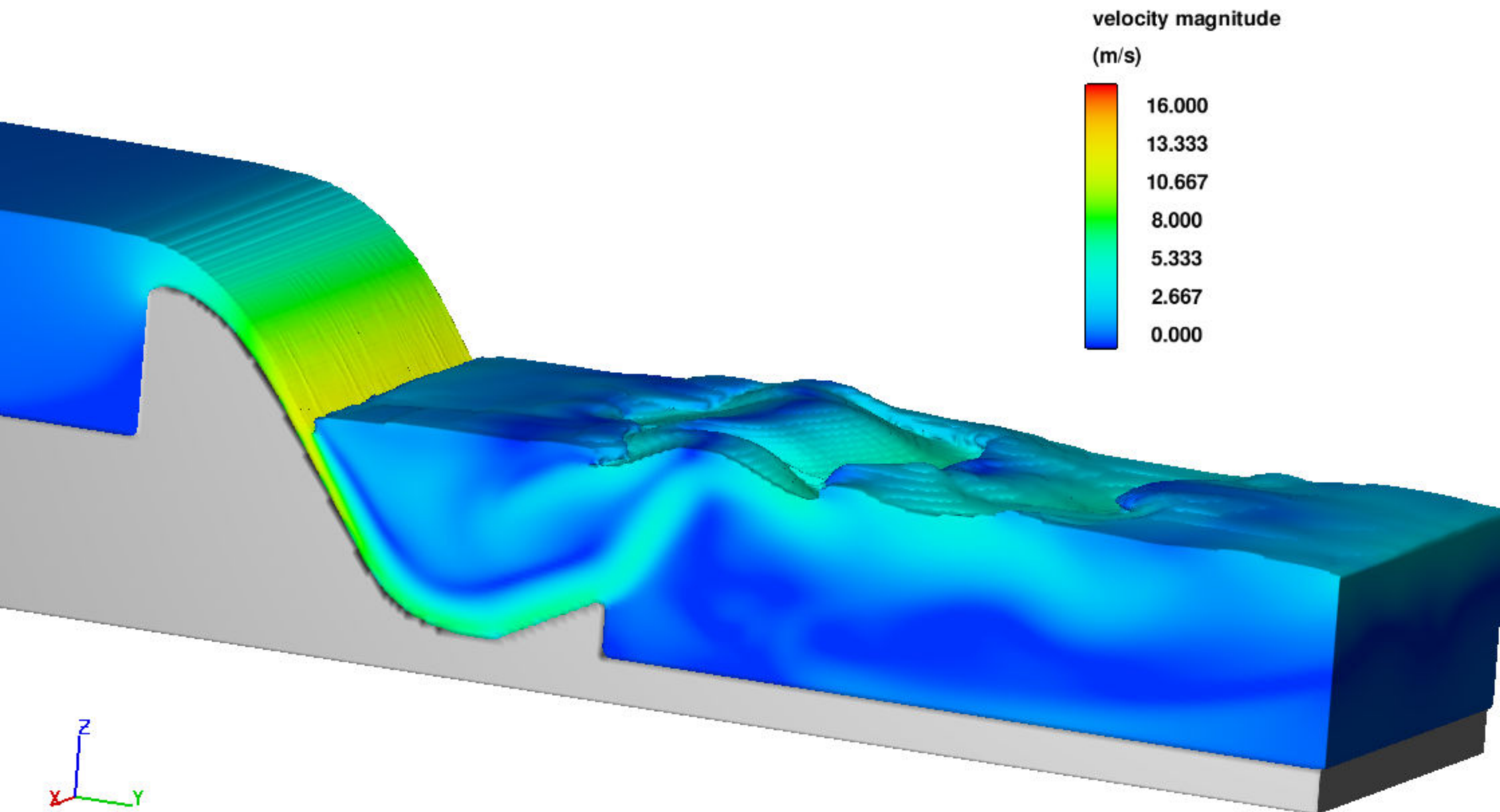


TITLE LAKE MACDONALD (SIX MILE CREEK DAM) -
DAM SAFETY UPGRADE
SPILLWAY
GENERAL PLAN AND SECTIONS

DRAWING NUMBER
SK-1000

REVISION
A

Six Mile Creek Dam - ogee spillway
CFD model - Velocity profile for 1:100 AEP flood event



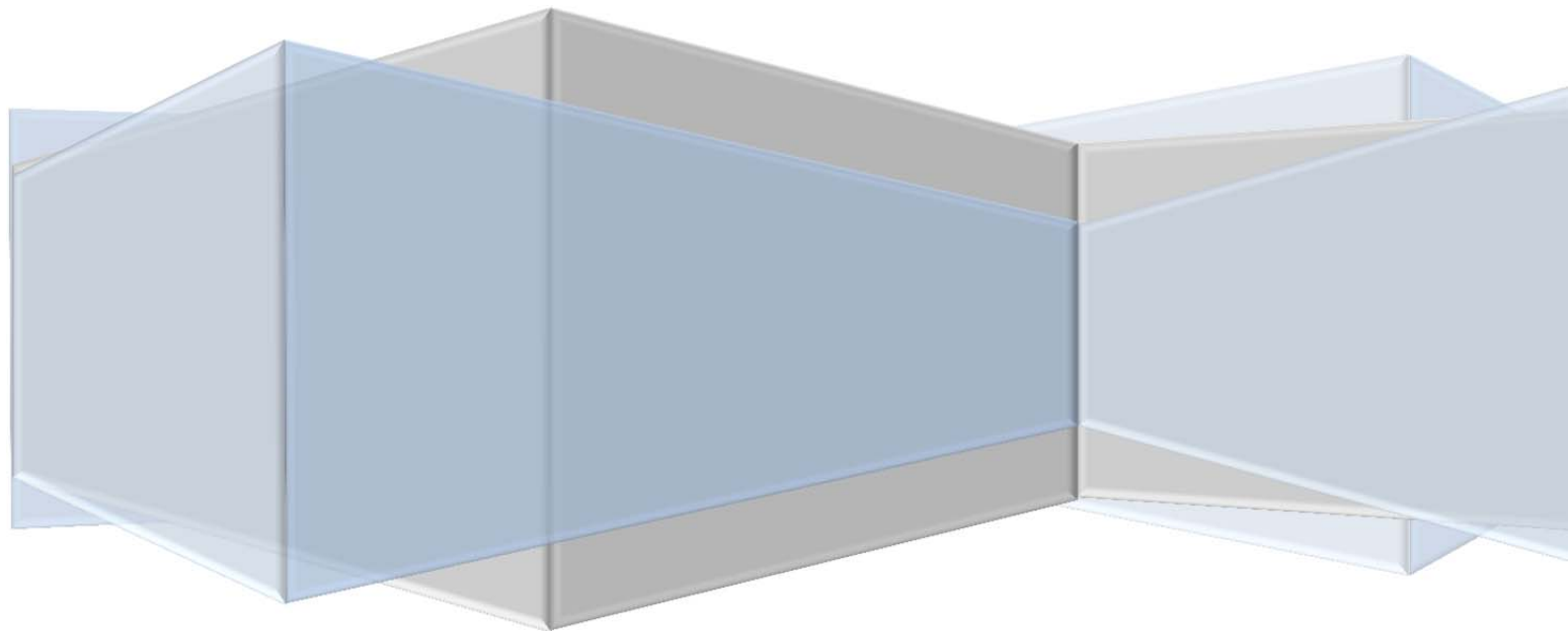


Fish passage options for Six Mile Creek Dam Six Mile Creek

A. P. Berghuis

March 2018

**Aquatic Biopassage Services
for Seqwater**



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1. Executive summary

Seqwater is undertaking a Dam Safety Upgrade for Six Mile Creek Dam, located on Six Mile Creek near Cooroy. Aquatic Biopassage Services has been contracted to provide technical input on assessment and selection of a fishway for the dam upgrade.

A previous evaluation by AECOM (2016) determined that a trap-and-haul system was the only potentially feasible fishway option for upstream passage at the site. Performance uncertainties as well as structural, hydrological and biological aspects were considered likely to adversely affect operational performance.

Desktop assessments and expert reviews supported by onsite surveys by FRC Environmental (2016) determined that 28 native fish species including the listed Queensland lungfish and Mary River cod as well as six native turtle species occur in Six Mile Creek. All of the fish species listed are migratory in some form and some of the turtle species migrate for dispersal and breeding purposes. Accordingly, it is necessary that safe and effective passage upstream and downstream of Six Mile Creek Dam be provided.

Five design types for fishways at Six Mile Creek Dam have been evaluated in the current report, two volitional designs: the vertical-slot and bypass channel and three mechanical designs: the fishlock, fishlift and trap-and-haul.

A workshop session attended by Seqwater personnel from storage planning, operations, approvals and environment as well as ABS evaluated design for an upstream passage fishway at Six mile Creek Dam. Table 3 in the current document provides the results for comparisons of the six fishway design options.

In numerical order the highest scoring fishways were:

1. simplified fishlift
2. trap and haul
3. full-length bypass channel
4. fish lock

The vertical-slot and modified bypass were eliminated due to unsuitability for the site.

The current report provides the basis for further investigation into the most suitable design for fish passage at Six Mile Creek Dam. Factors such as suitability for fish passage, operational range, constructability, operation and maintenance and construction cost will determine the final design. In order to satisfy the requirements of a development application for the upgrade works all relevant aspects of the DILGP State code 18: *Constructing or raising waterway barrier works in fish habitats* must be addressed.

A process for the further development of a suitable fishway at Six Mile Creek Dam through to final design and approval is provided in Section 7 of the current report.

2. Proposed development

Seqwater is undertaking a Dam Safety Upgrade for Six Mile Creek Dam, located on Six Mile Creek near Cooroy. The upgrade will address specific dam safety risks to bring the structure into compliance with current industry guidelines and the requirements of the Water Supply (Safety and Reliability) Act 2008.

The upgrade will preserve the storage at its current 8,018 ML capacity and its Full Supply Level (FSL) of 95.32 m AHD. The spillway configuration will change, but spillway height, spill conditions and discharge to Six Mile Creek will remain the same. The particulars of the proposed upgrade have been determined to trigger assessable development under the Planning Act 2016 for waterway barrier works, and subsequent requirements under the Fisheries Act 1994.

A detailed assessment for fish passage options at the site is required to meet regulatory requirements to the satisfaction of the fisheries regulator (Department of Agricultural and Fisheries – DAF). In particular, the structure is likely to require a fishway retrofitted to match the existing constraints of the site, such as space and water yield, unless this options assessment shows there is no practical fishway option for the site.

The State Development Assessment Provisions (SDAP) provisions in regards to waterway barrier works require the development application to address the Performance Outcomes (POs) contained within SDAP Code 18: Constructing or raising waterway barrier works in fish habitats. The formal development application must address the POs in Table 18.2.1 and 18.2.2 of the SDAP.

Aquatic Biopassage Services has been retained by Seqwater to provide the following:

1. Technical input on assessment and selection of a fishway for the dam upgrade
2. Provide technical advice and input into the detailed design process
3. Technical input on spillway design with respect to aquatic fauna downstream passage
4. Support engagement with the regulator (DAF), through technical advice on fishway options assessment

The current report provides background detail and evaluation of fishway design options to address Step 1 above.

3. Proposed works

During a Portfolio Risk Assessment (PRA) of its 26 referable dams, Seqwater identified numerous failure modes for Six Mile Creek Dam and the estimated societal risk was assessed to be unacceptable against the ANCOLD risk criteria. Upgrade options involve increasing the spillway capacity, to meet the 100% acceptable flood capacity (AFC) requirement. Site conditions and geotechnical constraints require a highly efficient spillway to limit the overall spillway width the size of flow dissipation infrastructure. A labyrinth weir was selected as the most hydraulically and cost effective spillway option for achieving AFC requirements.

In addition to a new spillway structure, the proposed dam safety upgrade detailed by AECOM (2016) includes:

- Reconstruction of the right embankment
- Buttressing and partial reconstruction of the left embankment
- Construction of a new saddle dam

4. Details of the waterway

Six Mile Creek Dam is located on the upper reach of Six Mile Creek, a low-gradient upper catchment tributary of the Mary River. Downstream of the dam, the creek consists of shallow moderate length pools separated by riffles and shallow glides over sand and a rainforest canopy as riparian cover.

Previous fish passage reviews

AECOM (2016) was commissioned by Seqwater to assess fish passage options at Six Mile Creek dam as part of a dam safety upgrade project. Preliminary biological and habitat surveys were completed in Six Mile Creek and in the Lake Macdonald stored waters by FRC Environmental (2016).

The requirements for passage of the aquatic fauna identified in Six Mile Creek were investigated to support assessments of potentially suitable fishways in regards to:

- Commonwealth and Queensland legislative requirements
- topographic constraints
- hydrological constraints
- engineering features

Five fish passage options were considered:

- vertical slot fishway
- fish lock
- fishlift
- bypass channel
- trap-and-haul fishway

Of the above options, AECOM (2016) determined that a trap-and-haul system was the only potentially feasible fishway option for upstream passage at the site. However the report suggested that a number of performance uncertainties prevented confirmation that a trap and haul fishway would adequately provide fish passage at the site. Several of the site's structural, hydrological and biological aspects were also considered likely to adversely affect the operational performance of a trap and haul fishway.

AECOM (2016) further determined that in the context of the Mary River basin as a whole the impounded habitat of Lake Macdonald represents an area of reduced environmental value. A recommendation was made that the impacts of the fish passage barrier at Six Mile Creek Dam would be better served by restoring fish passage beyond the Gympie Weir in the middle Mary River where it would provide greater environmental and fisheries-resources benefits overall.

Hydrology of Six mile Creek and Dam

The report by AECOM (2016) provided a summary of the hydrology of Six Mile Creek and flows from Six Mile Creek Dam. Six Mile Creek has semi-perennial flow, with 50th percentile mid-reach flows in the creek being an order of magnitude lower than the 50th percentile flows in the upper Mary River (50 vs 500 ML/d). Based on gauging at the mid-reach of Six Mile Creek (Cooran gauging station), which is below the dam, flows greater than 10 ML/day occur approximately 80% of the time. Six Mile Creek Dam is located in the upper reaches of the creek and there is no gauging of inflows to the dam. Seqwater models dam inflows for operational purposes, which indicates that the upper reaches of Six Mile Creek receive inflows greater than 10 ML/d around 40% of time. Spillway outflows greater than 10 ML/d occur around 20% of time.

Six Mile Creek Dam is a relatively small impoundment, with a Full Supply Volume (FSV) of 8,018 ML. The dam receives high annual inflows and frequently spills. This contrasts with many large dams, which capture most inflows and spillway flows are infrequent, perhaps only one or two times per year on average.

To assess the hydrology of the Six Mile Creek Dam system and potential fishway operation, Seqwater adapted a water balance model (GoldSim) to determine inflow, storage, and outflow characteristics for various scenarios. The model was used to simulate system performance using government sourced weather data for the period of 1890 to 2011 (evaporation, rainfall and inflows). The model was also adapted to simulate various hydrological scenarios at the dam site; including no dam, with dam, and with dam plus fishway releases. These simulations provide an overview of system performance over a long period, using historical weather records, and provide an indication of future performance of proposed scenarios.

Fishway release scenarios focussed primarily on release options of 20 ML/d and 50 ML/d, based largely on Seqwater experience with other fishways where lesser maximum flows released continuously were typically insufficient as attraction flows. Further discussion is provided in *Fishway Operation* below. A summary of the water balance simulation is provided below.

No Dam Case

A no dam simulation provides information on the natural hydrology and flow conditions when fish would likely have natural migration cues. This assessment was based on flow duration analysis of catchment inflows.

Across all seasons, a no dam case shows that >20 ML/d flows would occur 26% of time, and >50 ML/d flows would occur 16% of time. Within seasons, inflows at the dam location are greatest in autumn, particularly for low flows, followed by summer and winter periods. Spring inflows are significantly lower based on the simulation, with 50th percentile flow of around 1 ML/d compared with 5-20 ML/d 50th percentile flows in other seasons.

With Dam Case (existing)

The existing dam scenario confirms that the dam water level is often within the top 25% of capacity. Stored water levels greater than 6,000 ML (75% FSV) occur around 92% of the time. The dam also spills frequently, around 23% of the time. Note that this case will continue for the post-upgrade dam (assuming no fishway releases).

Across all seasons, the existing dam scenario shows that >20ML/d flows occur 17% of time, and >50ML/d flows 13% of time. Compared with the no dam case, current dam operations do not significantly impact downstream flow frequency, particularly at higher flows.

For further context of inflows and outflows, the mean annual water balance for the simulation period yielded the following:

- 33,732 ML/y mean annual inflow and direct rainfall
- -7,166 ML/y mean annual evaporation, extraction and environmental releases
- -26,539 ML/y mean annual spillway overflows

Fishway Operation

Following on from modelling the hydrology of Six Mile Creek Dam, various fishway scenarios were simulated to ascertain the water security impacts of operating a fishway.

Based on Seqwater operation of other fishways, attraction flows of at least 15-20 ML/day is typically required to trigger any significant upstream migration. As Six Mile Creek Dam is an existing water supply dam and may not be able to accommodate fishway releases at all times, focus was placed on high flow operation where the bulk of fish transfer is expected to occur. Therefore, fishway flows at 20 and 50 ML/d were used as to assess performance. Variable fishway flows (<20 ML/d) may be investigated further at a later stage of options development.

In addition to fishway operation flows, potential operating rules were developed to broadly assess impacts of fishway operating models on water security and natural hydrology. For each rule, a minimum fishway operating level of 70% Full Supply Volume (FSV) was set to reflect the dam hydrology. As discussed in *Hydrology of Six mile Creek and Dam*, the dam is typically above 70% FSV (92-95% of time) and the spillway flows often. If the FSV falls below 70%, this would be indicative of a dry spell where water conservation to meet existing water supply needs outweigh fishway release needs.

For each fishway release rate, three different types of operating rules were assessed:

- A –operate fishway only when dam is spilling (dam spill is > 5 times fishway flow capacity).
- B –operate fishway only when dam above 70% of Full Supply Volume (FSV) and there is catchment inflow (inflow > 5 times fishway flow capacity).
- C –operate fishway only when dam above 70%.

In general, for both the 20 and 50 ML/d releases rates, simulation of the operating rules found the following:

- A – No impact on current water supply or average lake area; fishway operates 8.9% of time at 20 ML/d release and 5.5% of time at 50 ML/d.
- B – No impact on current water supply or average lake area; fishway operates 11.0% of time at 20 ML/d release and 6.1% of time at 50 ML/d.
- C – Minimal impact on current water supply when extractions are capped to water allocation. Significantly impact on the maximum Historical No Failure Yield (HNFY), which limits any future changes in water supply allocation to cater for growth.

Rule C imposes very frequent fishway operation that exceeds the frequency of flows for the natural hydrology and may impact on downstream ecology. The fishway operates 65.7% of time at 20 ML/d release and 44.7% of time at 50 ML/d.

In summary, all of the above scenarios were possible from a water security perspective based on current allocations. However, operating rule B based on minimum lake storage and catchment inflow was considered the most practical. Operating rules A and B provide some replication of natural hydrology, whereas rule C would result in more permanent flows and such a scenario is not consistent with the natural hydrology. A fishway operating case of 20 ML/d was considered to be adequate on the basis of being sufficient attraction flow, while allowing for extended operation of a fishway compared with 50 ML/d.

The use of operating rule B is supported by data from long-term fish passage assessments that indicates upstream fish movement occurs during all flow conditions but that the highest migrations occurring during increased flows and immediately following a flood peak (Berghuis, *et.al.* 2000; Pitman & Berghuis, 2016^a, 2016^b; Pitman, 2017; SunWater, 2011). Optimisation of the inflow aspect of (i.e. >5 times fishway flow capacity) operating rule B is also recommended to determine the water security impact and operating time benefit.

The operation of a fishway under all flow release conditions is an ideal situation. However, the reach scale habitat assessment from FRC (2016) indicates that habitat pools for large fish in Six Mile Creek is discontinuous and that natural barriers may limit extensive upstream movement at lower flows. Further evaluation of the level of connectivity from the Six Mile Creek Dam wall downstream to the crossing of Six Mile Creek by Louis Bazzo Drive is recommended.

Data on the relationship between headwater and tailwater levels over the modified spillway during the most common range of flows is not currently available. As a minimum, it is vital that the levels for 1, 2 and 5 year AEP events are determined prior to commencing the design of any fishway at Six Mile Creek Dam.

5. Fish species of Six Mile Creek

Biological and habitat surveys were completed in Six Mile Creek and in the Lake Macdonald storage by FRC Environmental (2016). A desktop assessment and expert review supported by two onsite surveys determined that 28 native and four alien or noxious species occur in Six Mile Creek. The presence of a translocated native fish banded grunter (*Amniataba percoides*) and the noxious Tilapia (*Oreochromis mossambicus*) immediately downstream of Six Mile Creek Dam were confirmed in surveys performed by the Lake Macdonald Fish Stocking Group.

The findings of FRC Environmental (2016) was that the fish fauna in Six Mile Creek downstream of Six Mile Creek Dam were in generally good condition and that habitat is likely to support spawning for Mary River cod. The impounded waters of Lake Macdonald were considered likely to favour a sub-set of native fish suited to lacustrine and fringe habitats and recreational species that have been stocked and established in the dam.

Table 1. Fish species present in Six Mile Creek from FRC Environmental (2016) and data from Lake Macdonald Stocking Group.

☺ = translocated native species, ☹ = alien/noxious species.

Length size class: small = <100 mm, medium = 100 mm to <300 mm, large = 300 mm to 1000 mm.

Species	Common Name	Size as adults
<i>Ambassis agassizii</i>	Agassiz's glassfish	small
<i>Ambassis marianus</i>	estuary glassfish	small
<i>Anguilla australis</i>	southern shortfin eel	large
<i>Anguilla reinhardtii</i>	longfin eel	large
<i>Amniataba percoides</i>	banded grunter	medium
<i>Glossamia aprion</i>	mouth almighty	small
<i>Craterocephalus marjoriae</i>	silverstreak hardyhead	small
<i>Craterocephalus stercusmuscarum</i>	flyspecked hardyhead	small
<i>Gobiomorphus australis</i>	striped gudgeon	small
<i>Hypseleotris spp.</i>	common carp gudgeons	small
<i>Hypseleotris compressa</i>	empire gudgeon	small
<i>Mogurnda adspersa</i>	purple spotted gudgeon	small
<i>Philypnodon macrostomus</i>	dwarf flathead gudgeon	small
<i>Philypnodon grandiceps</i>	flathead gudgeon	small
<i>Melanotaenia duboulayi</i>	crimson spotted rainbowfish	small
<i>Maccullochella mariensis</i>	Mary River cod	large
<i>Macquaria novemaculeata</i>	Australian bass	medium
<i>Macquaria ambigua</i>	yellow belly☺	medium
<i>Tandanus tandanus</i>	eel tailed catfish	medium
<i>Neosilurus hyrtlui</i>	Hyrtl's tandan	small
<i>Pseudomugil signifer</i>	Pacific blue eye	small
<i>Retropinna semoni</i>	Australian smelt	small
<i>Nematalosa erebi</i>	bony bream	medium
<i>Neoceratodus forsteri</i>	Queensland lungfish	large
<i>Oreochromis mossambicus</i>	Tilapia	medium
<i>Trachystoma petardi</i>	pinkeye mullet	large
<i>Mugil cephalus</i>	sea mullet	large
<i>Notesthes robusta</i>	bullrout	medium
<i>Leiopotherapon unicolor</i>	spangled perch	medium
<i>Scleropages leichardti</i>	southern saratoga☺	large
<i>Gambusia holbrooki</i>	eastern Gambusia☹	small
<i>Xiphophorus maculatus</i>	platy☹	small
<i>Xiphophorus hellerii</i>	swordtail☹	small
<i>Poecilia reticulata</i>	guppy☹	small

The findings of FRC (2016) determined that macroinvertebrate communities were highly variable in Six Mile Creek due to limited microhabitat diversity. Aquatic plants are absent or rare in Six Mile Creek downstream of Six Mile Creek Dam, although they are common in Lake Macdonald.

Use of fishways by fish species in Six Mile Creek

All of the species listed in Table 1 should be considered migratory and the majority of species have been recorded using or attempting to utilise fishways. The largest species that are likely to utilise a fishway at Six Mile Creek Dam are the Queensland lungfish and Mary River cod.

Queensland lungfish have been recorded successfully utilising fishways in the Burnett River (Berghuis, *et.al.* 2000; SunWater, 2011; DAFF, 2013). However, triggers for upstream migration remain poorly understood and there are physical and possibly behavioural limitations to the successful use of fishways by the species.

Assessment of the vertical-slot fishway at the 3.96 m high Ben Anderson barrage on the Burnett River indicated that passage of Queensland lungfish was negatively impacted by the 150 mm wide slots (Stuart and Berghuis, 2002). All of the lungfish that successfully ascended the fishway were less than 930 mm in length and those fish that did ascend had obvious scale damage along the body.

A more recent fishway assessment at the Claude Wharton fishlock at Gayndah identified that 44% (144 individuals) of the transponder tagged Queensland lungfish detected at the fishway entrance successfully migrated upstream (DAFF, 2013).

No published data exists for passage of Mary River cod through fishways, however various size classes of Murray cod (*Maccullochella peelii peelii*) regularly utilise fishways in the Murray-Darling system. Passage of Murray cod through a 300 mm slot width vertical-slot fishway in the river Murray was detailed in a paper by Stuart *et.al.* (2008). Following this and other research the optimum slot dimensions for fishways designed for large Murray cod is considered to be 350 mm wide and 1500 mm deep, however smaller cod up to 800 mm long will successfully utilise fishway slots 250 mm wide and 800 mm in depth (Dr Ivor Stuart pers. com.).

The Mary River cod is not known to grow as large as the Murray cod with most fish being smaller than 700 mm (Pusey *et. al.* 2004). However, captures of Mary River cod in the mainstem Mary River that are larger than 600 mm in length are not uncommon (T. Espinoza, DNRM pers. com.).

Data from FRC (2016) indicates that the fish communities present in Six mile Creek are dominated by small-bodied fish species down to 20 mm in length. The passage of small fish is less constrained by the physical dimensions of the fishway and impacted more by the velocity and turbulence of flow in relation to their swimming ability. Some fish species such as gudgeons, gobies and glass (juvenile) eel will ascend wetted surfaces with little flow, other small to medium-bodied species require greater depths. An important factor in passing small to medium-bodied fish is the provision of a variety of flow conditions with areas of low velocity and turbulence under all operational conditions.

Turtle species of Six Mile Creek

A desktop assessment and expert consultation by FRC Environmental (2016) indicated that six native turtle species were present in Six Mile Creek (Table 2) and that no introduced turtle species are known to occur or likely to occur. Surveys determined that the upstream zone had the highest diversity and abundance of turtles and that the saw-shelled turtle was the most abundant species.

Table 2. Turtle species present in Six Mile Creek from FRC Environmental (2016)

Species	Common Name
<i>Chelodina expansa</i>	broad shelled river turtle
<i>Chelodina longicollis</i>	eastern long necked
<i>Emydura macquarii krefftii</i>	Krefft's river turtle
<i>Wollumbinia latisternum</i>	saw shelled turtle
<i>Elusor macrurus</i>	Mary River turtle
<i>Elseya albagula</i>	white throated snapping turtle

The specific migratory habits of the turtles present in Six Mile Creek are poorly understood and are likely to vary between riverine and lacustrine habitats. Data obtained by FRC Environmental (2016) suggested that Krefft's river turtle has sex biased dispersal; males move in the wet season when flows increase, females move to traditional nesting sites during the breeding season. The Eastern longneck turtle will disperse overland into isolated pools and dams, whereas the broad shelled river turtle maintains a home range.

Impoundment infrastructure can cause injury and death of many turtles that aggregate at the infrastructure. Large impoundment structures are barriers to the movement of turtles up and downstream and no existing fishway has been proven sufficient for enabling turtles to pass safely beyond impoundment infrastructures. Screens that prevent trash entering and blocking water release intakes on the upstream side of impoundment infrastructures can trap large numbers of turtles and cause their death (Limpus, 2008).

Use of fishways by turtles

The use of fishways by turtles is not well documented; the monitoring program for the fishlift at the 37 m high Paradise Dam identified 75 individuals using the fishway, predominantly composed of Krefft's river turtle as well as saw shelled turtle. The results suggested that turtles are limited to low velocity conditions, in all but one capture flow releases were equal to or less than 5 ML/day from the fishway entrance with no supplementary flow from outlets (SunWater 2011).

Comments from Dr Col Limpus of the Queensland Department of Environment and Heritage Protection indicated that freshwater turtles are poor swimmers in open water but will move against flow if it is shallow and there is suitable substrate they can anchor to. Alternatively, they will travel overland for short distances and re-enter the water provided there are no impassable barriers.

The movement of turtles beyond Six Mile Creek Dam will require consideration within the design to maximise passage via the fishway where practical. Opportunities to provide pathways for passage and minimise injury to turtles should be considered within the design of the upgraded dam.

6. Fishway design requirements

All fish passage barrier sites have differing design requirements; successful fish passage at Six Mile Creek dam will require a design that provides:

- passage of small and juvenile fish down to 20 mm in length;
- passage of large fish such as lungfish and Mary River cod over 1 m in length;
- passage of all size classes of fish up to at least the 1:5 year flow;
- a practical option for constructability within site;
- a practical option for hydrological constraints;
- the lowest practical operational and maintenance requirements over time.

The size range of fish species expected to utilise the passage facility has a significant influence on the design of the structure. Larger fish are generally strong swimmers however; they may be limited by the dimensions of the fishway.

In order to maximise passage opportunity for Queensland lungfish and Mary River cod the vertical slots of any fishway design should not be less than 250 mm in width.

Water depth can also be a major consideration for large fish, not only in regards to their physical dimensions but also behaviour. In open water, large Queensland lungfish regularly enter water that is less than 500 mm in depth (author pers. obs.); however, it is not known if this depth would be acceptable in fishway conditions.

The single most important design component that influences a fishways' success is the entrance. If the entrance does not attract fish from the stream then the fishway will not function efficiently. The key entrance criteria are:

- The fishway entrance must be accessible under all operational flows.
- The fishway entrance must be at the 'limit of upstream migration' i.e. at a point where fish cannot move further upstream without entering the fishway.
- Fish attracted to the spillway can enter the fishway without having to swim back downstream.
- Attraction flows are appropriate for all size classes of fish.
- Attraction water sourced from high quality surface water.
- Adequate hydraulic conditions in fishway for all fish sizes.

Adequately addressing these key criteria does necessarily not favour any single fishway design type, but can be more easily achieved certain design types.

The following points provide a summary and conclusion of the detail provided above:

- To ensure passage of large fish It is recommended that fishway openings are made as wide as practical but no narrower than 250 mm and as deep as possible but no shallower than 1 m.
- An important factor in passing small to medium-bodied fish is the provision of a variety of flow conditions and depths under all operational conditions.
- Satisfying the key entrance criteria is the single most important design component that influences a fishways' success.

- A biopassage structure at Six Mile Creek Dam has the potential to impact on turtles and must therefore be designed in such a way to prevent any injury and enhance turtle passage beyond what is currently available. A dedicated facility or procedure to pass turtles should be investigated.

7. Fishway design options for upstream passage

The options report by AECOM (2016) investigated five design types for fishways at Six Mile Creek dam, two volitional designs: the vertical-slot and bypass channel and three mechanical designs: the fishlock, fishlift and trap-and-haul

Of the designs listed above only the trap and haul was considered suitable but was deemed to be restricted by a number of factors unique to Six Mile Creek Dam. Notwithstanding the findings of AECOM (2016), the listed designs remain the most practical fish passage solutions for any moderate sized dam or weir. The current report provides a further review of design options.

Vertical-slot

Vertical-slot fishways are pool type structures where water passes through the full height of a slot linking the pools and creating a flow constriction. The width of the slot opening and slope (minimum 1:20) of the fishway channel control the water velocity through each slot. The pool volume dissipates hydraulic energy and provides resting areas for ascending fish. The vertical-slot design can operate in varying headwater and tailwater levels, and allow fish to pass through the fishway at any depth in the channel. Typical applications for the design are for weirs lower than 5 m in height.

A major challenge for vertical-slot fishway design has been to cater for all of the expected differences in swimming ability and migration behaviour of the fish species and sizes. Temporary modifications to a vertical-slot fishway in the Murray River created very low turbulence and high roughness that resulted in increased passage success for small fish less than 30 mm in length (Stuart *et al.* 2008). Subsequent vertical-slot designs have been modified by limiting discharge with sills or slot inserts to reduce hydraulics and by roughening of the fishway floor with rocks.

The successful downstream passage of fish has been documented at vertical-slot fishways on Queensland streams (Stuart and Berghuis, 2002). However, the major pathway for downstream passage of fish appears to be via the spillway during inflows to the system (author pers. ob.).

A vertical-slot fishway option was discarded by AECOM (2016) due to the 11 m differential between the headwater and tailwater at Six Mile Creek Dam. The high differential does preclude the installation of a standard vertical-slot fishway design, mainly because smaller fish are likely to tire before fully ascending. An alternative to a single channel may be the installation of a discontinuous vertical slot fishway with several separate sections each rising 2-3 m with large resting pools in between. However, such a design at Six Mile Creek Dam would be considered experimental and therefore carries a moderate risk of failure.

Bypass channel

The bypass fishway design is common in Europe where it is used to provide fish passage over low weirs. The bypass fishway is constructed within the bank of a stream on a lower 1:60 maximum slope. Flow control is provided by rock riffles similar to that seen in natural stream beds and separated by large low turbulence resting pools.

Although a natural bypass fishway option is practical from a fish passage efficiency perspective it was investigated and discarded by AECOM (2016) due to the lack of suitable area to install a channel predicted to be almost 1 km in length. The main drawback to the design was the potential impact on other facilities and the need to occupy land not owned by Seqwater. The layout proposed by AECOM (2016) also requires modification to bring the inlet closer to the dam spillway so that downstream migrating fish are able to locate it during spillway flow events.

Modified bypass channel

A recent modification to the bypass design is the installation of nature-like fishway (rock-ramp, rock-chute, concrete cone) sections set on a maximum slope of 1:30 separated by large zero slope resting pools. The benefit of this design is that the overall length of the bypass channel can be shortened somewhat and that the resting pools can be used at certain points in elevation and in areas where a bend of up to 180° is required. By providing an option to create a sinusoidal path, the footprint of the fishway can more easily be constrained to a limited area.

Bypass fishways are sensitive to fluctuating water levels and therefore operate most effectively with a single entrance and exit. Careful design is necessary to optimise fish passage opportunity over the full range of flow conditions.

The installation of the modified bypass fishway as specified above is likely to be reduced to approximately 500 m in length for Six Mile Creek Dam. Two options have been provided in Appendix A, one option is shown on the left bank where it can be incorporated into and around the reconstructed left embankment. The second option is on the right bank where it can be constructed as a sinusoidal channel downstream of the dam; immediately below the high flow spillway. The layouts for both concepts cause issues with existing infrastructure at the dam and roadways that need to be evaluated before proceeding with the bypass design.

Fishlock

A typical fishlock consists of a downstream channel at the base of the weir, connected to a vertical lock chamber and upstream channels located at the top of the weir. A Programmable Logic Control (PLC) unit controls operation of the fishlock with hydraulically actuated gates and valves operated in a set sequence. The water supply for fishlock attraction and fill phases is sourced from the weir pool via intakes in the upstream channel. Operation of the fishlock for upstream migration involves four main phases:

- Attraction of fish into the lock chamber via a flow release;
- Filling of lock chamber to level of impoundment;
- Exit of fish into the impoundment via a flow release;
- Draining of lock chamber to tailwater level.

An average fishlock cycle takes approximately 60 minutes to complete, although timing can be adjusted to cycle more quickly during peak migration periods or less frequently during periods of low migration.

Assessment of the efficacy of early fishlock designs found that the design was suitable for upstream fish passage beyond weirs up to 15 m in height (Berghuis et. al., 2000; Stuart et. al., 2007). The major factor that affected the effectiveness of the design was excessive operational downtime due to mechanical failure caused by unsuitable componentry particularly gates and control hardware.

Other factors were poor operational range of the fishways and discontinuous attraction flows for fish entering and exiting the fishlock in either direction. The number of fish recorded using fishlocks for downstream migration is low; it remains unknown whether this is due to the design or a preference to pass over the spillway during overtopping flows.

Subsequent improvements incorporated into the fishlock design have included:

- Addition of an entrance near the spillway, to attract fish into the lock at spillway flows as well as during outlet flows;
- Increased tailwater and headwater range (operation period extended to 98 % of flows);
- Attraction flow at entrance and exit continuous throughout the lock cycle;
- Attraction flow automatically adjusts continuously with tailwater height;
- Attraction flows that pulse or vary velocity at different river flows, through upgraded valves, water level sensors and software;
- Attraction flow drawn from the weir pool surface into the upstream channel to ensure high water quality and encourage fish to exit the fishway.

Two fishlocks that incorporate the design improvements listed above have been constructed in recent years, Claude Wharton Weir on the Burnett River (owned by SunWater) and Cedar Grove Weir on the Logan River (owned by Seqwater). Assessment of both fishlocks found that they provided upstream passage for the majority of species and size classes of fish identified at the site over a wide range of flow conditions (DAFF, 2013; Pitman and Berghuis, 2016^a). However, despite beneficial design improvements the successful migration of fish continues to be impacted by:

- non-operation due to mechanical issues;
- downtime following flood events;
- poor quality componentry such as flow sensors;
- process control issues with the PLC programming;
- a lack of knowledge on the downstream movement of fish via the fish lock design.

The fishlock option was discarded by AECOM (2016) due to the perception that they use substantial volumes of water and may increase energetic demands on fish or cause behavioural issues. An appropriately designed fish lock will not negatively influence upstream fish migration and is capable of being adjusted to suit the limitations on flow by altering the frequency of cycling to suit the conditions.

In theory, a fishlock design fishway would be highly suitable for Six Mile Creek Dam; however, reliability may continue to be an issue and high maintenance costs will remain a legacy issue. An example of the upgraded fishlock design utilised at Claude Wharton Weir is provided in Appendix A.

Fishlift

The fishlift design is very similar to a fishlock, the main difference is that fish are lifted over the dam wall in a water-filled hopper and released into the dam at impoundment level. The main benefit of not having a vertical lock chamber is that there are no delays associated with filling. Accordingly, a fishlift can complete a greater number of cycles per day without impacting on water usage.

Two fishlift designs have been incorporated into dams in Queensland rivers, Paradise Dam on the Burnett River (owned by SunWater) and Wyaralong Dam on the Logan River (owned by Seqwater). Assessment of Wyaralong Dam is ongoing, however the assessment of Paradise Dam found that the fishway proved to be highly effective at providing upstream passage for the migratory fish community during low and medium flow conditions.

Successful fish passage was provided for a wide range of species and size classes. Twenty-nine species of fish were recorded at the dam site and of these 25 species were recorded successfully utilising the upstream fishway. The fishlift successfully passed fish throughout the year and during all flow conditions. Under some conditions, large numbers of fish successfully used the fishway with over 50,000 fish recorded on a single day. Two species of turtles were documented successfully moving upstream during very low flow releases (SunWater, 2011).

The Paradise Dam fishlift was non-operational for 50% of the time that water was being released from the dam due to mechanical failure of the fishlift system and unsuitable fishway entrance or exit flow conditions during high flow conditions (SunWater, 2011). Since the completion of the monitoring program, several major flood events caused damage to dam infrastructure and the fishway that resulted in extensive fishway downtime and no fish passage at the site.

The fishlift option was discarded by AECOM (2016) due to the perception that they are unreliable and do not perform adequately. Reliability is potentially a major issue for all mechanical fishways. However, a fishlift design fishway should be considered a feasible option for the upgraded Six Mile Creek Dam.

At high structures such as Paradise and Wyaralong Dams with substantial water level fluctuation it is necessary to lower the fish hopper over and down the dam wall to the impoundment water level which adds complexity. As Six Mile Creek Dam is a lower height structure with less water level fluctuation a more simple design is likely to suffice.

Low dams such as at Holyoke on the Connecticut River in the north-east United States utilise a simple fishlift where the hopper is raised within a vertical scaffold and fish are sluiced into the headwater via a sloping exit channel that is set above full supply level. A notch in the dam spillway above a deep tailwater pool provides downstream passage for fish attracted to the spillway and a bypass screen system guides fish away from the hydroelectric turbines and into the tailwater via a sluice. An example of the fish lift design utilised at some sites overseas is provided in Appendix A.

A simple fishlift design similar to that detailed above may be a practical solution for fish and potentially turtle passage at Six Mile Creek Dam.

Trap and haul

The trap and haul design is a mechanical fishway that relies on operator intervention to transport fish over the dam wall, a typical cycle for upstream fish passage consists of three main phases:

- attraction into a trap chamber at the base of a dam via a flow release;
- holding of trapped fish for an extended period;
- collection of fish in a hopper and release to a sorting facility or transfer vehicle;
- transport and release fish into the impoundment upstream of the dam.

Although there are no limitations on how often a cycle can be undertaken, the labour intensive aspect of operation often limits transfers to once per day or less. The holding of various species and size classes of fish for extended periods increases the risk of predation, injury and escapement. Accordingly, it is important that the trap chamber is able to effectively attract and safely hold fish until a transfer occurs and that transfers are performed more frequently during periods of high migration.

The first purpose built trap and haul fish transfer facility in Australia was constructed downstream of Seqwater's Hinze Dam on the Nerang River when it was raised in 2011. Due to the layout of the dam, wall and spillway arrangement no other option for upstream fish passage was considered suitable for the site.

Assessment of the fishway determined that the original cone in the trapping chamber was unsuitable due to high escapement of fish. Subsequent trials with a modified cone trap resulted in a design that substantially reduced escapement and is more suitable for the site (Pitman and Berghuis, 2016^b).

Data from transfers at Hinze Dam fishway indicate that all of the fish species and size classes present downstream of the dam have been transferred into the impoundment. The fishway successfully transferred 26 fish species including high numbers of larger recreationally targeted fish as well as many small-bodied fish (Pitman, 2017).

Despite migratory fish being present downstream of the dam during the low environmental flows releases, only low numbers of fish entered the trap chamber. Analysis of all the available data from the fish transfer facility found that that increased flow during spilling events positively influenced fish catches at the facility (Pitman, 2017).

The trap and haul design is likely to be suitable for installation at Six Mile Creek Dam, however the high operational requirements on a daily basis during operation make it a less viable option. The low frequency of operation provided by a trap and haul fishway as well as the high potential for predation of trapped fish is likely to be considered unsuitable by DAF, particularly if other design options are practical for Six Mile Creek Dam.

8. Downstream passage

Other than for some of the major species, the downstream migration of fish in Australian river systems is poorly understood and the use of fishways for downstream migration is minimal compared to upstream passage. A telemetry study of downstream fish movement in the Logan River in coastal Queensland found that downstream fish movement via fishways was limited despite fish moving downstream to the weir wall and that the main mode of passage was over the weir wall during flows (Harding *et. al.*, 2017).

At Paradise Dam, a dedicated fishlock was provided for downstream passage due to concerns with the suitability of the fishlift design for downstream migration. The fishlock operated by flow over a low headloss gate that attracted fish into a vertical holding chamber where they were trapped until chamber was drained and all fish were sluiced into the tailwater. Many of the species of fish present upstream were documented using the fishlock and occasionally in large numbers. The downstream passage fishlock operated reliably with the only major downtime being the delay in the initial filling of the dam and during wet commissioning. However key catadromous species (migrate to sea to breed) and Queensland lungfish were absent from the list of species identified using the downstream fishlock (SunWater, 2012).

The lower height of Six Mile Creek Dam favours a non-mechanical design for downstream passage of fish during inflows that do not result in sufficient depth during overtopping. A suitably designed sluice that lowers fish into the tailwater may be more effective and simpler to operate. A gated notch in the dam abutment with a spiral pipe and structures to control water velocity is recommended as a starting point for design.

Additionally, the hydrology of Six Mile Creek with relatively frequent occurrence of dam spills lends the dam to function similar to a weir. Provided that safe downstream passage over the spillway is afforded, reliance on spillway overtopping for downstream migration is considered an adequate fall-back position if design of a downstream sluice is determined to be not practical.

9. Evaluation of design options for upstream passage fishway

Following an early draft of the current report, Seqwater personnel from storage planning, operations, approvals and environment, as well ABS attended a workshop session to evaluate the designs for an upstream passage fishway at Six Mile Creek Dam. The results for comparisons of the six fishway design options are provided in Appendix B. All categories had a maximum score of five with fish passage suitability and potential operational range covering 50% of the weighting with the other 50% evaluating construction, operation and maintenance.

In numerical order the highest scoring fishways were:

1. simplified fishlift
2. trap and haul
3. full-length bypass channel
4. fish lock

The vertical-slot and modified bypass channel concepts were eliminated due to unsuitability for the site.

The simplified fishlift will be progressed to concept design to understand the spatial and operating level constraints that may be present at the site. The fish lock will also be progressed to concept for comparative purposes and as the only other automated option that is likely to be feasible at the site.

The further development of the simplified fishlift design to a workable concept will rely on determining the outstanding aspects listed in Steps 1 & 2 of Section 10 - Further development.

10. Further development

The current report provides the basis for investigation and evaluation of the most suitable design for fish passage at Six Mile Creek Dam. In order to satisfy the requirements of a development application for the upgrade works all of the relevant requirements of State code 18: *Constructing or raising waterway barrier works in fish habitats* must be addressed.

The following list identifies the recommended process for further development of a suitable fishway at Six Mile Creek Dam:

1. Collate outstanding data:

- Connectivity of fish habitat downstream of the site;
- Projected headwater/tailwater levels at a range of flows (minimum release, 1, 2 and 5 year AEP);
- Structural and operational limitations in regards to the design options identified.

2. Design workshop

The design workshop allows fishway design issues to be identified and discussed with input from all the relevant stakeholders and experts.

Fish passage issues to be discussed are:

- Discuss existing data, identify any outstanding data gaps;
- Initiate steps to fill data gaps where necessary and practicable;
- Relate hydrological data to site;
- Requirements for fish passage across temporary structures associated with the construction of the dam/weir (e.g. haul roads, bunds etc.);
- Interactions between fishways and other dam/weir components e.g. intake works, environmental release works etc.;
- Operation of the dam and fishway design implications;
- Fish passage over the spillway and spillway/dissipater design that maximises fish survival.

- Concept designs agreed upon and early designs disseminated for review prior to next meeting.

3. *Post-design workshop meetings (regular)*

- Discuss findings of the review of the concept designs in regards to engineering and biological constraints and opportunities.
- Discuss post-construction monitoring requirements, including design elements related to monitoring.
- Establish processes for developing post-construction monitoring, budgets for monitoring, monitoring outcomes, contingencies for post-construction adjustments etc.
- Establish processes for developing fishway management plan including operation and maintenance manual, maintenance program, contingency plans for fishway failure, continuous improvement program etc.

4. *Pre-lodgement advice from DAF*

- Issue concept designs to DAF for review and advice;
- Convene a face-to-face meeting with DAF to discuss the selected concept design and obtain in principle approval.

5. *Determine extent of modelling required*

Once concept designs are agreed to in principle by DAF, investigate requirements for modelling of the concept design over the widest practical range of flows. Depending on design type, either a computational fluid dynamics or a scale model will need to be developed. Outcomes of the modelling exercise are then incorporated into the detailed designs.

6. *Final Design meeting*

- Discuss final designs and agree on any further modifications
- Agree on any requirements for a fishways inspection program during and close to completion of construction
- Outline contents of Fishway Management and Operations Plan for the site
- Set up ongoing processes to deal with issues arising such as:
 - Monitoring outcomes;
 - Associated modifications to the operation or structure of the fishways;
 - Operating contingencies.
- Agree on commissioning process and key players.

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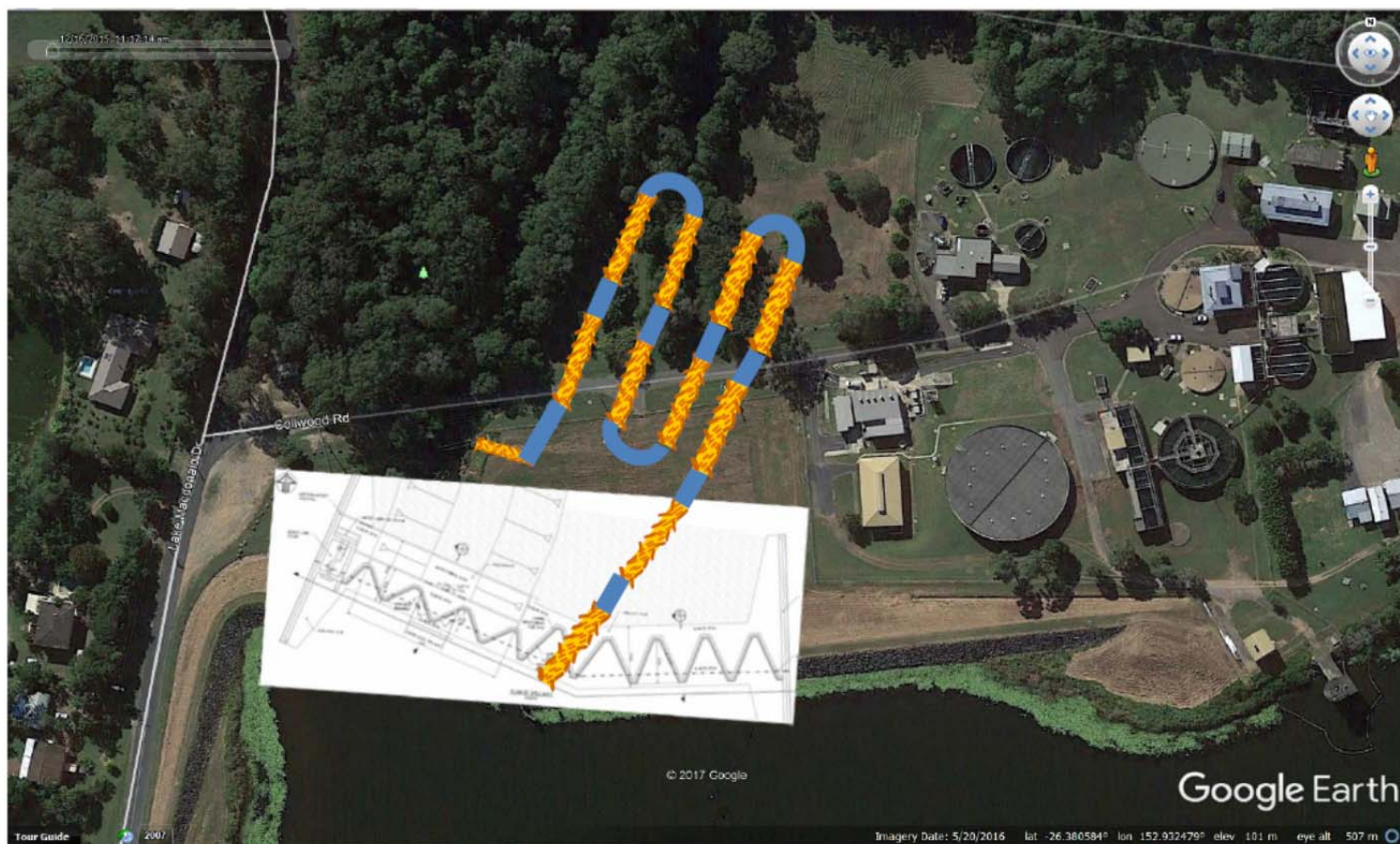
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Appendix A: Figures



Lake MacDonald Dam bypass fishway, Six Mile Creek
Concept layout for bypass fishway - right bank
(not to scale)
for SeqWater



Figure i. Schematic of a potential bypass fishway on right bank.



Lake MacDonald Dam bypass fishway, Six Mile Creek
 Concept layout for bypass fishway - left bank
 (not to scale)
 for SeqWater



Figure ii. Schematic of a potential bypass fishway on left bank.



Figure 6 Potential layout for bypass channel fishway

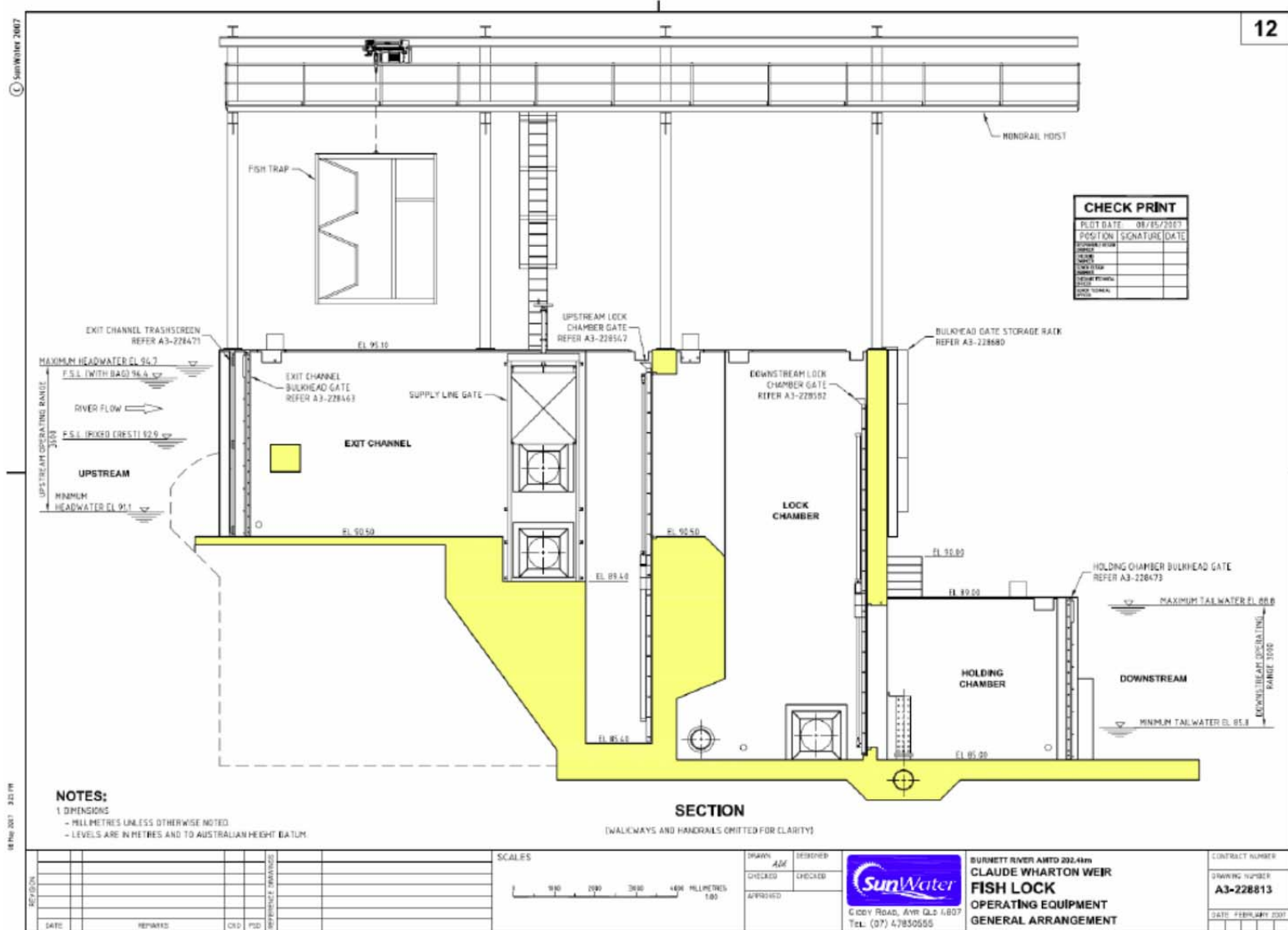


Figure iii. Section view schematic of the Claude Wharton Weir fishlock, from DAFF (2013).

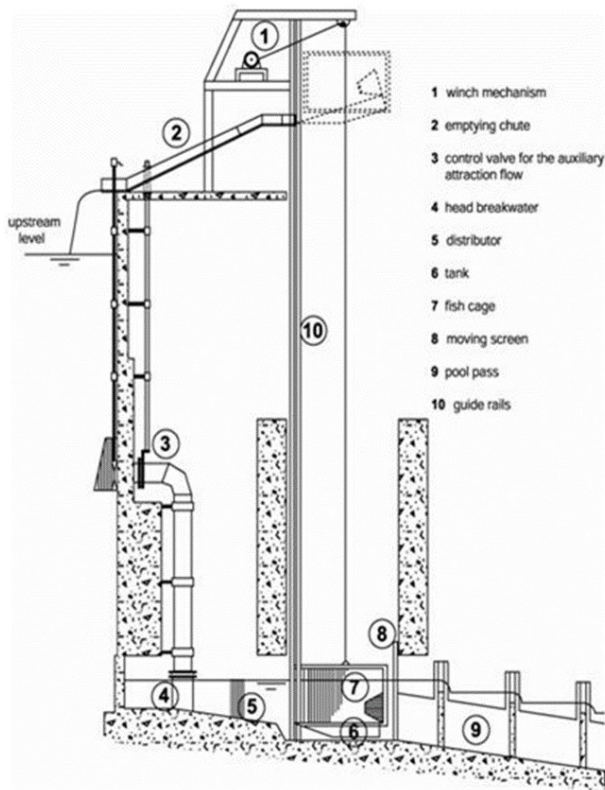


Figure iv. Section view schematic of vertical travel fishlift, from Chanseau & Larinier (2008) and Holyoke Dam fishlift showing entrance chamber with hopper in place (central) and exit sluice with gate in closed position (at right) images by A. Berghuis

Appendix B: Multi-Criteria Analysis of fishway options

	Scored									Non-scored		
	Fish Suitability / Performance [50% weight]			Engineering and Operation [50% weight]						Score	Capital Cost	O&M Cost
	Small Fish	Very Large Fish (e.g. Mary River Cod & lungfish)	Operational Range	Constructability/ Specialist direction	Commissioning Requirements	Operation	Maintenance	Design impact/ Approvals impact	Stakeholder issues			
Weighting	20	20	10	15	10	7.5	7.5	5	5	100	Qualitative	Qualitative
Vertical Slot - Concrete	4	4	4	0	4	5	4	4	5	N/A	High	Low
Bypass channel - full length	5	3	2	3	4	5	3	1	5	355	Medium	Low
Bypass channel - modified	5	3	2	0	4	5	3	4	5	N/A	High	Medium
Simplified fishlift	5	4	5	4	3	4	2	3	3	395	High	Medium
Fishlock	4	3	5	3	2	4	1	3	3	322.5	High	Medium
Trap & haul	5	4	5	4	3	1	3	2	3	375	Medium	High

Scoring: 1-5 where higher is better

Evaluation criteria	Ability of design option to cater for a range of small and large bodied species based on experience in Australia, fish community present and likely concept of each option for the site Biopassage of turtles was not considered a key driver for Lake Macdonald. This aspect is to be further considered at later stage.	o Operational Range - the range of headwater and tailwater levels for which an option could practically be developed Due to likely fishway operational rules, this criteria may not be a significant driver	o Constructability - based on feasible construction of the option. Any option that is not constructable to be scored as zero and screened out of options assessment o Specialist direction - some design options may require more specialist supervision during construction than others (minor input to evaluation)	o Commissioning Requirements - the requirements for and complexity of commissioning the option to achieve performance criteria (including automation)	o Operation - Operator input and reliability/robustness of operation o On-going Fish Monitoring Requirements - also includes the probable requirements for fish monitoring	o Maintenance - Amount, frequency and ease of completing maintenance	o Design impact - Ability to progress design on a no regrets basis Ability to drop in or out of design scope depending on regulator discussions o Approvals impact - Regulator appetite for utilising option	o Stakeholder Issues - the use of the area as a public amenity, aesthetics. Also, impacts on local landowners and environmental interest groups.	o Any individual criterion scores of zero were considered a no go. These were screened out of the total score.	o Relative cost - cost estimates not available for workshop, but a relative ranking of cost of design and construction may be useful for evaluation alongside a weighted score.
Evaluation criteria commentary	o Performance is scored on the assumption that the option is operating as designed and specified (e.g. operator availability, working as intended). o Potential issues with reliability and operator input are included as part of the O&M aspect.	o Assuming a 70% FSV operational floor for all options o Dam hydrology indicates that >70% FSV occurs 95% of time based on long timeframe simulation	o Vertical slot fishway was not considered technically feasible due to the height required and the lack of clear space available for ramping on-site. o Modified bypass channel was not considered technically feasible due to the lack of space available for ramping on-site.		o The requirement for monitoring of fishway effectiveness or sorting of fish was considered to be relatively equal amongst all options	o Mechanical fishways were rated based on required maintenance relative to passive fishways and also based on their historical robustness in Australia and tendency to require subsequent investigations/repairs.	o This criterion was added to capture the uncertainties around undertaking regulator discussions while progressing detailed design to meet a tight construction start date.	o Particular focus on potential noise and impacts. Aesthetic impacts were assessed based on potential impact or benefit (i.e. community interest in fishway operation)		

Workshop participants

Andrew Berghuis	Aquatic Biopassage Services (ABS)	Fisheries Biologist
Barton Maher	Seqwater	Principal - Storage planning
Brett Peterson	Seqwater	Senior Project Manager
David Roberts	Seqwater	Senior Scientist
Michael Peel	Seqwater	Senior Operations Engineer (hydrology)
Michel Raymond	Seqwater	Senior Operations Engineer (dams)
Murray Dunstan	Seqwater	Manager - Operations Northern Region
Steven Cox	Seqwater	Environmental Approvals Coordinator

	Fish Suitability / Performance			Engineering and Operation					
	Small Fish	Very Large Fish (e.g. MRC & lungfish)	Operational Range	Constructability/ Specialist direction	Commissioning Requirements	Operation	Maintenance	Design impact/ Approvals impact	Stakeholder issues
Vertical Slot - Concrete	Requires design with low turbulence and velocity.	Slot-width has potential to restrict very large individuals	This option can usually provide good operational range, though untested with this height of structure.	Not feasible given height of structure (not practically used above 6 m). Also requires long channel that cannot be accommodated within existing constraints.	Post-construction check only	Minimal operator intervention required to initiate or run operation.	Maintenance straight-forward, even post-flood. The structure would be located in the flood impact area, but assumed that it will be engineered to withstand typical flood impacts.	Requires long channel to incorporate large resting pools for every 1 m vertical rise	No significant noise or other impacts. Could have community interest benefit.
Bypass channel - full length	Very suitable	May be restricted by shallow depth at low flows	Lesser operational range due to hydraulics of natural channel, though can be modified with pipework. Untested with this height of structure.	Option is constructible and technically feasible, but would require non-Seqwater land with approvals issues (i.e. National Park land). Entrance/exit locations relative to spillways also a potential issue and depends if designed as bi-directional or upstream only.	Post construction check during flow with minor adjustment to hydraulics	Minimal operator intervention required to initiate or run operation. Depends on complexity of pipework to allow for operational range.	Maintenance straight-forward, even post-flood as it would mostly be out of the flood impact area.	Significant issue with feasibility and timing of securing approval for installing this infrastructure on National Park land.	No significant noise or other impacts. Could have community interest benefit, likely to be a drawcard.
Bypass channel - modified	Very suitable	May be restricted by shallow depth at low flows	Lesser operational range due to hydraulics of natural channel, though can be modified with pipework. Untested with this height of structure.	Not feasible with height of dam and length of channel required. The channel cannot be accommodated within existing constraints (space, contours, existing services).	Post construction check during flow with minor adjustment to hydraulics	Minimal operator intervention required to initiate or run operation. Depends on complexity of pipework to allow for operational range.	Maintenance straight-forward, though would require more effort than vertical slot option following flood, assuming rock is used in riffles.	Requires long channel to incorporate large resting pools for every 1 m vertical rise	No significant noise or other impacts. Could have community interest benefit.
Simplified fishlift	Very suitable provided low turbulence and velocities are provided	Very suitable, unknown for Mary River Cod (MRC)	Assumed that designs can easily achieve the operational range based on 70% FSV	Similar to lock, but may be integrated into the outlet tower	Commissioning of mechanisms can be difficult to fine tune and make robust (compared to passive options)	Fish lifts are known to work effectively and require minimal operator input when operating to specification. Assessment was based on a simplified fishlift, which is should eliminate some complexities that cause issues elsewhere, however reservations on reliability remain.	Robustness of design was thought to be good if engineering is sufficiently simple, off the shelf parts are utilised and automation is reliable. Could be scored similar to trap & haul, however there was less confidence in reliability based on Australian implementations where expensive post-construction investigations and repairs are common.	Inherently linked to dam design and requires a firm decision on the option.	Potential for noise during operation and would require mitigations. Could have community interest benefit.
Fishlock	- Mechanism of fishlock makes it more difficult to ensure (and validate) fish transfer - Cycle time is likely to be lower than fishlift or trap and haul due to lock chamber filling volume	- Mechanism of fishlock makes it more difficult to ensure (and validate) fish transfer - Cycle time is likely to be lower than fishlift or trap and haul due to lock chamber filling volume	As above	Space same as lift, but takes up more space than lift and probably requires more foundation	Difficult to validate lock chamber functions and efficacy for fish transfer	Similar to a fishlock on O&M. Fishlocks are known to operate effectively when in service and require minimal operator input.	Similar to a fishlock on O&M. Robustness of operation is thought to be good if designed appropriately. Scored lower than fishlift due to complexity of mechanisms and sensors, need to have exit slot in spillway below FSL, and difficulty accessing lock chamber for maintenance/repairs (confined space).	Inherently linked to dam design and requires a firm decision on the option.	Low potential for noise during operation. Structure and operation largely enclosed and not of community interest.
Trap & haul	Very suitable provided low turbulence and velocities are provided. Low transfer rate may increase predation	Very suitable, unknown for MRC	Group thought that operational range of this option is typically better than lift/lock, but not a differentiator on the basis of operation at Lake Macdonald and likely operating rule	Requires separate barrier weir, foundation issues, separate engineering challenges	Commissioning of mechanisms can be difficult to fine tune and make robust (compared to passive options)	Known to work effectively, but has significant operator requirements. Robustness of operation typically compromised by staff availability - business hours and other duties, e.g. most important time is in high flows and immediately following a flood peak, where operators are likely to be focussed on necessary safety tasks.	Maintenance requirements and robustness of design is relatively good based on experience at Hinze Dam	Option is decoupled from the dam structure and design could be progressed at any time. Option is unlikely to be supported where another option without manned operation is available.	Potential for noise during operation and would require mitigations (though likely to operate only during daylight hours). Could have community interest benefit.

General Comments	Dam Ops Comments - Upgraded dam likely to be eyeballed daily, but could be as little as 3 times a week - Automation is preferable, but must be robust - Operator access and ease of use important - Prefer that operators don't require specialised qualifications (e.g. crane ticket) - Public access, vandalism and safety all to be considered	Pest Fish - Pest fish are recognised as a potential impact of a fishway at the dam - This will be considered as part of the impacts/benefits of a fishway - This aspect was not included as part of evaluation criteria - Note that all options could feasibly accommodate fish sorting if required (though sorting is not preferable and defeats the purpose of minimising manned operation bottlenecks) - DAF input required	Fishway Operating Rules - Fishway operating rule B is the preferred mode as a starting point - Rule B: operate fishway only when dam above 70% FSV and there is catchment inflow (>5 times fishway flow capacity) - Optimisation of the operating rules will be needed after option selection, DAF consultation, and through design - Any option is expected to operate over a range of flows, particularly during spillway flows and following a flood peak	Mechanical Fishway Issues - MCA group and wider Seqwater business has reservations about utilising mechanical fishways based on past experience, particularly with Queensland implementations of fish lifts and associated issues. - The simplified fishlift option was presented by ABS using functional examples from the USA with the concept of vertical lift only, with simple mechanisms, off the shelf parts, and sluice release to the lake. - The MCA workshop group consensus was that a simplified fishlift could work, in a similar fasion to Hinze Dam trap and haul in terms of attraction flows and hopper mechanics, but reservations on implementation remain.					
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Appendix 5 Lake Macdonald Lowering Bathymetry

Lake Macdonald Project Bathymetry - 89 m level



PROJECT Lake Macdonald
PROJECT NO 30031970

DATE 06-06-2018
CREATED BY Nyall DAWSON
SOURCES ESRI Basemap



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Lake Macdonald Project Bathymetry - 90.5 m level



PROJECT Lake Macdonald
PROJECT NO 30031970

DATE 06-06-2018
CREATED BY Nyall DAWSON
SOURCES ESRI Basemap

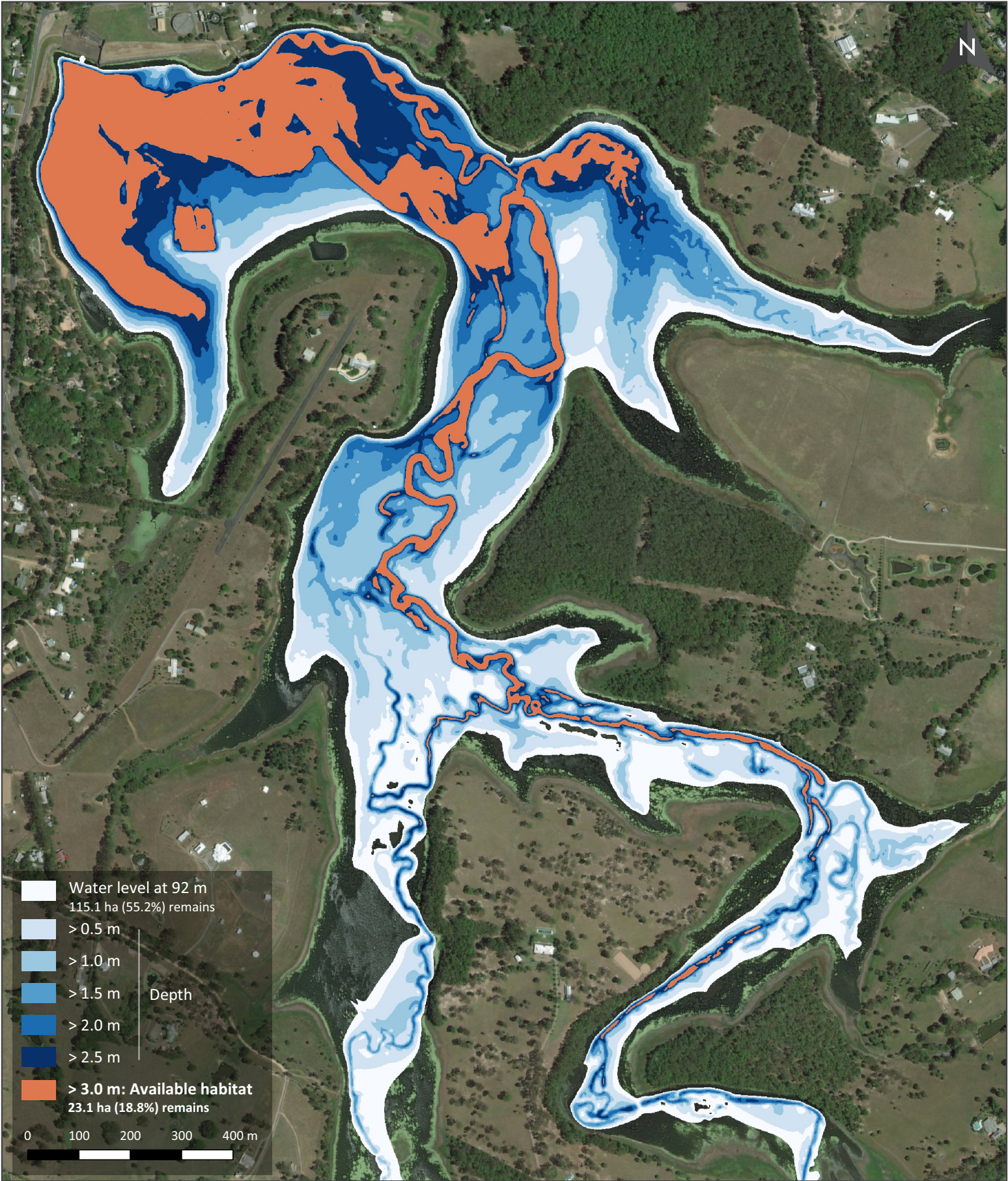


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Lake Macdonald Project Bathymetry - 92 m level



PROJECT Lake Macdonald
PROJECT NO 30031970
DATE 06-06-2018
CREATED BY Nyall DAWSON
SOURCES ESRI Basemap

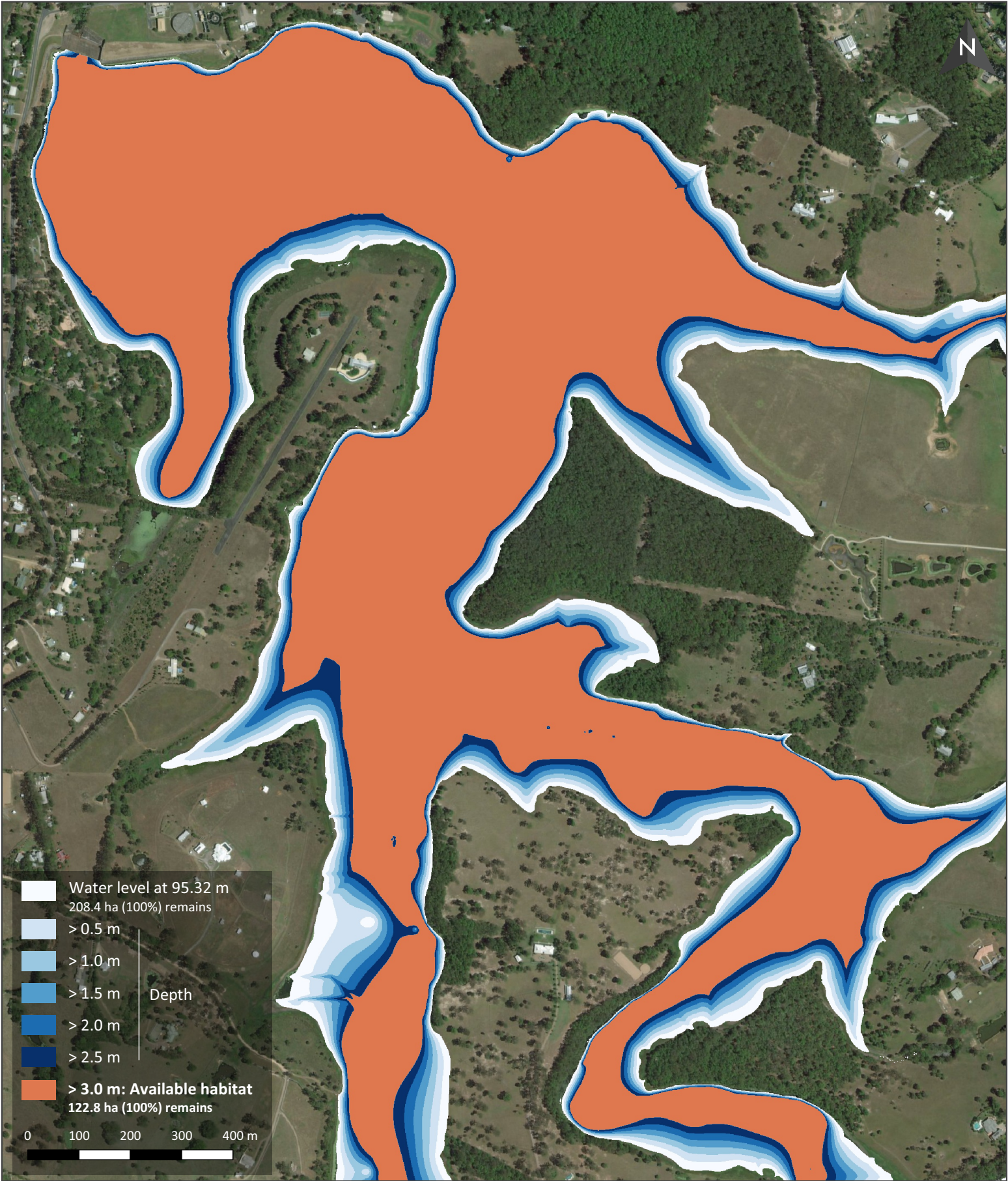


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Lake Macdonald Project Bathymetry - 95.32 m level



PROJECT Lake Macdonald
PROJECT NO 30031970

DATE 06-06-2018
CREATED BY Nyall DAWSON
SOURCES ESRI Basemap



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Appendix 6 Updated Koala Assessment Tool

Revised Koala Habitat Assessment Tool

Clearing of RE vegetation within the Project area will comprise a maximum of 1.45 hectares, with previously cleared and disturbed land utilised to the greatest extent possible. Clearing of vegetation in total, which includes RE vegetation, will be around 3 hectares. A koala habitat assessment has been completed in accordance with the EPBC Act referral guidelines for the vulnerable koala. The koala habitat assessment tool concluded that the Project area contains koala habitat with a value of 7. Projects that score 5 or more contain habitat critical to the survival of the koala (refer to Table 5-16).

While the koala habitat assessment tool indicates that the Project area includes habitat critical to koala survival, the area to be cleared borders an already highly modified environment and no evidence of koalas was found during the field survey. As such, it is considered that the Project is unlikely to adversely affect habitat critical to the survival of koalas.

Table 5-16: Koala Habitat Assessment Tool

ATTRIBUTE	SCORE	COASTAL
Koala occurrence	+1 (medium)	There is one koala record within 2 km of the edge of the impact area within the last 5 years according to the Atlas of Living Australia and BioMaps (WildNet database). The koala was recorded 1 km downstream of Lake Macdonald in 2015. During the field survey no evidence of koalas or scats was detected within the Project or study area. It was determined that if a koala population is present within the area, it is likely to be at a low density.
Vegetation composition	+2 (high)	Has forest or woodland with 2 or more known koala food tree species. Mature <i>Eucalyptus grandis</i> and <i>Lophostemon confertus</i> have been identified within the direct clearing footprint. Vegetation communities in this area provide suitable foraging habitat and comprise secondary trees for koala.
Habitat connectivity	+2 (high)	Area is part of a contiguous landscape of equal to or more than 500 ha. The Project area shares a border with Tewantin National Park which covers approximately 1,300 ha. The proposed clearing within the Project area is confined to the existing edges of vegetation. Therefore clearing for the Project will not separate currently connected habitat.
Key existing threats	+2 (high)	Areas that are likely to have some degree dog or vehicle threat present. Koala occurrence is +1 (medium) and there is little or no evidence of koala mortality from vehicle strike or dog attack at present, however due to the semi suburban nature and high recreational use of the area, it is likely that the existing koala population has some degree of dog or vehicle threat present.
Recovery value	0 (low)	Habitat is unlikely to be important for achieving the interim recovery objectives. Clearing of RE vegetation within the Project Area will not exceed 1.45 ha, and clearing of vegetation in general will not exceed 3 ha. Due to the lack of koala occurrence within the Project area and the large surrounding habitat of similar ecological value, it is unlikely that the Project will impact interim recovery objectives.