

**Long-Term Intervention Monitoring Project
for the lower Goulburn River**

Final Monitoring and Evaluation Plan

prepared for the

Commonwealth Environmental Water Office

Submitted by:

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Introduction

The Commonwealth Environmental Water Holder (CEWH) is responsible under the *Water Act 2007* (Cth) for managing Commonwealth environmental water holdings. The holdings must be managed to protect or restore the environmental assets of the Murray-Darling Basin, and other areas where the Commonwealth holds water, so as to give effect to relevant international agreements. The Basin Plan (2012) further requires that the holdings must be managed in a way that is consistent with the Basin Plan's Environmental Watering Plan. The *Water Act 2007* (Cth) and the Basin Plan also impose obligations to report on the contribution of Commonwealth environmental water to the environmental objectives of the Basin Plan.

Monitoring and evaluation are critical for supporting effective and efficient use of Commonwealth environmental water. Monitoring and evaluation will also provide important information to support the CEWH meet their reporting obligations.

The Long-Term Intervention Monitoring Project (LTIM Project) is the primary means by which the Commonwealth Environmental Water Office (CEWO) will undertake monitoring and evaluation of the ecological outcomes of Commonwealth environmental watering. The LTIM Project will be implemented at seven Selected Areas over a five year period from 2014-15 to 2018-19 to deliver five high-level outcomes (in order of priority):

1. Evaluate the contribution of Commonwealth environmental watering to the objectives of the Murray-Darling Basin Authority's (MDBA) Environmental Watering Plan
2. Evaluate the ecological outcomes of Commonwealth environmental watering at each of the seven Selected Areas
3. Infer ecological outcomes of Commonwealth environmental watering in areas of the Murray-Darling Basin not monitored
4. Support the adaptive management of Commonwealth environmental water
5. Monitor the ecological response to Commonwealth environmental watering at each of the seven Selected Areas.

This Monitoring and Evaluation Plan (M&E Plan) details the monitoring and evaluation activities that will be implemented under the LTIM Project for the Lower Goulburn River Selected Area. This M&E Plan includes:

- A description of the Selected Area, including details of Commonwealth environmental water to be delivered
- Evaluation questions relevant to the Selected Area
- Monitoring indicator methods and protocols
- A monitoring schedule
- Evaluation methods and protocols
- A communication and engagement plan
- A project management plan, including project governance; risk assessment; quality planning; and health, safety and environmental planning.

In May 2018, the Commonwealth Environmental Water Office invited the Lower Goulburn Long-Term Intervention Monitoring Project team to develop proposals for additional monitoring over the winter period 2018–19. The final approved activities under this program variation are described in an addendum (Appendix B) to this Monitoring and Evaluation Plan (Webb et al. 2018), and referred to briefly in the relevant sections below. All new text added to this report in 2018 is in maroon typeface to distinguish it from the original 2014 document.

1. Lower Goulburn River Selected Area

The Goulburn River extends from the northern slopes of the Great Dividing Range north to the Murray River near Echuca (Figure 1-1). Mean annual discharge for the catchment is approximately 3,200 GL (CSIRO 2008), and approximately 50% of that is on average diverted to meet agricultural, stock and domestic demand.

The Goulburn River Selected Area includes the main river channel between Goulburn Weir and the Murray River (235 km), along with any low-lying riparian or wetland / floodplain assets that are connected to the river channel by in-channel flows up to bank full. This Selected Area corresponds to Reaches 4 (Goulburn Weir to confluence with Broken River at Shepparton) and 5 (confluence of Broken River to Murray River) described in environmental flow studies and environmental watering plans (Cottingham et al. 2003, 2007; Peter Cottingham & Associates 2011). Environmental flows in the lower Goulburn River will not be used to deliver overbank flows or water the floodplain, therefore for the purposes of the LTIM Project, the Lower Goulburn River Selected Area is considered a Riverine System under the Australian National Aquatic Ecosystem (ANAE) classification (Brooks *et al.*, 2013).

The environmental flow reaches in the Goulburn River were determined after an analysis of stream hydrology, morphology and regulation. The reasons for dividing the Goulburn River downstream of Goulburn Weir into two environmental flow reaches is sound and Commonwealth environmental water is used to address specific environmental flow objectives in those reaches. Previous environmental flow monitoring programs in the lower Goulburn River (e.g. the Victorian Environmental Flows Monitoring and Assessment Program, and the Commonwealth short-term environmental water monitoring program) have based their sampling design around the existing environmental flow reaches and we propose to do the same for the LTIM Project.

The zone definitions for the lower Goulburn River will therefore be:

- Zone 1 – Main channel of the Goulburn River and associated wetlands and backwaters that are connected to the main channel at flows less than bankfull between Goulburn Weir and the confluence of the Broken River (i.e. Environmental Flow Reach 4).
- Zone 2 – Main channel of the Goulburn River and associated wetlands and backwaters that are connected to the main channel at flows less than bankfull between the confluence of the Broken River and the Murray River (i.e. Environmental Flow Reach 5).

Specific proposed monitoring sites within these zones are detailed in Table 4-5.

The Goulburn Broken Regional River Health Strategy (GBCMA, 2005) identifies the Goulburn River as a high priority waterway due to its significant environmental values. The river and its associated floodplain and wetland habitats support intact River Red Gum forest, and numerous threatened species such as Murray Cod, Trout Cod, Squirrel Glider, and Eastern Great Egret. The river, its associated floodplain and wetland habitats also contain many important cultural heritage sites, provide water for agriculture and urban centres, and support a variety of recreational activities such as fishing and boating. Further description of the lower Goulburn River is included in Gawne *et al.* (2013).

The two major water regulation structures on the Goulburn River are Lake Eildon and Goulburn Weir. Lake Eildon has a capacity of approximately 3,334 gigalitres, and provides water to the majority of the Shepparton, Central Goulburn, Rochester and Pyramid/Boort irrigation areas. Water is diverted at Goulburn Weir into the East Goulburn Main Channel and is harvested into Waranga Basin (capacity 432 gigalitres).

Flow in the middle Goulburn River (i.e. Between Lake Eildon and Goulburn Weir) is higher than it would naturally be in summer and early autumn to supply irrigation needs, but is lower than natural at other times of the year. The diversion of irrigation water at Goulburn Weir and inflows from tributaries such as the Broken River and Seven Creeks have helped to retain the natural seasonal flow patterns (i.e. high winter flows and low summer flows) in the lower Goulburn River. Significant Inter-Valley Transfer (IVT) flows may also be released into the lower Goulburn River from Goulburn Weir during summer and early autumn to supply water entitlements traded from the Goulburn River system to the Murray River system. IVT flows do not persist for the whole season and therefore do not reverse the natural seasonal flow pattern nor compensate for water harvested higher in the catchment. The regulation described above has reduced the average annual flow in the lower Goulburn River downstream of Goulburn Weir to 1,340 GL, which is less than half of the estimated pre-regulated flow.

The sections of the Goulburn River between Lake Eildon and Shepparton have a naturally confined floodplain (up to 4 km wide). Constructed levees confine the floodplain along the Goulburn River downstream of Shepparton. Flood water leaving the channel of the Goulburn River downstream of Shepparton either returns to the channel (where blocked by

levees), or flows north via the Deep Creek system that discharges to the Murray River downstream of Barmah. The Broken River is a major tributary of the Goulburn River, discharging at Shepparton.

As well as the impact of long term flow reduction, the lower Goulburn River is heavily affected by the recent severe, extended drought, and the following 2010/11 and 2012 floods. During the drought, amphibious and flood tolerant bank vegetation retreated down the bank and was replaced by terrestrial vegetation. The extended floods in 2010/11 and 2012 killed off all the terrestrial vegetation leaving bare river banks, susceptible to erosion. Vegetation re-establishment is only now starting to occur. Golden perch, a flow cued spawner, also did not significantly spawn during the drought (Koster *et al.*, 2012), making spawning a priority to rebuild populations and age classes.

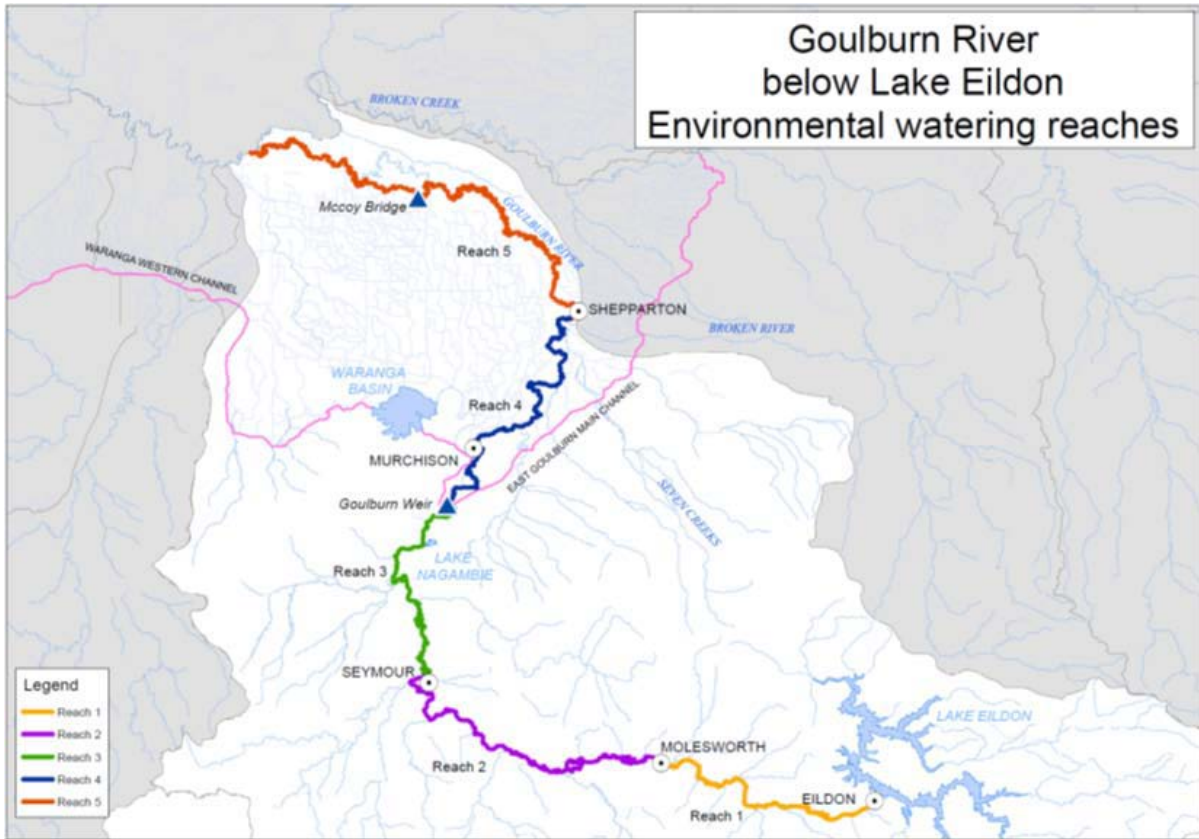


Figure 1-1. Map of the Goulburn River Catchment including the five environmental flow reaches of the Goulburn River downstream of Lake Eildon. The LTIM project will focus on the Lower Goulburn River which extends from Goulburn Weir to the Murray River and includes Reaches 4 and 5 shown on the map. Map reproduced from COA (2012b).

2. Commonwealth environmental watering

As of the 31st March 2013, the Commonwealth held 192.9 GL of high security and 11.0 GL of low security environmental water entitlements in the Goulburn River (Table 2-1). The Goulburn River receives other environmental flows through Bulk Entitlements, Environmental Entitlements held by the Victorian Environmental Water Holder, Environmental Entitlements for The Living Murray and intervalley transfers (see Gawne *et al.*, 2013 for more details). However, the Commonwealth environmental water entitlement provides most of the water that is used to meet specific environmental flow objectives in the lower Goulburn River channel.

Table 2-1: Commonwealth environmental water entitlements as at 31 August 2018 (<http://www.environment.gov.au/water/cewo/about/water-holdings>).

Entitlement type	Entitlement held (GL)	Entitlement held Long term average annual yield (GL)
Goulburn (high reliability)	255.2	270.2
Goulburn (low reliability)	42.5	19.3

2.1 What type of watering is proposed?

Watering options include increasing baseflows throughout the year, and provision of freshes in winter, spring, summer and autumn. It is expected that Commonwealth environmental water will be used to provide flows up to 9,000 ML/day, and these may rise to approximately 15,000 ML/day if timed to coincide with natural high flow events. These managed flows could be up to three quarters of bankfull flows and may connect some low lying wetlands via anabranches, but are more likely to be approximately one third to one half the magnitude of bankfull flows. Commonwealth environmental water will not be used to contribute to flows greater than 19,000 ML/day at Shepparton to avoid flooding of private property or infrastructure (Gawne *et al.*, 2013). Commonwealth environmental water will therefore not provide overbank flows in the lower Goulburn River and will not water any parts of the lower Goulburn River floodplain or associated wetlands.

Commonwealth environmental water may also be delivered through the lower Goulburn River from Lake Eildon to meet a variety of environmental watering requirements in the Murray River and other parts of the Southern Connected Basin. These flows may contribute to environmental outcomes in the lower Goulburn River.

2.2 What are the expected watering outcomes?

Baseflows and freshes are managed in the lower Goulburn River to achieve a range of ecological outcomes:

- Baseflows aim to improve fish habitat and allow fish movement, and improve macroinvertebrate habitat (including instream vegetation) and therefore macroinvertebrate abundance.
- Freshes aim to improve spawning of Golden Perch, encourage fish migration/movement, encourage the recovery of bank vegetation and increase macroinvertebrate habitat and therefore abundance.

If all planned flow components are delivered, substantial volumes of Commonwealth environmental water will be invested in fish breeding and fish movement (particularly for Golden Perch), re-establishing bank vegetation that has been lost through drought, floods or land clearing, and increased macroinvertebrate abundance. Monitoring activities that test the effect of environmental water delivery on river fish populations, riparian bank vegetation and macroinvertebrate abundance are therefore considered the highest priorities for the lower Goulburn River Selected Area.

As the CEWO does not intend contributing to bank full and overbank flows along the Goulburn River, changes in floodplain vegetation health will not occur as a result of environmental flows. Monitoring that specifically targets floodplain habitats or biota is considered a low priority for the lower Goulburn River Selected Area.

2.3 Practicalities of watering

Water in desirable flow patterns is released from Goulburn Weir, either by reducing water harvesting into Waranga Basin or by increasing water released from Lake Eildon. Current river flows from natural catchment runoff, normal minimum flows or irrigation releases (e.g. Inter-Valley Transfers), and environmental transfers to Murray environmental sites are assessed to see how well they provide desirable environmental flow regimes in the lower Goulburn River. Environmental

water is released when required to increase flows to desirable levels. These other sources of water are more fully described in Gawne *et al.* (2013).

Environmental releases to maintain minimum flows are usually set as a standing order with the water authority (i.e. Goulburn-Murray Water), providing access to water to maintain the desired flow. Freshes are normally planned and released as specified flow events, but flows or timing can be modified as catchment runoff, or the risk of catchment runoff, changes.

Low flows and freshes up to approximately 3,000 ML/day are relatively easy to deliver, being well within the capacity of the water supply system. However, as targeted flows rise above 3,000 ML/day, constraints to delivery become increasingly likely. If delivered under dry conditions, the maximum release rates downstream of Lake Eildon and high rates of irrigation delivery can limit the flows downstream of Goulburn Weir to 5,000 to 6,000 ML/day. Private irrigation pumping along the lower Goulburn River can also be affected by flows above 3,000 ML/day, particularly if flows persist for longer than about seven days. Under wet conditions with catchment runoff, Eildon release capacity can be reduced (by downstream tributary flows or the threat of floods). Goulburn Weir can cease harvesting and increase flow downstream of the weir relatively easily, but only if catchment runoff is being diverted to Waranga Basin at the time. Timing of releases (particularly from Lake Eildon) to augment flows from catchment runoff to achieve desired flow rates can also be difficult.

Monitoring the physical and ecological effects of environmental flows is particularly sensitive to the timing of fresh events as well as catchment runoff and irrigation releases because high flows and localised heavy rainfall can restrict access to the river or monitoring sites and sampling efficiency. These constraints can in some cases affect the capacity to reliably evaluate the effect of particular flow events, although it is not expected to be a major issue for managed environmental flow releases.

3. Evaluation questions

3.1 Basin-scale and Area-Specific evaluation questions for each monitoring discipline

The LTIM Project aims to evaluate the broad effect of Commonwealth environmental watering across the whole Basin as well as specific responses to environmental watering at each Selected Area. The following section considers each monitoring discipline separately and highlights the Basin-scale evaluation questions that our proposed monitoring will inform and describes Area-Specific evaluation questions that we aim to address.

3.1.1 Ecosystem type

Basin-scale evaluation questions

The interim Australian National Aquatic Ecosystems (ANAE) classification will be validated at monitoring sites to address the following Basin-scale evaluation questions:

- What did Commonwealth environmental water contribute to sustainable ecosystem diversity?
- Were ecosystems to which Commonwealth environmental water was allocated sustained?
- Was Commonwealth water delivered to a representative suite of ecosystem types?

All environmental flows in the lower Goulburn River will target permanent lowland river habitats. Brooks *et al.* (2013) has classified all of the lower Goulburn River as a Riverine System according to the interim ANAE classification. Based on our extensive knowledge of the lower Goulburn River and our proposed monitoring sites we think the initial classification is correct and no further assessment is needed to separately classify the ecosystem type for each monitoring site. The only exception to this may be tree condition assessments that include habitats on the adjacent floodplain.

Area specific evaluation questions

- Nil

Commonwealth environmental water is not expected to inundate floodplain habitats in the Lower Goulburn River and therefore there are no area specific evaluation questions related to Ecosystem type.

3.1.2 Vegetation diversity

Basin-scale evaluation questions

The M&E Advisor intends to use vegetation diversity monitoring of the riparian zone in different Selected Areas to address the following Basin-scale evaluation questions:

Short-term (one-year) and long-term (five year) questions:

- What did Commonwealth environmental water contribute to vegetation species diversity?
- What did Commonwealth environmental water contribute to vegetation community diversity?

These questions will be addressed by quantitatively measuring the abundance of different plant species in the riparian zone of the channel (i.e. between the low flow water level and top of the bank) on multiple occasions over the planned life of the LTIM Project. The vertical elevation of each monitoring point will be recorded to link the vegetation data with short and long term inundation patterns. Repeat measurements will be taken every year or every second year of the program to assess long term changes in the composition and distribution of riparian vegetation at selected sites. Monitoring will also occur before and several months after planned spring high flows to determine the more immediate effects of those flows on riparian vegetation.

Area-specific evaluation questions

Prolonged drought, followed by record breaking floods has significantly altered the vegetation community on the banks of the lower Goulburn River. Particular effects include the loss of some plant species that were not able to tolerate the extreme conditions and the physical removal of virtually all plants in some sections of the river that experienced severe

bank erosion. The GBCMA is delivering a combination of summer low flows and spring freshes to try and promote the rehabilitation of native riparian vegetation communities.

We will aim to use the vegetation diversity monitoring to address the following Area-specific evaluation questions:

Long-term evaluation questions

- What has CEW contributed to the recovery (measured through species richness, plant cover and recruitment) of riparian vegetation communities on the banks of the lower Goulburn River that have been impacted by drought and flood and how do those responses vary over time?
- How do vegetation responses to CEW delivery vary between sites with different channel features and different bank conditions?

Short-term evaluation questions

- Does the CEW contribution to spring freshes and high flows trigger germination and new growth of native riparian vegetation on the banks of the lower Goulburn River?
- How does CEW delivered as low flows and freshes at other times of the year contribute to maintaining new growth and recruitment on the banks of the lower Goulburn River?
- **What does Commonwealth environmental water delivered in winter contribute to plant propagule transport and subsequent deposition in the lower Goulburn River?**

Vegetation diversity monitoring will occur at sites with different physical form and different bank condition and therefore we will aim to determine how these factors influence riparian vegetation responses to environmental watering. Moreover, the program will aim to determine whether responses to environmental watering events in the first few years are repeated in subsequent years, or whether responses are primarily determined by the condition and 'maturity' of vegetation communities when specific flows are delivered. This monitoring will help the GBCMA determine appropriate ways to modify their environmental watering programs to either facilitate post-disturbance recovery or to maintain riparian communities that are in good condition.

The vegetation monitoring program will be greatly enhanced by physical habitat assessments including 2-D hydraulic modelling and bank erosion. Two dimensional hydraulic modelling will help predict the sheer forces that particular parts of the river bank experience under different flow conditions and allow vegetation responses in different environments to be compared. Bank condition monitoring will help explain any gross differences in vegetation responses to flow at different sites. Monitoring vegetation and physical habitat parameters concurrently may also help to determine the extent to which different types of vegetation buffer the river banks from erosion during floods and high flows.

3.1.3 Fish (river), Fish (larvae) and Fish (movement)

Basin-scale evaluation questions

The M&E Advisor has prescribed three different fish monitoring methods for river channels. These include annual surveys of adult fish populations within the river channel, targeted larval surveys between spring and late summer, and tracking the movement of tagged fish throughout the year. These three monitoring techniques provide data that will be variously used to address long-term and short-term evaluation questions at the Basin-scale:

Long-term (five year) questions:

- What did CEW contribute to native fish populations? (annual fish surveys, larval surveys, movement)
- What did CEW contribute to species diversity? (annual fish surveys, larval surveys)

Short-term (one year) questions:

- What did CEW contribute to fish community resilience? (annual fish surveys, larval surveys)
- What did CEW contribute to native fish survival? (annual fish surveys, larval surveys)
- What did CEW contribute to native fish reproduction? (annual fish surveys, larval surveys, movement)
- What did CEW contribute to native fish growth rates? (annual fish surveys)
- What did CEW contribute to native fish dispersal? (movement)

- **What does CEW delivered in the LGR contribute to Lamprey movement in the Lower Murray River and connected southern basin?**

Questions relating to population structure and species diversity will be assessed by measuring the abundance and age structure of different populations, richness of species within the community and the distribution of species within Selected Areas and across different Selected Areas throughout the Basin. Native fish community resilience and survival will be assessed through species distribution and age composition (e.g. species that are widespread and have a wide range of age classes are likely to be more resilient). Fish reproduction will be directly assessed through larval surveys and indirectly through annual surveys that check for a mix of age cohorts within the population. Fish tracking or movement will be specifically used to determine whether fish move in response to certain environmental flows, but will also be linked to questions about reproduction for species that migrate to preferred spawning areas to breed.

Area-specific evaluation questions

One of the main objectives of Commonwealth environmental water delivery in the lower Goulburn River is to maintain or improve the health of native fish communities. This is particularly important now because the Millennium Drought and then blackwater events that were associated with the 2010 and 2011 floods significantly reduced native fish populations in the lower Goulburn River. Golden Perch, and to a lesser extent Silver Perch, are the main targets for environmental water in the lower Goulburn River because their recruitment is linked to flows. The GBCMA delivers high flows or freshes during spring to trigger Golden Perch spawning and tries to maintain relatively stable low flows throughout summer to protect edge and backwater habitats within the channel that are likely to provide good nursery habitats for developing fish larvae. The area specific questions for fish monitoring in the lower Goulburn Area include:

Long-term (five year) questions

- What did CEW contribute to the recruitment of Golden Perch in the adult population in the lower Goulburn River? (annual fish surveys, larval surveys, movement)

Short-term (one year) questions

- What did CEW contribute to Golden Perch spawning and in particular what magnitude, timing and duration of flow is required to trigger spawning? (larval surveys and movement)
- What did CEW contribute to the survival of Golden Perch larvae in the lower Goulburn River? (annual fish surveys and larval surveys)
- What did CEW contribute to the movement of Golden Perch in the lower Goulburn River and where did those fish move to? (movement)

These assessments, particularly assessments of larval survival and recruitment, will benefit from complementary 2-D Hydraulic Modelling that will quantify the distribution, quantity and quality of slackwater habitats within the channel under different flow conditions. Much of the fish monitoring described above will also be conducted in the lower Murray Selected Area and the Edward Wakool Selected Area. Golden Perch are likely to move between the lower Goulburn River and those other two selected areas and co-ordinated monitoring across all three areas throughout the LTIM Project will provide a unique opportunity to understand that movement and how flow regimes and other factors in one area can affect Golden Perch populations in other areas.

3.1.4 Macroinvertebrates

Basin-scale evaluation questions

- Nil

Following submission of the draft monitoring and evaluation plan, macroinvertebrates were revised from a category II indicator to category III. It appears likely that no other Selected Areas will be monitoring macroinvertebrates, eliminating the possibility of basin-scale (or even multi-Area) evaluation.

Area-specific evaluation questions

The M&E Advisor originally prescribed a standard monitoring method that used a combination of artificial substrates, sweep samples and decapod traps. With the change in macroinvertebrates to a category III endpoint, we have made modifications to the standard method described below that will address the following evaluation questions:

Long-term and short-term questions:

- What did CEW contribute to macroinvertebrate diversity?

We are of the opinion that the value of macroinvertebrate assessment in previous environmental flow monitoring programs has been thwarted by a focus on diversity and the use of standard Rapid Bioassessment Sampling procedures. In large lowland rivers, such as those targeted by the LTIM Project, the macroinvertebrate communities tend to be dominated by species that favour relatively simple habitats and are able to tolerate moderate to poor water quality. Environmental flows delivered to these rivers are more likely to influence macroinvertebrate abundance and biomass than diversity. Such effects are important, because macroinvertebrates are an important component of riverine foodwebs and therefore changes in biomass will have cascading effects on other biota such as fish. The revised standard method allows a quantitative assessment of macroinvertebrate biomass using approaches that have been well tested in the Murray River, and therefore we will include a second macroinvertebrate evaluation question:

- What did CEW contribute to macroinvertebrate biomass?

The environmental flow recommendations for the lower Goulburn River include low flows and summer freshes to maintain habitat and provide food for macroinvertebrates. Part of the revised standard method will monitor macroinvertebrate emergence rates to see if environmental flows influence macroinvertebrate breeding and reproduction. The detail provided below is intended to provide some context, and explain how the proposed emergence monitoring will make use of and add value to the other data. This additional monitoring is being structured as a PhD project, and therefore additional costs of its inclusion are minimal (the budget is for extra travel and supplies). Greater emergence would lead to breeding and recruitment of new aquatic invertebrates to the river. This would be expected to increase the amount of food available to fish.

Overall, our proposed monitoring program will aim to answer the following questions in the lower Goulburn River:

- What did CEW contribute to macroinvertebrate diversity and biomass in the lower Goulburn River? Specifically what combination of freshes and low flows are required to maximise macroinvertebrate biomass in the river?
- What did CEW contribute to macroinvertebrate emergence, and hence reproduction, in the lower Goulburn River?
- Does CEW contribute the exploitation of novel habitats by large-bodied crustaceans in the LGR?
- What does CEW contribute to algal biofilm production in the LGR?
- Do rates of algal productivity in the LGR differ between summer and winter?

3.1.5 Stream metabolism

Basin-scale evaluation questions

The key objective of the stream metabolism monitoring program is to determine the effects of environmental watering actions on the rates of gross primary production (GPP) and ecosystem respiration (ER). These processes support and sustain aquatic foodwebs, and hence are directly related to ecosystem health and viable fish populations. Important drivers for these processes, notably nutrients (water column chlorophyll-a and organic carbon concentrations) and light, will be collected concurrently to allow flow effects to be distinguished from nutrient variations, phytoplankton effects and daily weather fluctuations.

This monitoring protocol for stream metabolism addresses the following Basin scale evaluation questions:

Short-term (one-year) and long-term (five year) questions:

- What did Commonwealth environmental water contribute to patterns and rates of decomposition?
- What did Commonwealth environmental water contribute to patterns and rates of primary productivity?

Area-specific evaluation questions

Overbank flows are considered particularly important drivers of stream metabolism as they flush large amounts of carbon and nutrients from the floodplain into the river. Commonwealth environmental water will not be used to deliver overbank flows in the lower Goulburn River and therefore the area-specific monitoring will focus on how low flows, freshes and high flows within the river channel affect stream metabolism. The effect of these flows can be compared to responses to any natural overbank flows if they occur during the life of the LTIM Project. There is also the potential to

compare these responses against other Selected Areas (specifically the Edward Wakool System for which A/Prof Michael Grace is also the monitoring provider for stream metabolism) which are more likely to experience overbank flows. The nutrient concentrations are much lower in the Edward-Wakool system which provides a strong constraint on primary production. The Goulburn vs Edward-Wakool comparison is ideally suited to examine the interaction of flow and baseline nutrients. However, whether or not to include this extra two-Area assessment will be decided upon once the details of basin-scale evaluation of stream metabolism are made clear. The extent, timing and duration of inundation of backwater habitats within the channel or on adjacent floodplain habitats is expected to have a significant effect on both GPP and ER and so 2-D hydraulic modelling that quantifies changes in such habitats under different flow conditions will greatly improve any interpretation of stream metabolism data and results.

The following area-specific evaluation questions will be considered:

- How does the timing and magnitude of CEW delivery affect rates of GPP and ER in the lower Goulburn River?
- How do stream metabolism responses to CEW in the lower Goulburn River differ from CEW responses in the Edward Wakool system where the likelihood of overbank flows is higher and the nutrient concentrations are generally much lower?
- What does CEW delivered in winter contribute to ecosystem metabolism in the LGR?
- Is ecosystem metabolism in winter in the LGR a substantial component of the full-year ecosystem metabolism?

3.1.6 Physical habitat

Basin and area-scale evaluation questions

Nearly all environmental flow recommendations are predicated on the assumption that changes in flow magnitude will alter hydraulic habitats within the river channel, and that the specific quality, quantity and distribution of these habitats as well as the timing of when they are provided will influence ecological processes and ecological responses to particular flow regimes. The importance of physical habitat change is explicitly described in the great majority of Cause and Effect Diagrams presented in MDFRC (2013) and referred to in Section 3.3 of this M&E Plan.

Most river channels are geomorphologically diverse and therefore discharge will affect habitat availability in a non-linear way. The relationship between discharge and habitat quality and quantity is arguably more explicit and more quantifiable than biotic responses to flow. Quantifying change in hydraulic habitat with discharge will be vital for explaining biotic responses (of lack thereof) to environmental flows. This is particularly relevant for larval fish, riparian bank vegetation, and macroinvertebrate abundances that are closely associated with specific hydraulic habitats such as slackwaters. For these reasons we argue that detailed two dimensional hydraulic modelling should be included as part area-specific monitoring.

Specific evaluation questions that relate to physical habitat responses to flow include:

- What did CEW contribute to the provision of productive habitat (e.g. slackwater habitats) for the recruitment, growth, and survival of larval and juvenile fish?
- What did CEW contribute to the provision of diverse and productive macroinvertebrate habitats?
- What did CEW contribute to inundating specific riparian vegetation zones and creating hydraulic habitats that favoured the dispersal and deposition of plant seeds and propagules?

We understand that the Edward-Wakool selected area is also proposing to monitor hydraulic habitat using compatible methods. If their monitoring program is funded, then there is the potential for large-scale analyses of response, although it is unclear whether such analyses would be undertaken by the Monitoring Adviser (A. Lowes, CEWO, pers. com.).

Despite the provision of explicit questions relating to hydraulic habitat, we see the main value of this monitoring activity as providing critical data for understanding responses of fish, macroinvertebrates and vegetation. Outputs from the 2-D hydraulic model will be driving data used in the analyses of these biotic responses.

3.1.7 Bank condition

Area-specific evaluation questions

There is currently a perception by some members of the community that environmental flow releases in the lower Goulburn River have contributed to erosion of the river bank. Riverbank erosion is a natural process, but if excessive will have significant implications for the survival and recruitment of riparian vegetation, water quality and sediment deposition on the streambed. Direct measurements of the river bank may be used to determine whether managed flow releases are contributing to the observed erosion and if so, how flow delivery may be altered to reduce impacts. Bank erosion will also be an important explanatory variable for interpreting the results of the riparian vegetation diversity assessment.

Specific monitoring questions include:

- Does CEW contribute to or increase the risk of bank erosion in the lower Goulburn River?
- How does the amount of river bank erosion affect vegetation responses to environmental water delivery?
- What does CEW delivered in winter contribute to sediment transport and deposition in the LGR?

3.2 Cause and effect diagrams

MDFRC (2013) prepared generic Cause and Effect Diagrams (CEDs) to describe the mechanisms by which environmental water delivery is expected to influence physical and ecological processes and outcomes in the Murray-Darling Basin. The monitoring activities that we propose to implement in the lower Goulburn River relate to 21 of the CEDs developed for the LTIM Project (see Table 3-1). We note that many of our proposed monitoring activities directly or indirectly relate to multiple CEDs (Table 3-1), which emphasises the breadth and complementarity of activities that we are planning, and the potential for results from one monitoring activity to inform or assist with interpreting the results of other monitoring activities. Moreover, the relevance of physical habitat measures to so many of the CEDs strongly supports our recommendation that hydraulic modelling (and possibly bank erosion) should be included in the LTIM Project for the lower Goulburn River.

Our discipline leads have all reviewed the relevant CEDs listed in Table 3-1 and confirm that they are adequate and appropriate for our purposes. There are two exceptions to this. We have provided a revised CED for macroinvertebrate diversity to take into account our proposed measurement of biomass and emergence (**Error! Reference source not found.**). The hypothesized causal elements are the same as for the previous macroinvertebrate diversity CED (Figure 6 in MDFRC, 2013). Second, MDFRC (2013) did not provide any specific CEDs for physical habitat. We have provided a new CED for hydraulic habitat (Figure 3-2), and for Bank Condition (Figure 3-3).

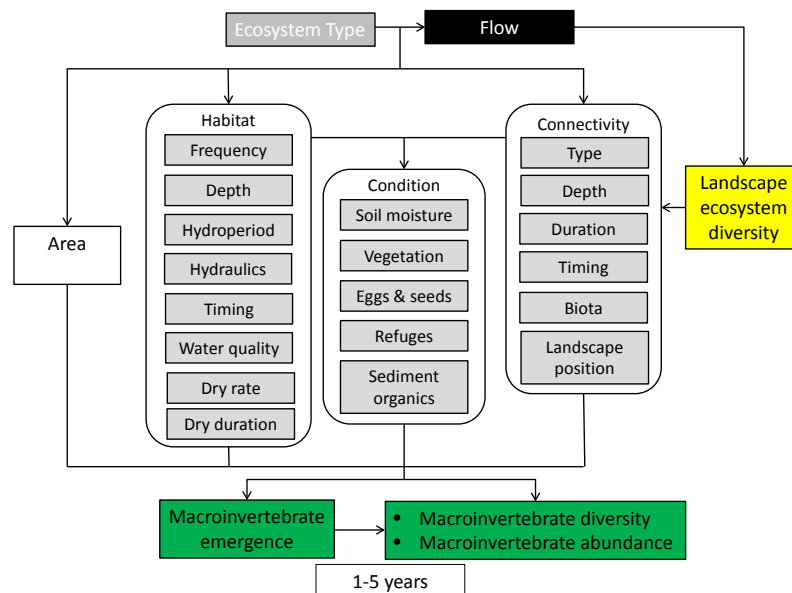


Figure 3-1: Revised CED for macroinvertebrate diversity, abundance and emergence; how they will be measured and how data will be used to evaluate responses to Commonwealth environmental water delivery.

Table 3-1: Cause and effect diagrams described in MDFRC (2013) that are relevant to the lower Goulburn River LTIM program. Dark shading indicates which monitoring activity relates directly to each CED. Light shading indicates indirect relationships.

Cause Effect Diagram		Vegetation Diversity	Macroinvertebrates	Fish (river)	Fish (larvae)	Fish (movement)	Hydrology	Bank Condition	Hydraulic habitat	Stream metabolism
Fig 3	Influence of flow regime and geomorphology on landscape vegetation diversity	Dark					Dark	Dark	Dark	
Fig 4	Influence of flow regime on vegetation condition and reproduction						Dark			
Fig 5	Influence of flow on vegetation recruitment and extent	Dark					Dark	Light	Light	
Fig 6	Influence of flow on within ecosystem macroinvertebrate diversity		Dark				Dark		Light	Light
Fig 7	Influence of flow on landscape fish diversity		Light	Dark	Dark	Dark	Dark		Dark	Dark
Fig 8	Influence of flow on fish condition		Light	Dark			Dark			Dark
Fig 9	Influence of flow on fish reproduction		Light	Dark	Dark	Dark	Dark		Dark	Light
Fig 10	Influence of flow on fish larval growth and survival		Light	Dark	Dark		Dark		Dark	Light
Fig 17	Hydrological connectivity influences of flow and fluvial morphology						Dark		Dark	
Fig 18	Influence of flow on biotic dispersal	Light	Light			Dark	Dark		Dark	
Fig 19	Influence of flow on geology and sediment transport						Dark	Dark	Dark	
Fig 20	Influence of flow on primary production	Light	Light	Light	Light	Light	Dark	Light	Light	Dark
Fig 21	Influence of flow on decomposition						Dark		Light	Dark
Fig 22	Influence of flow on nutrient and carbon cycling						Dark	Light	Light	Dark
Fig 25	Influence of flow on individual refugia		Light	Light	Light		Dark		Dark	
Fig 26	Influence of flow on landscape refugia		Light	Light	Light		Dark		Dark	
Fig 28	Influence of flow on ecosystem resistance	Light	Light	Light			Dark		Dark	Light
Fig 29	Influence of flow on ecosystem recovery	Light	Light	Light	Dark	Dark	Dark		Dark	Light
Fig 35	Influence of flow on dissolved oxygen						Dark			Dark
Fig 37	Influence of flow on dissolved organic carbon						Dark			Dark
Fig 38	Influence of flow on algal blooms						Dark			Dark

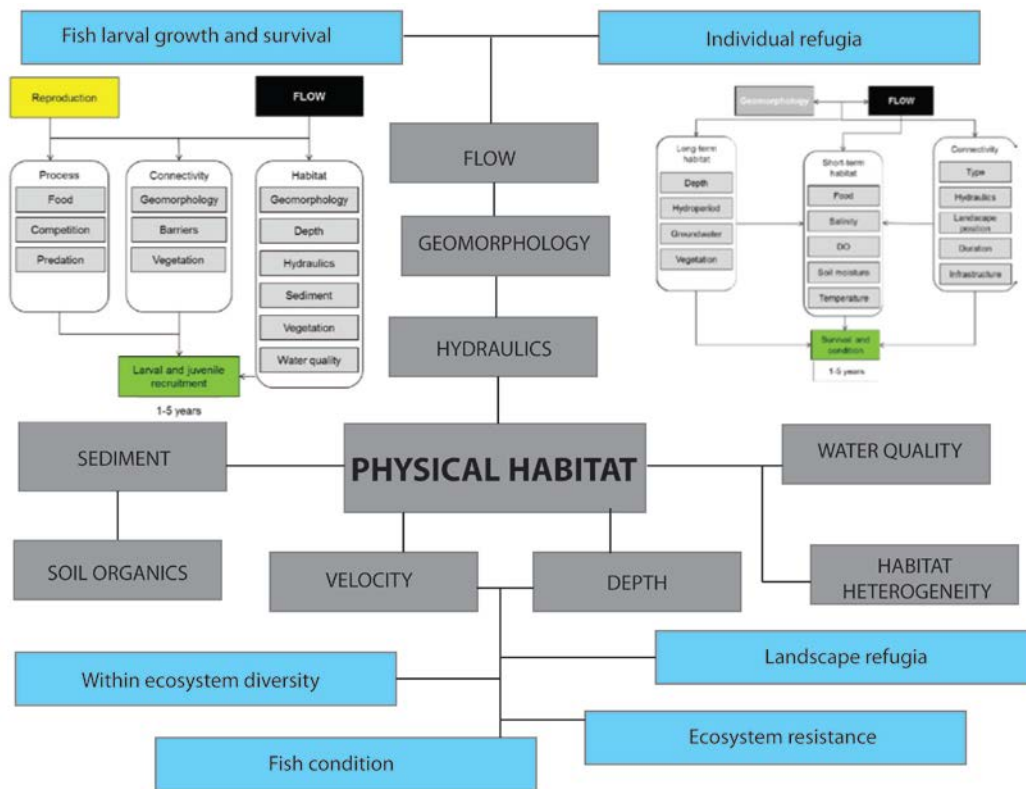


Figure 3-2: CED for hydraulic habitat, showing two other of the generic CEDs into which hydraulic habitat feeds. These two are examples, with many other CEDs also relying explicitly on hydraulic habitat.

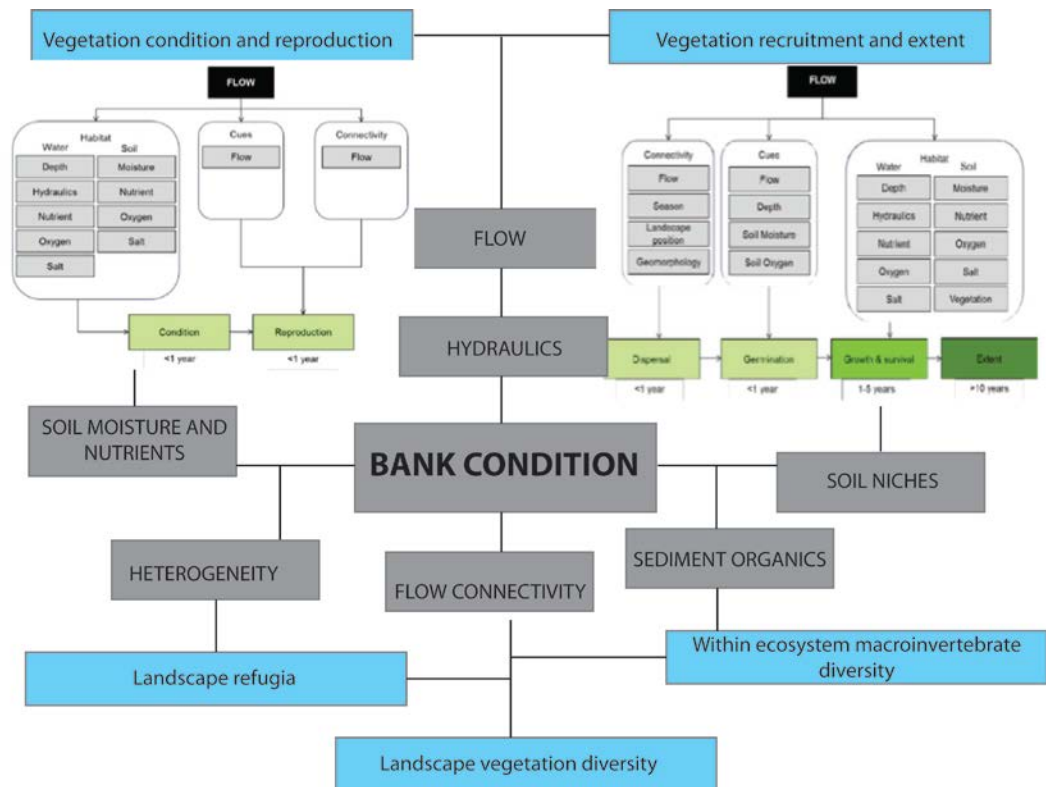


Figure 3-3: CED for bank condition, showing two other of the generic CEDs into which bank condition feeds. These two are examples, with many other CEDs also relying explicitly on bank condition (see SOP).

3.3 Indicators

The LTIM Project will measure a variety of physical, chemical and biological indicators that fall into one of the following three categories:

Category I – Mandatory indicators with mandatory standard protocols

Category I indicators are required to inform quantitative Basin-scale evaluation questions. The M&E Advisor has specified the Selected Areas where each Category I indicator is to be monitored and has specified standard protocols that must be used. The use of standard protocols is critical to ensure consistency for the Basin-scale analysis.

Category II – Optional indicators that have mandatory standard protocols

Category II indicators may be used to inform quantitative Basin-scale evaluations in the future, but it is up to individual M&E Providers to decide whether the indicator is likely to inform monitoring objectives that specifically relate to their Selected Area. If M&E Providers choose to monitor Category II indicators then they must follow the standard protocols specified by the M&E Advisor.

Category III – Optional indicators without standard protocols

Category III indicators will be primarily used to inform monitoring questions that relate to a particular Selected Area. M&E Providers will select the indicators and develop appropriate methods to monitor those indicators in their Selected Area. The monitoring results for all Category III indicators need to be reported in a manner specified by the M&E Advisor to ensure consistency across the whole LTIM Project.

The suite of Category I, II and III indicators that we propose to monitor in the lower Goulburn River and the Selected Area and Basin-scale monitoring objectives they will inform are summarised in Table 3-2.

Table 3-2: Matrix showing which monitoring activities will be used to address each Basin scale and Area specific evaluation question. Monitoring activities are separated into Category I, II or III and shading is used to indicate monitoring activities that will support the data analysis and interpretation without being the primary indicator for that question. **Additional monitoring added to the program for winter 2018–19 is not included in this table. Refer to the addendum document for details on these activities.**

Discipline	M&E Question	Category I			Category II			Category III			
		River Hydrology	Fish (river)	Stream Metabolism	Vegetation Diversity	Fish (larvae)	Fish (movement)	Macroinvertebrates (diversity & biomass)	Macroinvertebrates (emergence)	2-D Hydraulic Modelling	Bank Erosion
Basin-scale questions											
Vegetation	What did CEW contribute to riparian vegetation species diversity?	■			■					■	■
	What did CEW contribute to riparian vegetation community diversity?	■			■					■	■
Fish	What did CEW contribute to native fish populations?	■	■	■		■	■	■		■	
	What did CEW contribute to native fish species diversity?	■	■	■		■		■		■	
	What did CEW contribute to fish community resilience?	■	■	■		■		■		■	
	What did CEW contribute to native fish survival?	■	■	■		■		■		■	
	What did CEW contribute to native fish reproduction?	■	■	■		■	■			■	
	What did CEW contribute to native fish growth rates?	■	■	■				■		■	
	What did CEW contribute to native fish dispersal?	■					■				
Stream metabolism	What did CEW contribute to patterns and rates of decomposition?	■		■						■	
	What did CEW contribute to patterns and rates of primary productivity?	■		■						■	
Physical habitat *	What did CEW contribute to the provision of productive habitat for aquatic biota? *	■	■			■		■		■	
	What did CEW contribute to inundating riparian vegetation and creating hydraulic habitats that favour the dispersal and deposition of plant seeds and propagules?	■			■					■	

Area specific questions										
Vegetation	What did CEW contribute to the recovery of drought and flood affected riparian vegetation communities in the lower Goulburn River?									
	How do vegetation responses to CEW vary between sites with different channel features and different bank condition?									
	How does CEW contribute to germination and new growth of native riparian vegetation on the banks of the lower Goulburn River?									
	How does CEW contribute to the maintenance and survival of new vegetation growth and new vegetation recruitment on the banks of the lower Goulburn River?									
Fish	What did CEW contribute to the recruitment of Golden Perch in the lower Goulburn River?									
	What did CEW contribute to Golden Perch spawning in the lower Goulburn River?									
	What did CEW contribute to the survival of Golden Perch larvae in the lower Goulburn River?									
	What did CEW contribute to the movement of Golden Perch in the lower Goulburn River?									
Macroinvertebrates	What did CEW contribute to macroinvertebrate diversity and biomass in the lower Goulburn River?									
	What did CEW contribute to macroinvertebrate emergence and reproduction in the lower Goulburn River?									
Stream metabolism	How does the timing and magnitude of CEW delivery affect rates of GPP and ER in the lower Goulburn River?									
	How do stream metabolism responses to CEW in the lower Goulburn River compare to responses in the Edward Wakool System?									
Bank Condition	How does CEW affect bank erosion in the lower Goulburn River?									

4. Selected Area schedule of monitoring

The M&E Provider team for the lower Goulburn River Selected Area considered a wide range of monitoring activities that would address Basin-scale and Area-specific evaluation questions in the lower Goulburn River and conducted a rigorous evaluation to rank them in order of importance. The process that was followed and the outcome are described in Section 4.1; detailed justifications for including or excluding particular monitoring activities are provided in Section 4.2.

4.1 Overview of monitoring

4.1.1 Focus of our monitoring

We decided that the LTIM Project for the lower Goulburn River should primarily focus on the types of environmental flow components that are likely to be delivered to the river over the next five years and should evaluate how well the delivered flows meet their intended environmental objectives. In the lower Goulburn River, Commonwealth Environmental Water will predominantly be used to deliver the following flows:

- Spring and summer freshes and high flows to trigger spawning and recruitment of native fish (particularly Golden Perch) within the main river channel;
- Adequate summer low flows to maintain habitat for fish within the river channel;
- Summer freshes and low flows to promote the growth of native riparian vegetation on the river bank and to prevent encroachment by terrestrial plants;
- Summer freshes and low flows to maintain habitat and increase the biomass and diversity of aquatic macroinvertebrates;

Planned environmental flows in the lower Goulburn River will be wholly contained within the river channel. There are significant floodplain habitats along the lower Goulburn River, but Commonwealth environmental water will not be used to water them.

4.1.2 Process we followed to identify and rank monitoring activities

We held a two-day project workshop at the Goulburn Broken Catchment Management Authority offices in Shepparton to determine which monitoring activities would best address the environmental flow evaluation questions for the lower Goulburn River. The workshop was facilitated by our project co-ordinator and project leader and was attended by our project discipline leads for fish, vegetation, macroinvertebrates, stream metabolism, hydrology and physical habitat, project team members from the Goulburn Broken CMA, a representative from the M&E Advisor and two representatives from the CEWO.

Each of our monitoring discipline leads was asked to describe what monitoring would be needed to address Basin-Scale and Area-Specific evaluation questions for fish, vegetation, macroinvertebrates, stream metabolism and water quality, and physical habitat in the lower Goulburn River. Those discussions considered the main objectives of environmental water delivery in the lower Goulburn River, the priority Basin-scale evaluation questions identified by the M&E Advisor, the likelihood that the monitoring would be able to address Basin-scale and Area-Specific evaluation questions, the extent to which the proposed monitoring would be able to use existing data or support other complementary investigations, the potential to co-ordinate with monitoring planned in other Selected Areas, and the expected cost of the proposed monitoring and therefore its value for money. Discipline leads also indicated which Zones should be monitored, the type and the number of sites that should be monitored in each zone and what other monitoring activities should be implemented at the proposed sites to maximise sampling efficiency and to ensure that results from different monitoring activities could be used in some analyses to more reliably evaluate the effect of environmental flows in the lower Goulburn River.

The presentations by discipline leads and associated discussions with the rest of the project team identified 11 monitoring activities that if implemented would address the Basin-scale and Area-specific evaluation questions that are most relevant to the lower Goulburn River (see Table 4-1). These eleven monitoring activities formed the basis of our proposed M&E Plan for the lower Goulburn River, which is discussed in more detail in Section 4.1.3.

Table 4-1: Monitoring activities to address all evaluation questions relevant to the lower Goulburn River.

Proposed monitoring activities	
Hydrology – measurements of streamflow	Macroinvertebrate diversity and biomass
Fish (River) - Annual adult fish surveys	Macroinvertebrate emergence
Fish (larvae) – larval fish surveys during spawning season	Stream metabolism – measures of gross primary production and respiration
Fish (Movement) – tagging selected fish so that their movement can be detected with fixed monitoring stations.	Physical habitat – 2D Hydraulic models
Tree Condition – (ground truthing of floodplain vegetation to inform large area remote sensing imagery)	Physical habitat – bank erosion
Vegetation diversity – direct quantitative measurements of riparian vegetation on the banks of the river channel	

Our estimated costs to implement all of the proposed monitoring significantly exceeded the indicative budget that the CEWO would grant each M&E Provider. We therefore conducted a structured vote and discussion to rank the relative importance of each monitoring activity. Hydrology was excluded from the ranking process because it is critical to all assessments. Moreover, the existing flow gauges on the lower Goulburn River provide a reliable measure of flow throughout both Zones and new flow gauges will not need to be established for the LTIM Project. Macroinvertebrate emergence was not considered separately from diversity and abundance because at that stage it was not a part of the LTIM standard method (the ranking took place when Macroinvertebrate diversity was still a Category II endpoint).

We used a modified Delphi process to attempt to reach group-level consensus on the priority of monitoring activities. Each workshop participant was given 10 votes to distribute across the nine nominated monitoring activities to indicate their level of support. Participants had to use all 10 votes and could allocate between zero and five votes to each activity. We tallied the votes to determine a preliminary ranking for each monitoring activity and then asked people who had voted quite differently to other participants (i.e. they gave a particular monitoring activity many more votes or far fewer votes than other participants) to explain the reason for their decision. This review process was particularly useful for highlighting important aspects of the monitoring activity that the discipline leads may have overstated or not made clearly enough in their initial presentations. After this review, participants were offered the chance to modify their votes. The final votes were then tallied to rank the monitoring activities in the agreed priority order.

The ranking process identified larval fish surveys, 2-D hydraulic modelling, annual adult fish surveys, stream metabolism, riparian vegetation diversity and macroinvertebrate assessments as the most important for the lower Goulburn River. Each of these monitoring activities polled more than three times as many votes as the other monitoring activities (see Table 4-2). It is worth noting that these six monitoring activities were considered the most important in the first and second voting rounds, although the order changed slightly between the votes (Table 4-2). The large number of votes and consistency between voting rounds confirms that our project team collectively agree that they are the most important monitoring activities for the lower Goulburn River.

Table 4-2: Results of project workshop vote to rank proposed monitoring activities in priority order, plus CEWO ranking

Rank	Monitoring activity	Indicator Category	First round votes	Final votes	CEWO
1	Fish (larvae)	II	33	33	High
2	2-D Hydraulic Model	III	24	26	High
3	Fish (river)	I	27	24	High
4	Stream Metabolism	I	14	22	High
5	Vegetation Diversity	II	22	21	Medium
6	Macroinvertebrate diversity & abund.	III	16	20	Medium
	Macroinvertebrate emergence	III			Medium
7	Fish (movement)	II	10	6	Medium/Low
8	Bank Erosion	III	3	1	Medium
9	Tree Condition	I	1	0	Low

Hydrology was excluded from the vote because it is critical to all monitoring activities.

The most notable aspects of the ranking are:

1. Tree condition monitoring was considered the least important, despite the M&E Advisor originally specifying it as a Category I monitoring activity for the lower Goulburn Area. Our project team argued that monitoring tree condition on the lower Goulburn River floodplain was not relevant for the LTIM Project because Commonwealth environmental water will not water the floodplain or influence the condition of floodplain vegetation. We understood that the proposed monitoring primarily aimed to ground truth results for a Basin-wide remote sensing analysis. However, we argued that direct measurements of tree condition which are taken in the nearby Barmah and Gunbower Forests for The Living Murray (TLM) Condition Monitoring Program could be used to calibrate the remote sensing imagery for the lower Goulburn River. We consulted Shaun Cunningham about this option, and he confirmed that such an approach would be possible. We therefore argued that the costs associated with directly measuring tree condition could be better spent on directly evaluating responses to environmental flow releases in the lower Goulburn River. Subsequently, the CEWO supported our recommendation to exclude tree condition monitoring, and it is not part of the final monitoring program.
2. Two dimensional hydraulic modelling was identified as the second most important monitoring activity despite it being a Category III indicator and despite the Basin Plan having no specific objective to use environmental water to modify in-stream habitats. Our project team considers physical habitat monitoring to be as critical as hydrological monitoring to the LTIM Project because most of the ecological objectives that environmental flows aim to address rely on the flows creating favourable hydraulic conditions. The relationship between physical habitat and ecological responses are explicitly represented in the Cause-Effect-Diagrams that the M&E Advisor has prepared for the project and that alone justifies their inclusion in the monitoring program. Hydraulic responses to environmental flows can be more reliably measured than many ecological responses and as such can indicate whether particular environmental flows have achieved their objective. Moreover, hydraulic information may be important in instances where environmental flows fail to deliver an expected ecological response. In such cases, hydraulic models may be used to determine whether the flows created the necessary conditions for the expected ecological response. If they did, then we may conclude that factors other than flow prevented the expected response.
3. The six most important monitoring activities cover a wide range of ecological indicators and there was relatively little difference in the total number of votes allocated to each.

This ranking process differs somewhat from the later-released recommendation from the CEWO to prioritise monitoring activities based upon i) regional priorities, ii) the likelihood of demonstrating a response to Commonwealth environmental water, and iii) contribution to adaptive management. However, given the clear cut nature of the results, we did not attempt to re-rank the endpoints based on these considerations; we are confident that the outcome would have been the same. The rankings also agree closely with the subsequent CEWO rankings for further development of the monitoring program. The only exception to this was the ranking of Medium for Bank Condition after it received only 1 vote during our internal processes. With subsequent, co-investment from the Victorian Environmental Water Holder, Bank condition monitoring was included in the final monitoring program.

In 2018, a separate less formal ranking process was used to identify monitoring matters for inclusion in the additional winter monitoring. This took the form of an initial proposal followed by feedback from CEWO. It is not detailed further.

4.1.3 Final monitoring program, which focusses on Zone 2

The costs for implementing the six highest priority monitoring activities plus hydrology in Zones 1 and 2 still far exceeded the indicative budget (initial estimate was \$4.7M). Our project team discussed how the program could be modified to further reduce costs and unanimously agreed that we would prefer to restrict monitoring to a single Zone than omit high-priority monitoring activities. We felt that retaining a range of indicators but restricting monitoring to a single zone would deliver the following benefits:

1. Monitoring a wide range of indicators would provide a thorough and integrated assessment of the effect of environmental flows especially if multiple indicators were monitored at the same sites. This approach will allow results from one monitoring activity to inform the analysis and interpretation of other monitoring activities and is in keeping with the physical and biological links between different components of riverine ecosystems (see Figure 4-1). For example, measuring stream metabolism and the distribution and quality of slackwater habitats under different flow conditions are particularly relevant to macroinvertebrate and larval fish monitoring activities. Stream metabolism results will indicate whether there is enough energy in the foodweb to support an increase in fish and macroinvertebrate biomass and hydraulic model outputs will indicate whether suitable nursery habitats persist for

long enough and at the right time to allow fish eggs and larvae to develop and to support different macroinvertebrate species. Monitoring that detects changes in macroinvertebrate biomass as a result of particular environmental flows may also help to explain observed changes in fish community composition and growth rates throughout the LTIM Project.

2. If the number of monitoring activities were reduced it is likely that the program would end up focussing primarily on fish because environmental flows in the lower Goulburn River are primarily delivered to improve native fish communities. Having such a narrow focus represents a significant risk to the CEWO because if monitoring fails to detect any response by fish to environmental flows in the lower Goulburn River it will be difficult to argue that the investment in environmental flows has been worthwhile. Monitoring a suite of indicators will help to explain null responses and will also increase the probability of detecting intended benefits of environmental flows.
3. Finally, as a group we philosophically support the idea that it is better to monitor things well in a small number of locations than spread the effort too thinly across many areas. Too often, token monitoring activities are repeated in many river systems because organisations do not have the funds to implement a proper monitoring program and because many river managers want monitoring in their particular river system. The result of such an approach is that none of the programs manage to effectively answer their stated questions and the monitoring effort will have been wasted. If resources are pooled to ensure monitoring is done well in a small number of areas then the results will be more conclusive. Those results can then more readily be extended to other areas where monitoring was not conducted.

In subsequent negotiations, the CEWO supported our proposal for comprehensive monitoring of nine indicators in the lower Goulburn River, but only in Zone 2 (see Table 4-3). In addition to hydrology, we will monitor adult and larval fish, fish movement, hydraulic habitat, ecosystem metabolism, macroinvertebrate diversity and abundance (including macroinvertebrate emergence), vegetation diversity, and bank condition. We selected Zone 2 because that is where most of the previous fish surveys have been done, it is where the greatest amount of Golden Perch spawning has been detected, and it is closer to other fish populations in the Murray River, Edward Wakool and Murrumbidgee River systems.

There is a strong conceptual argument for monitoring the full suite of endpoints, beyond the points listed above. Figure 4-1 shows how the different selected monitoring activities will complement each other in telling the 'story' of environmental flows in the lower Goulburn River. Results for monitoring endpoints at higher trophic levels (fish) may only be interpretable with knowledge of how responses at lower trophic levels have responded to changes in flow regime. Accordingly, we propose to monitor hydrology, physical habitat (2D hydraulic models and bank condition), vegetation diversity, fish larval surveys and stream metabolism at the same sites in Zone 2 so that data from one monitoring activity can inform the analysis and interpretation of other components.

Macroinvertebrate monitoring will also be conducted at one of the main monitoring sites in Zone 2. The macroinvertebrate evaluation questions will mainly focus on short-term responses to spring or early summer high flow events. Because we will be using artificial substrates, and because flow patterns should be reasonably consistent within each Zone of the lower Goulburn River, we do not expect to see much variation between sites within individual Zones. To save costs, we therefore will only monitor macroinvertebrates at one site in Zone 2. However, we will monitor macroinvertebrates in the lower reaches of the Broken River as well to control for any confounding effects of season, flow and water temperature. One of the main hypotheses that will be tested in the macroinvertebrate monitoring program is whether freshes in late spring or early summer increase the biomass of macroinvertebrates. The timing of these flows coincides with an increase in water temperature and general biological productivity so we would expect to see an increase in macroinvertebrate biomass at that time regardless of whether particular flows are delivered. The Goulburn Broken CMA also manages environmental flows in the Broken River and can adjust the timing of flows to ensure that high flows are not delivered in both rivers at the same time. Comparing changes in macroinvertebrate biomass in the Goulburn River before and after managed flows against changes in macroinvertebrates in the Broken River over the same time period without managed flows will provide a reliable indication of the contribution that flows make to macroinvertebrate biomass

Co-investment from the Victorian government (Department of Environment and Primary Industries and the Victorian Environmental Water Holder) means that we can also include fish movement and bank condition in the monitoring program, despite them being rated a lower priority than other monitoring activities. The costs of fish movement monitoring are relatively small, especially if only Golden Perch are targeted, because tags can be inserted into fish that are caught during the annual adult fish surveys, and fish movement recorders are already in place at various sites in the lower Goulburn River and nearby sections of the Murray and Edward Wakool Rivers. Similarly, the costs for bank condition monitoring also will be relatively low if it is linked to vegetation diversity monitoring. With these

considerations, and with the extra co-investment from Victoria, the CEWO has agreed to fund the remaining costs of these activities.

A detailed schedule of the proposed monitoring plan is provided in Section 4.3 and detailed costs are provided in the accompanying budget spreadsheets.

Table 4-3: Overview of monitoring activities proposed for the lower Goulburn River. Activities are concentrated in Zone 2 to address the highest priority evaluation questions for the lower Goulburn River, but some activities extend into Zone 1.

Monitoring activity	Category	Zones	No. sites per zone	Rationale for inclusion
Hydrology	I	1&2	2 + 3 + 1	Accurate flow data is critical for all aspects of the M&E Program. Flow data are also required for the lower Broken River to inform the Macroinvertebrate analysis
Fish (River)	I	2	10	Would be good to do in both zones, but it is not feasible given the costs associated with implementing the prescribed Standard Methods. Zone 2 was chosen because it has the greatest abundance of Golden Perch and populations in this zone are likely to have greater connection and exchange with populations in the Murray River and other nearby systems.
Fish (Larvae)	II	1&2	1 + 3	A high priority focus for the Goulburn River. Monitoring will target both zones because nursery habitats are likely to vary between each zone. However, given the considerable expense of larval sample sorting, there will only be a single monitoring site in Zone 1.
Fish (Movement)	II	1&2	NA	Fish may be caught from any zone, but listening stations have already been established throughout the lower Goulburn River and other nearby systems to record any tagged fish.
Vegetation diversity	II	2	2	This monitoring will quantify short term and long term changes in vegetation communities on the river bank. We recommend that it be conducted in both Zones to cover a wide range of channel forms that are present in the lower Goulburn River. The sites should be the same as have been used for the VEFMAP and Commonwealth Short-term monitoring program to capitalise on previous data.
Macroinvertebrates	III	2 + Broken	1	Macroinvertebrate monitoring should also be conducted in both Zones to properly characterise responses throughout the lower Goulburn River. We also recommend monitoring a site in the Broken River to control for potential confounding effects between flow, season and water temperature.
Stream Metabolism	I	1&2	2	Stream metabolism measurements will quantify the energy flow in each system and will inform interpretation of all biological monitoring results. It should therefore be conducted in each Zone where biological monitoring is proposed.
Physical habitat (2D Hydraulic Model)	III	1&2	2	Although not identified by the M&E Advisor as a critical indicator for evaluating the effect of environmental water delivery, the importance of flow induced changes to physical habitat are made explicit in the LTIM Project Cause Effect Diagrams. Measuring changes in hydraulic habitats as a result of environmental flows will determine whether the delivered flows have had their intended effect and will help the interpretation of any biological monitoring results. Two dimensional models should be developed in both Zones to support biological monitoring.
Physical habitat (Bank Erosion)	III	1&2	2	There is concern that environmental flows are contributing to bank erosion in the lower Goulburn River. Moreover, the rate of bank erosion at a particular site is likely to influence riparian vegetation responses to environmental flows. Bank erosion should be conducted at the same sites as Vegetation Diversity monitoring.

4.2 Activities extended to Zone 1

Some monitoring activities will also be extended into Zone 1. These are 'high' priority activities (Table 4-2), with the exception of the annual fish community surveys. For this activity, there are no economies of scale (i.e. the number of trips would need to be doubled), and the costs associated with monitoring 10 sites per Zone plus additional surveys to collect otolith samples are too great to implement in both Zones. Hydrology, stream metabolism and hydraulic habitat

monitoring in Zone 1 will be a replication of the Zone 2 program. The additional cost for each option is less than the single zone equivalent program, because we are able to take advantage of economies of scale, particularly with regards to the mobilisation costs of sampling trips. Fish larvae will also be monitored in Zone 1, but due to the high cost of this activity (particularly because we will be using a sampling intensity greater than that required by the standard method), we will include only a single site in Zone 1.

The medium priority activities, fish movement and bank condition will also be monitored in Zone 1. Fish movement has only been costed as a 2-zone program; there is no saving by restricting monitoring to Zone 2 only. The monitoring stations are already largely in place, and all stations in both zones can be visited during a 2-day trip to download data.

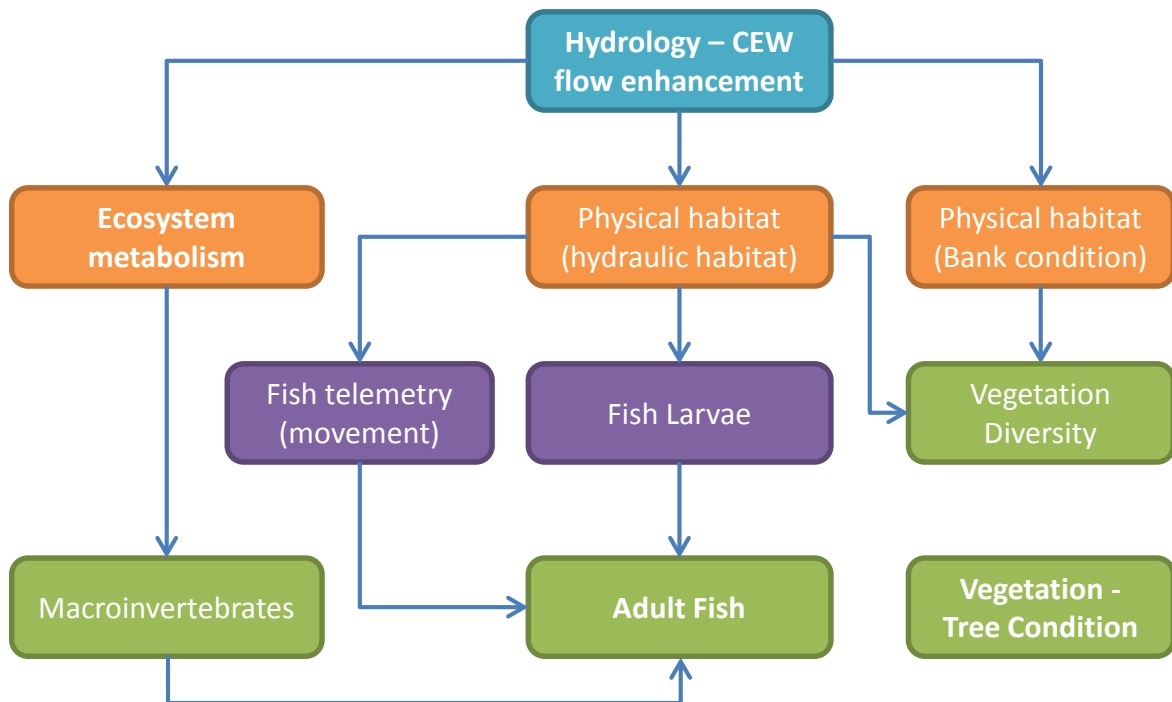


Figure 4-1: Conceptual linkages among components of the proposed core monitoring program. Boxes are monitoring activities and arrows are the linkages among them. Category I activities are printed in bold typeface. Blue box is the system pressure – enhancement of flow regime through CEW. Orange boxes are proximate effects of CEW on physical habitat and ecosystem function, all of which are needed to understand biotic responses. Purple boxes are intermediate biotic responses, needed to understand the ultimate biotic responses. Green boxes are the ultimate biotic responses, which are generally the focus of Basin Plan evaluation questions. Note that there is no conceptual linkage from CEW to Vegetation Tree Condition in the lower Goulburn River, as CEW will not be used to inundate the floodplain. Because of this, and although it is included in this diagram, it is not included in the final monitoring program.

4.3 Rationale for including or excluding each monitoring discipline

This section provides more detailed arguments for the inclusion of the particular monitoring activities for the lower Goulburn River Selected Area. All monitoring activities are included here.

4.3.1 Hydrology

There are five established flow gauges in the lower Goulburn River that provide high quality data over a long period and have good rating curves. The gauges at Goulburn Weir and Murchison provide good information about flows in Zone 1, and the gauges at Loch Garry and McCoys Bridge provide good flow information for Zone 2. The fifth gauge is at Shepparton, which is close to the boundary between Zone 1 and Zone 2 and can be used to check flow conditions and assumptions for either Zone. An additional established gauge in the lower Broken river will be used to provide flow data for the macroinvertebrate analysis.

Reliable daily and instantaneous flow records are critical to determine whether the environmental water released from storages meets the target flows throughout the river. These hydrological data are critical to analysing the results of all of the biological and physical monitoring activities that are proposed in this M&E Plan. The existing flow gauge network in the lower Goulburn River and the small number of large tributaries that flow into it, provide a reliable measure of flow at

most points along the river from Goulburn Weir to the Murray River and therefore meet the hydrological monitoring requirements for the LTIM Project. We therefore do not propose to establish new gauges. This decision saves monitoring costs that can be used for greater benefit on other monitoring activities and also means that we will have reliable historical flow data for each of our monitoring zones as well as access to new data from the start of the monitoring program. If new flow gauges were needed, we anticipate that it would take several years to establish reliable rating curves and therefore reliable data may not be available until the middle or near the end of the monitoring program.

The Victorian Environmental Flows Monitoring Assessment Program (VEFMAP) developed one-dimensional hydraulic models at four sites in the lower Goulburn River. Models have been developed for sites at Moss Road and Darcy's Track in Zone 1, and at Loch Garry and McCoys Bridge in Zone 2. The models for both Zone 1 sites and the McCoys Bridge site can be adopted as they are, but the model for the Loch Garry site will need to be amended to better account for an active anabranch in the middle of the modelled area. An older hydraulic model is also available for the Goulburn River at Wyuna (downstream of McCoys Bridge). However the model was developed prior to the 2010 floods and will not account for any morphological changes that occurred during those floods. Moreover, water levels at the site are potentially influenced by backup water from the Murray River under certain flow conditions. For these reasons we do not propose to use the Wyuna model as a primary input to the current monitoring program.

The hydrological monitoring budget includes staff time to convert continuous hydrograph records into summaries of particular flow components (e.g. days per year of discharge over / under a certain threshold, number of flow events over a threshold value, etc.). These flow components will be determined as part of the evaluation procedures, and are more useful for assessing ecological effects of environmental flows than are raw flow series

4.3.2 Fish (annual adult surveys of river populations, larval surveys and movement)

Supporting native fish populations is a key element of the Basin Plan's goal to protect biodiversity. The Goulburn River supports a diverse native fish fauna with high conservation and recreational angling value. Species of conservation significance include Trout Cod, Murray Cod, Silver Perch, Golden Perch and Freshwater Catfish. Conservation of the fish fauna of the Goulburn River has been recognised as a high priority by fisheries management and natural resource management agencies (e.g. GERFMP 2002; GBCMA 2004). In particular, the provision of environmental flows to support native fish populations has been identified as a key environmental watering objective for the Goulburn River (Peter Cottingham & Associates and SKM, 2011). Indeed, in terms of Commonwealth water being invested for environmental objectives, flow allocation for native fish represents a major investment of water (e.g. 58 GL for fish habitat maintenance, 138 GL for fish breeding/movement). Given this investment, it is critical that the LTIM Project evaluates the effect that CEW has on native fish populations in the lower Goulburn River. Quantifying relationships between fish populations (e.g. abundance, distribution, population structure) and environmental flows in the lower Goulburn River will help the GBCMA adaptively manage environmental flows in the Goulburn River and support decisions regarding environmental flows for fish throughout the Murray-Darling Basin.

The proposed fish monitoring will build on 10 years' worth of monitoring and research assessing the status of fish populations in the Goulburn River (Koster et al. 2012) as well as monitoring undertaken since 2006 as part of the Victorian Environmental Flows Monitoring and Assessment Program. When complete, the Goulburn River fish LTIM Project will represent one of the longest continuous sets of fish monitoring data collected in the Murray Darling Basin. Moreover, it will cover a wide range of climatic conditions including record drought, record floods and a major blackwater event that contributed to widespread fish kills. The next five years' monitoring will be particularly important in assessing the ongoing recovery of fish populations from those extreme disturbances.

The Goulburn River fish LTIM Project is also crucial to informing and interpreting the results of monitoring in other areas of the Basin. Golden Perch have the capacity to disperse throughout the Basin and there is potentially a high level of connectivity between population in the lower Goulburn River, lower Murray River, Edwards-Wakool system and Murrumbidgee River. Co-ordinated monitoring across these four regions may be used to assess the influence environmental flows in one area (e.g. spawning in the Goulburn River) have on fish populations in other areas (e.g. recruitment in lower Murray).

The fish monitoring program will include annual adult fish surveys, larval survey and an assessment of fish movement. The three methods complement each other, and including all three will significantly increase the number of evaluation questions and associated research questions that can be answered through the program. The arguments for including each fish monitoring activity are presented below

Annual adult fish surveys

Annual fish surveys in the river channel is a Category I monitoring activity that will provide critical information for the Basin-scale assessment. When added to the existing fish survey data for the lower Goulburn River it will provide a record of how the fish community has changed over a period of 15 years and how those changes relate to river flow. Moreover annual surveys will help to determine whether fish spawning (detected through larval surveys) or fish movement that may be triggered by environmental flow releases result in successful recruitment.

A Standard Operating Procedure for Fish (River) assessments is presented in Appendix A.

Larval fish surveys

The larval surveys for the lower Goulburn River will collect larvae of all fish species, but will be designed more specifically to detect Golden Perch spawning. Golden Perch is one of only two fish species (along with silver perch) in the Murray Darling Basin thought to require increased discharge to initiate spawning. Indeed, environmental flows in the Goulburn River are explicitly used to promote spawning and recruitment of Golden Perch (Peter Cottingham & Associates and SKM, 2011) and, as part of environmental water delivery for the Goulburn River, one of the key flow objectives is to deliver freshes to promote the spawning of Golden Perch (Peter Cottingham & Associates and SKM, 2011).

The annual adult fish surveys can be used to identify any young-of-year Golden Perch in the lower Goulburn River, but given Golden Perch can move long distances, direct larval surveys are required to determine whether high flows released into the lower Goulburn River actually trigger fish spawning.

The larval fish program will build on and add to an existing 10 year data set monitoring the spawning responses of fish to flows in the Goulburn River (Koster et al. 2012) and will represent one of the longest continuous sets of larval fish data collected in the Murray Darling Basin. Relatively few spawning events have been recorded in the lower Goulburn River to date. That is mainly thought to be due to the lack of large flows during the drought. A managed flow release in spring 2013 (which used Commonwealth environmental water) triggered the most significant Golden Perch spawning event that has been recorded in the lower Goulburn River in recent years and ongoing monitoring as part of the LTIM Project should aim to more reliably determine the specific timing, magnitude and duration of flows that are needed to trigger significant spawning events. That information can then be used to help the Goulburn Broken CMA actively manage environmental flows in the future.

The larval fish program will also inform and complement monitoring in other Selected Areas. Fish have the capacity to disperse throughout the Basin and there is potentially a high level of connectivity between regions, particularly the Goulburn, lower Murray, Edwards-Wakool and Murrumbidgee rivers. That connection means that environmental flows in one area (e.g. spawning in the Goulburn River) has the potential to strongly influence outcomes in other areas (e.g. recruitment in lower Murray). In other words, monitoring of fish spawning responses in the Goulburn River may help to explain changes in recruitment and abundance in other selected areas. Thus, the Goulburn River larval fish LTIM Project will contribute to a comparison and contrast of spawning and recruitment responses of Golden Perch at sites across much of the Murray Darling Basin, thereby informing Basin-level responses.

A Standard Operating Procedure for Fish (Larvae) assessments is presented in Appendix A.

Fish movement

Biotic dispersal or movement is critical to supporting connectivity of native fish populations, which is a key element of the Basin Plan's goal to protect Ecosystem Function. In particular, movement within and between water-dependent ecosystems (i.e. connectivity) can be crucial for sustaining populations by enabling fish to recolonise or avoid unfavourable conditions. For some fish species, movement also occurs for the purposes of reproduction and therefore contributes to the Basin Plan's goal to protect Biodiversity.

The Goulburn River fish movement program will target Golden Perch and will build on the existing six-year acoustic telemetry project (currently funded by CEWO) monitoring movement of native fish in the Goulburn River and Murray River (Koster et al. 2012). While fish movement monitoring is considered a lower priority than the annual adult fish surveys and larval surveys, the cost of implementing it is relatively small given a network of tracking stations already exist throughout the lower Goulburn River and other nearby river systems. We therefore think it represents a good value for money monitoring investment.

The Goulburn River fish movement program will complement monitoring of fish movement proposed as part of the LTIM Project in the Murrumbidgee, Edward-Wakool and Gwydir rivers. In particular, it will enable a comparison and contrast of the movements of native fish at sites across much of the Murray Darling Basin thereby informing Basin-level responses.

The Goulburn River fish movement program will also be crucial to informing and interpreting the results of monitoring within the other selected areas. Fish have the capacity to disperse throughout the Basin and there is potentially a high level of connectivity between regions, particularly the Goulburn, lower Murray, Edward-Wakool and Murrumbidgee Rivers. Therefore the influence of environmental flows in one area has the potential to strongly influence outcomes in other areas. In other words, monitoring of fish movement within the Goulburn River might help to explain changes in fish abundance within other selected areas.

We have had discussions with fish discipline leads from the Lower Murray, Edward-Wakool and Murrumbidgee Selected Areas and agreed that the LTIM Project represents a unique opportunity to co-ordinate fish movement monitoring across all three areas. We will work with one or both of the other three Selected Areas (depending on whether they also get funding) to ensure compatible tracking equipment is used and to share data. We note that compatible tracking stations have already been established in the lower Goulburn, Edward Wakool and Murrumbidgee Rivers as part of other research programs. We will specifically investigate whether individual Golden Perch move between any of these four selected areas over the course of the LTIM Project and consider whether particular flow events triggered or facilitated that movement.

A Standard Operating Procedure for Fish (Movement) assessments is presented in Appendix A.

4.3.3 Vegetation diversity

Riparian and aquatic vegetation underpins aquatic systems by: (1) supplying energy to support food webs, (2) providing habitat and dispersal corridors for fauna, (3) reducing erosion and (4) enhancing water quality. In the Goulburn River drought and floods have reduced the quantity, quality and diversity of riparian bank vegetation over the last 10-15 years. However, minimum summer and winter low flows and periodic freshes are recommended to help rehabilitate and main riparian vegetation along the lower Goulburn River. The recommended flow components shape aquatic plant assemblages by influencing (1) inundation patterns in different elevation zones on the bank and hence which plants can survive in each zone; (2) the abundance and diversity of plant propagules dispersing in water; and (3) where those propagules are deposited and germinate.

Vegetation diversity has been monitored at four sites in the lower Goulburn River every two years since 2008 as part of the Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP), and has been assessed for the Commonwealth Short Term Monitoring Project. Including vegetation diversity monitoring in the LTIM Project for the lower Goulburn River will extend those data sets and allow the effect of different flow components to be assessed in wet and dry climatic conditions. The results will be used to identify what flows are needed to maintain or rehabilitate riparian vegetation in the lower Goulburn River depending on its current condition and state of recovery. The results will also be used to broadly inform appropriate water management in other systems recovering from extreme events.

Through discussions with other M&E Providers, we understand that the lower Goulburn River is one of the only Selected Areas where vegetation diversity monitoring on the river banks will occur. Most other Selected Area teams are focussing on vegetation responses in wetlands. Given that environmental flows in the lower Goulburn River are being specifically used to water bank vegetation and the fact that bank vegetation is unlikely to be monitored elsewhere, we think that it will be important to include this monitoring activity in the program.

Vegetation diversity monitoring in the lower Goulburn River will be greatly enhanced by complementary monitoring such as two dimensional hydraulic modelling and bank condition. In the Goulburn River it is likely that at some locations vegetation will fail to re-establish despite the provision of Commonwealth environmental water due to the steepness of the bank, bank erosion and bank failure. Monitoring bank condition will allow us to adjust the expectation of the effect of environmental watering based on local conditions. Similarly, developing 2D hydraulic models will allow us to understand the role local flow velocities play in plant re-establishment and to assess what portion of the bank experiences conditions suitable for re-colonisation.

Monitoring vegetation diversity over five years will also provide an opportunity to develop student research projects to address related questions. Such projects would be funded separately from the CEWO budget, but could use the data and provide results that will help the overall LTIM Project. Potential projects include:

- An investigation of how vegetation responses to environmental watering are affected by:
 - Bank slope;
 - Soil compaction, soil type, and soil moisture;
 - Availability of soil and aerial seed banks;

- The degree of synchronicity between flow events and seasonal patterns of propagule dispersal; and
- Site features that favour the deposition and retention of water dispersed propagules.
- An assessment of whether water regimes required to re-establish vegetation communities differ from those required to maintain established plant communities.

A Standard Operating Procedure for Vegetation Diversity is presented in Appendix A.

4.3.4 Macroinvertebrates

One objective within the SEPP Waters of Victoria is to ensure that Victorian rivers have a diverse fauna. Environmental flows can help achieve this target. In addition to their inherent value, macroinvertebrates are an important source of food for fish and other vertebrates and therefore it is important to know whether these events increase macroinvertebrate biomass. Understanding the effects of environmental flows on macroinvertebrates has been thwarted by their high spatial and temporal variability in streams and the use of Rapid Bioassessment methods that are unable to measure important variables such as abundance. The newly developed protocols produced by CEWO, and revised for inclusion in this proposal, reduce spatial variability and provide information on abundance on artificial substrates. This will provide an unprecedented opportunity to measure the benefits of flows on macroinvertebrates at a local scale.

In addition to macroinvertebrate diversity and abundance, we will examine macroinvertebrate emergence. The project will use a method of sticky traps to collect emerging insects at the main macroinvertebrate monitoring sites. The traps will be set before, during and after planned environmental flow releases to determine whether specific flows trigger certain aquatic macroinvertebrates to emerge from the water and mate. We will implement this complementary program in the lower Goulburn River and investigate possibilities for implementing it in other selected areas. The results of the research could then be used to evaluate the effect of environmental flows on insect emergence in morphologically distinct river systems.

A Standard Operating Procedure for Macroinvertebrate assessments is presented in Appendix A.

4.3.5 Stream metabolism

Whole stream metabolism measures in-stream production and consumption of organic carbon (via monitoring dissolved oxygen) by the key ecological processes of photosynthesis and respiration. Healthy aquatic ecosystems need both processes to generate new biomass (food for invertebrates and fish) and to break down plant and animal detritus to recycle nutrients to enable growth to occur. Metabolism measurements allow us to examine and quantify the energy base underpinning aquatic foodwebs, and how this base is affected by flow regime. Such measurements are especially important when foodwebs are constrained by food supply. Rates of production and consumption that are too high indicate a likelihood of algal blooms or anoxia. Increased discharge will provide a new supply of nutrients and organic carbon that can stimulate metabolism. These nutrients and carbon may come from the floodplain or within channel benches and infrequently connected backwaters.

The LTIM Project provides a great opportunity to compare metabolic responses to flow in river catchments that have different flow regimes and different morphologies. We are particularly interested in comparing metabolic responses to flow in the lower Goulburn River with responses in the Edward-Wakool system which is proximally close, but will have lower baseline nutrient concentrations and much greater off-channel inundation at intermediate flows. Exactly the same method and data analysis will be performed in the Lower Goulburn and Edward-Wakool Selected Areas enabling comparative assessment between both catchments, but a final decision as to whether to undertake such a cross-system analysis within this project will be delayed until the form of basin-scale evaluation of stream metabolism becomes clear. Assoc. Prof. Mike Grace is the domain expert for stream metabolism in both catchments and is ideally placed to oversee the monitoring and interpret results between the Lower Goulburn and Edward-Wakool selected areas.

A Standard Operating Procedure for Stream Metabolism is presented in Appendix A.

4.3.6 Two dimensional hydraulic model development

Hydraulic conditions (velocity and depth), rather than flow volume, are arguably the most important determinants of fish and macroinvertebrate population dynamics. These relationships are made explicit in the Cause and Effect Diagrams presented in MDFRC (2013), and interactions between stream form and flow magnitude are likely to be the main reason why similar flow regimes have different environmental outcomes in geomorphically different rivers. For example, slackwater habitats have been shown to be important nursery areas of fish larvae and juvenile fish, and are also areas of high productivity for zooplankton and some macroinvertebrates. Flows that maximise the quality and quantity of

slackwater habitats at critical times in a particular river system are most likely to trigger a significant ecological response. Measuring changes in the distribution and quality of hydraulic habitats under different flow conditions is therefore critically important in determining whether specific flow management actions are providing the conditions required for an intended ecological outcome. Such information will improve the interpretation of ecological monitoring results. Specifically they will increase our ability to attribute good ecological outcomes to the delivery of Commonwealth environmental water and where relevant help explain why delivered water failed to achieve its intended ecological outcomes.

Two-dimensional hydraulic modelling can quantify the relationships between flow and physical habitat in a particular river reach and is the most efficient way of assessing how Commonwealth environmental water delivery affects physical habitats. Model results can be used to produce habitat rating curves that can be used to predict the quality, quantity and distribution of specific hydraulic habitats under a wide range of given flow magnitudes.

Building 2D hydraulic models at representative sites in the lower Goulburn River selected area will:

1. Enable the benefit of all types of Commonwealth environmental water deliveries to be determined,
2. Provide evidence of how Commonwealth environmental water supports ecological values (e.g. Ecosystem diversity objectives),
3. Produce explanatory variables for population dynamics (e.g. retention of larval and juvenile fish) thereby reducing risks of 'false negatives', and
4. Allow adaptive management of Commonwealth environmental water delivery patterns to better support ecological objectives.

Hydraulic habitat, as recommended for the lower Goulburn River, is also proposed for the Edward-Wakool system (Physical Habitat lead Robyn Watts). The outputs from that system will enable comparison of the perennial, relatively stable flow of the Goulburn River with the ephemeral and relatively flashy flows of the Edward-Wakool. Both systems provide important habitat for fish species such as Murray Cod and Golden Perch so modelling and measuring changes to hydraulic habitat under different flow conditions will allow us to explicitly link the effect of flow related habitat changes to population dynamics.

A Standard Operating Procedure for the development of two dimensional hydraulic models is presented in Appendix A.

4.3.7 Bank condition

The bed and banks of a river channel translate the discharge provided through the channel into the physical habitat available to fish, macroinvertebrates and plants (i.e. the velocity of flow, depth of water and sediment that provides the conditions for biota). Bank condition and its influence on vegetation is directly linked to flow delivery, as has been recently demonstrated in the Goulburn River through the CEWO short term monitoring program. Not quantifying this link is a risk to demonstrating the benefits of Commonwealth environmental watering, particularly when vegetation responses are influenced by erosion.

Erosion pins and qualitative measurement of bank condition can be easily paired with vegetation monitoring and will complement monitoring underway throughout the Victorian section of the Basin. Understanding the relationship between flow regulation and bank condition may enable greater explanation of biotic responses (or lack thereof) to Commonwealth environmental water at both the local and Basin-scale, and inform adaptive management.

We will also conduct visual monitoring along the Goulburn River to assess the relationship between environmental flow management and bank condition. In conjunction with erosion pin monitoring for the banks of the Goulburn River (proposed for the LTIM Project) this will provide qualitative and visual evidence of changes to banks, and the role this plays in the propagation and establishment of bank vegetation following environmental flow deliveries. The repeat cross sections provided by VEFMAP will also provide ongoing value to determining channel change in the Goulburn River and for comparison with change in other systems in the basin where repeat survey is undertaken (e.g. Edward Wakool).

A Standard Operating Procedure for the bank condition monitoring is presented in Appendix A.

4.4 Monitoring schedule

The proposed monitoring schedule for the LTIM Project in the lower Goulburn River is presented in Table 4-5. Proposed sites are also detailed here. The monitoring schedule indicates planned monitoring. Unexpected events such as floods, blackwater events or prolonged drought may cause us to revise the schedule. For example, if floods drastically alter

vegetation cover on the river banks then we may need to conduct an unscheduled vegetation diversity survey to quantify those changes and establish a new baseline for subsequent assessments. We do not have enough budget to conduct additional monitoring, but can substitute a scheduled sampling event for an unscheduled sampling event. If a significant unexpected event occurs, we will convene a meeting with the Discipline Leads to discuss potential implications and decide on any required amendments to the monitoring schedule. We will invite representatives from the M&E Advisor and the CEWO to attend that meeting and will seek approval from the CEWO before implementing any amendments to the monitoring schedule, and or transferring monitoring budget from one discipline to another.

A detailed monitoring schedule will be prepared every year as part of the annual monitoring plan. That plan will include any agreed amendments to the proposed schedule and also provide greater detail about the timing of particular monitoring activities such as larval fish sampling, which will be timed to occur before during and immediately after specific environmental flow releases.

5. Evaluation

5.1 Basin-scale evaluation

We will supply data as required to be used in the Basin-scale analysis as outlined in the Evaluation Plan. Furthermore, we will use the results of Basin-scale evaluation to inform statistical analysis of Area-level data for future years (see below).

5.2 Area evaluation

Evaluation of data from the Goulburn River LTIM Project will mainly be conducted through the University of Melbourne. Analyses will be centred on the 1 and 5-year evaluation questions described above. The use of standard approaches to statistical analysis (although the individual analyses will most certainly differ) will provide consistency of results format and reporting among the different evaluation questions. The centralized approach to data analysis and evaluation will also provide an opportunity to consider results holistically in order to give an overall high-level assessment of the effect of Commonwealth Environmental Water in the lower Goulburn River.

5.2.1 Statistical analysis

Statistical analyses of the monitoring data will centre on describing continuous relationships between flow regime, physical habitat, and associated ecological response. These three components can be considered the middle steps of a DPSIR (Driver-Pressure-State-Impact-Response) model of environmental the interaction between human society and the environment (EEA 2007). In general, for the Murray-Darling Basin, river regulation is the driver of the system, the altered flow regime the pressure, altered physical habitat the State, which Impacts upon the biota. Environmental flow regimes are the Response that seek to mediate either or both of the Driver and Pressure, or directly improve the State (Figure 5-1). The framework equally applies to a restored flow regime (with CEW) being a positive 'Pressure' on the system, leading to positive Impacts on the biota, which is the nature of the relationships described in the Cause Effect Diagrams for the LTIM Project.

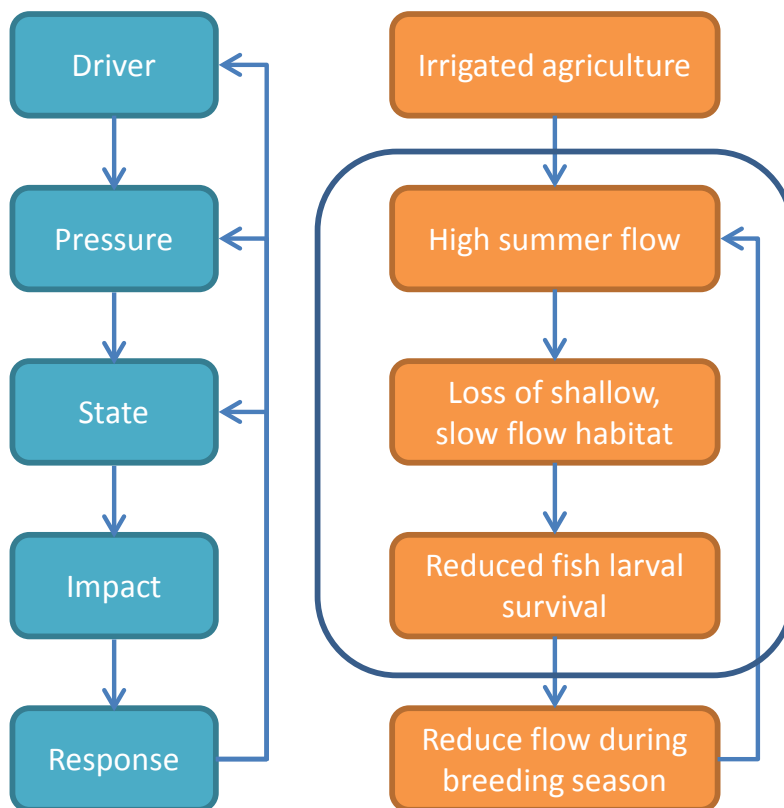


Figure 5-1: Impacts of flow regulation and restoration of flow regimes fits the Driver-Pressure-State-Impact-Response (DPSIR) framework for reporting environmental issues. Orange elements provide an example of the DPSIR system relevant to the lower Goulburn River, with the specific management response (reduced flow during fish breeding system) intended here to target the Pressure of 'high summer flow'. Our statistical analysis will focus upon the boxed section of the diagram, linking Pressure (flow regime) to State (Physical habitat) and Impact (Ecological condition), both in terms of the degraded flow regimes, and ecological benefits of the management Response.

We will primarily seek to use Bayesian statistical approaches to analyse the monitoring data. Bayesian approaches have proved very successful for analysing data collected under the Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP) (Webb *et al.*, 2013), and have also successfully been used in CEWO short-term intervention monitoring in the Goulburn River in 2012/13. Project Leader Webb has pioneered the use of Bayesian approaches for analysing environmental flows data (Webb *et al.*, 2010), and has a growing international reputation for this.. He demonstrated that Bayesian approaches are well suited to dealing with the ‘experimental design’ problems that beset analysis of environmental flows monitoring data. Such problems include a lack of before/after contrasts, and difficulty with finding true control systems for the large and unique rivers being evaluated. Low replication further reduces the statistical power of analyses to detect important effects. Bayesian statistical analyses can reduce the impact of many of these problems. See Webb *et al.* (2010) for a non-technical explanation of this. He will lead this activity, with assistance from the University of Melbourne Research Assistant.

Bayesian approaches are inherently flexible, and can combine data and information from multiple sources to strengthen the conclusions that can be gained from monitoring data (McCarthy and Masters, 2005). Here, we may be able to use previously-collected data and/or other information from research and monitoring in the lower Goulburn River to create ‘informative prior probability distributions’ for the statistical analyses. An informative prior distribution means that estimates of parameters in statistical analyses are less uncertain than they would have been if they were parameterized using monitoring data alone. We will also be able to use the results of the Basin-scale evaluation for this purpose (e.g. use the Basin-scale evaluation results from 2014/15 to inform Area-level analysis of 2015/16 data). These various sources of information additional to the monitoring data will reduce uncertainty in conclusions drawn from statistical analyses. In the VEFMAP work, we have used formal expert elicitation to develop prior probability distributions, and the resulting models have been far stronger than those informed only by monitoring data (Webb *et al.*, in review).

Another feature of this ability to employ prior information is that statistical analyses can be used to assess cumulative effects as more years of data become available. For example, if an analysis is structured to incorporate one years’ worth of data, then the first year of analysis could employ ‘minimally-informative’ prior distributions. In the second year, the analysis results from year 1 could be used as the prior distribution, and updated with the new data, and so on. Such an analysis is likely to gain greater precision and hence more precise predictive ability (see below) over time. Alternatively, analyses can be structured to incorporate multiple years of data simultaneously.

We believe the use of Bayesian analyses will also be a useful input to Basin-scale evaluation in its own right. Statistical analysis of basin-scale data may use Bayesian analysis (M.J. Stewardson, Monitoring Adviser, pers. comm.), and the code developed for the Goulburn River analyses will be a useful starting point / input to such analyses

The flexibility of Bayesian models also allows us to model the counterfactual scenario necessary to answer the evaluation questions. There is no control river for the Goulburn River, and data have not been collected prior to the implementation of environmental flows. Thus we cannot use a factorial comparison of monitoring data to assess the ecological benefits of Commonwealth Environmental Water. Using the fitted Bayesian models, we can make quantitative predictions of what would have been seen under different flow scenarios (e.g. no environmental water, partial allocations, full allocations) and compare these to answer the evaluation questions. In a non-replicated system such as the Goulburn River (and indeed the majority of the Selected Areas), there is no other way to reach strong conclusions regarding the evaluation questions.

However, the flexibility of Bayesian statistical analyses also means that they can become complicated. Communicating the results of such analyses can be challenging. In research associated with the VEFMAP program, we have been using parameterized Bayesian models to make predictions of what ecological response will be seen under different flow scenarios. These predictions are driven by the monitoring data (as well as the prior probabilities described above. They thus provide a robust indication of what will be seen under different flow regimes, and do not require an understanding of model structure and complexity for one to understand the results (e.g. Figure 5-2). This allows managers and other end-users to focus upon the implications of model results rather than struggling to understand them.\

5.2.2 Specific proposed analyses

Table 5-1 below provides a summary of analyses expected for the evaluation questions listed above, along with major driving and covariate data, and where those data will be obtained. The majority of data will be sourced directly from our own monitoring program. Where this is not the case, we have excellent relations with potential data providers and are confident of obtaining data.

Table 5-1: Evaluation questions, probable type of statistical models, major driving data requirements, and where those data will be obtained from. We focus here upon the Area-Specific questions. The nature of statistical analysis means that this is a preliminary best estimate, and is likely to change as analysis proceeds.

Evaluation Question	Dependent variable	Independent variable (data source)	Analysis type
What did CEW contribute to the recovery of drought and flood affected riparian vegetation communities in the lower Goulburn River?	Cover and diversity measures of different vegetation functional groups on river bank	Inundation regime (hydrology discipline) Near bed flow velocity (2d hydraulic model) Erosion rates (Bank condition) Grazing pressure (Goulburn Broken CMA)	Non-linear response to inundation with additive effects of major covariates
How do vegetation responses to CEW vary between sites with different channel features and different bank condition?		Inundation regime (hydrology discipline) Channel bathymetry (2d hydraulic model) Erosion rate (Bank condition)	Similar model as above (probably simpler), but with extra explanatory variable of bathymetry to make the contrast
How does CEW contribute to germination and new growth of native riparian vegetation on the banks of the lower Goulburn River?	Abundance measurement of new growth of native species	Inundation regime (hydrology discipline) Grazing pressure (Goulburn Broken CMA)	Non-monotonic function (optimal at intermediate level) of inundation
How does CEW contribute to the maintenance and survival of new vegetation growth and new vegetation recruitment on the banks of the lower Goulburn River?	Similar to above, but not distinguishing native species. Functional groups used		
What did CEW contribute to the recruitment of Golden Perch in the lower Goulburn River?	Spawning data for previous season Electrofishing data	Flow summary statistics describing hydrological regime over the previous 12 months (hydrology discipline) Slackwater habitat over previous summer (2D hydraulic model)	Multiple linear model relating different aspects of flow regimes to Golden Perch recruits. Multiple years of data required
	Otolith data		
What did CEW contribute to Golden Perch spawning in the lower Goulburn River?	Abundance of eggs and larvae in drift samples	Discharge record (hydrology discipline) Water temperature (stream metabolism)	Logistic regression (threshold model) to identify critical discharge/temperature for spawning
What did CEW contribute to the survival of Golden Perch larvae in the lower Goulburn River?	Spawning data for previous season Electrofishing data	Flow summary statistics describing hydrological regime over the previous 12 months (hydrology discipline) Slackwater habitat over previous summer (2D hydraulic model)	Multiple linear model relating different aspects of flow regimes to Golden Perch recruits. Multiple years of data required
What did CEW contribute to the movement of Golden Perch in the lower Goulburn River?	Fish movement data	Discharge record (hydrology discipline)	Correlative analysis to assess flow conditions during major movement events
What did CEW contribute to macroinvertebrate diversity and biomass in the lower Goulburn River?	Macroinvertebrate richness Biomass of selected species	Discharge record over the two periods of sampling for macroinvertebrates (hydrology)	Difference in DV for impact site vs control modelled as a linear function of discharge between the two periods
What did CEW contribute to macroinvertebrate emergence and reproduction in the lower Goulburn River?	Sticky trap data	Discharge record before, during and after environmental flow event (hydrology)	Factorial comparison of the three periods, and assessment of whether this changes through time with different flow events
How does the timing and magnitude of CEW delivery affect rates of GPP and ER in the lower Goulburn River?	Ecosystem metabolism	Discharge record (hydrology) Water temperature (metabolism) Flow velocity (2d hydraulic model)	Multiple linear model in the first instance. This type of analysis has not been attempted before
How do stream metabolism responses to CEW in the lower Goulburn River compare to responses in the Edward Wakool System?			Similar model but with additional factor of the two river systems (sites nested within rivers)
How does CEW affect bank erosion in the lower Goulburn River?	Erosion pin measurements	Discharge data over period of pin deployment (hydrology) Near-bed flow velocity (2d hydraulic model) Bank reinforcement by vegetation (vegetation diversity)	Linear or threshold model relating discharge to erosion, with additive and categorical covariates

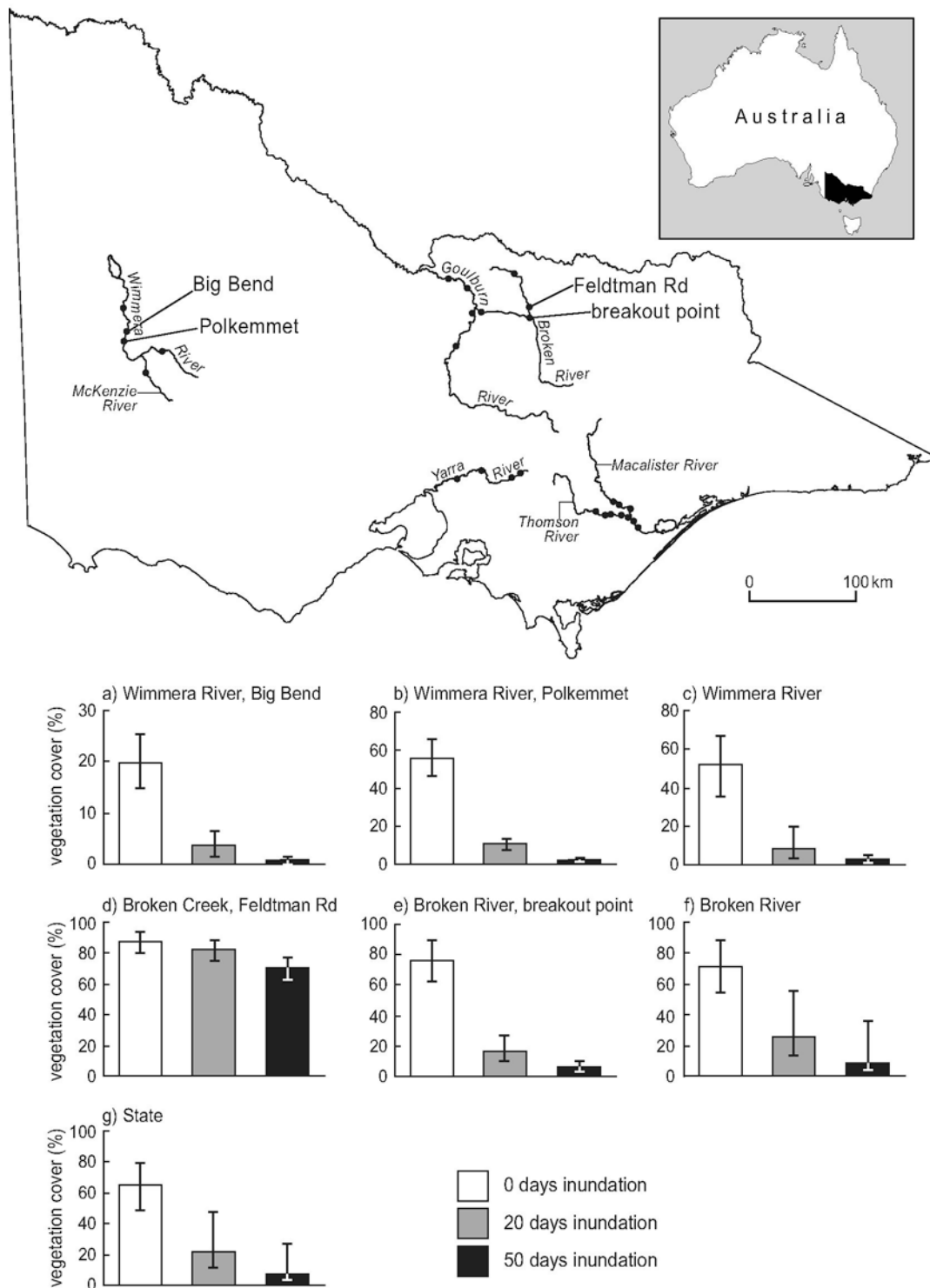


Figure 5-2: Simple ways of presenting results from a complex model. Bars are data-driven predictions of terrestrial vegetation cover in river channels subject to different durations of inundation during summer. Reproduced from Webb et al. (in review).

Overall, we have a strong belief that Bayesian analysis of the data generated by the Goulburn River Long-Term Intervention Monitoring Plan will maximise the value of the public funds invested in the collection of those data.

5.3 Program-level self-evaluation

In Sections 3 and 4, we have proposed a coherent program of monitoring, in which the different disciplines (e.g. fish) and activities (e.g. larval fish) complement each other to result in an overall assessment of the effect of Commonwealth

Environmental Water on the lower Goulburn River. It is important that this ethos is carried through to the collective evaluation of those data.

We will hold an annual meeting of the Goulburn River LTIM Project team to collectively consider the results of the previous year's monitoring and consider their implications holistically. Ideally, we will be able to draw a link between the effects of change in flow on primary productivity (stream metabolism) and habitat availability (physical habitat), and how this flows through to secondary production (macroinvertebrates) and the top predators (fish) (see Figure 4-1 in previous chapter). This holistic consideration may suggest changes to the statistical analysis and/or additional analyses. By the end of the project, we aim to produce a probabilistic model (Bayesian Belief Network) showing the quantitative links between the different disciplines and activities in the monitoring program. At the least, we will provide a descriptive model of the strength of linkages among the activities.

The meeting will take place after statistical analyses have been completed, but prior to the annual meeting with other Selected Areas and the CEWO. This timing will allow us to report on the 'story' of Commonwealth Environmental Water in the Goulburn River at the annual meeting of Selected Areas, and to include this information in the annual report.

As part of the statistical analysis of data from the different monitoring disciplines, and in concert with the annual meeting described above, we will review the sampling effort being used for the different activities (i.e. post-hoc power analysis). Sampling efforts for year 1 of the program have been set using directions from the standard methods or best available information. However, specific quantitative information (for activities where sampling effort was not dictated by a standard method) to allow us to assess sampling effort was only available for the assessment of vegetation species diversity. As data accumulate during the project, we will be able to conduct specific power analyses to assess the appropriateness of sampling effort. Three outcomes are possible. First, we find that sampling effort is appropriate, in which case we continue with the same level of sampling intensity. Second, we find that sampling effort is excessive, in which case we can reduce sampling effort for the activity and direct funds to other activities that may be underpowered. Third, we find that sampling effort is insufficient, in which case two responses are possible. First, we increase sampling effort using funds redirected from activities with excessive sampling effort. Second, if sampling effort is grossly insufficient, and few funds are available to increase effort, we abandon the activity and direct funds to activities that will then have sufficient statistical power to detect effects of Commonwealth Environmental Water. Such a re-direction of sampling effort would be a more efficient use of project funds than would be continuing a monitoring activity that had no chance of detecting a benefit. If our analyses suggest a change in sampling effort for any of the activities covered by Standard Methods, this will need to be negotiated in cooperation with the CEWO and other Selected Areas. The timing of these analyses, prior to the annual meeting of selected areas, provides an opportunity to do this. Overall, this annual (years 1-4 – there is no reason to do this in the final year) self-evaluation of the sampling program is consistent with principles of adaptive management sought by the CEWO.

6. Communication and engagement

6.1 External stakeholder engagement

6.1.1 Introduction

This communication plan details planned communication and engagement with parties outside of the LTIM Project. Those parties or stakeholders include environmental flow managers (i.e. CMA staff, CEWO, VEWH), environmental flow partners (i.e. CMA Board, G-MW, DEPi, MDBA), scientists and scientific organisations, river user groups (i.e. angling clubs, recreational users, tourism operators, irrigators, urban water authorities, Yorta Yorta Indigenous people) and the general public (i.e. landowners, government, education institutions). Each stakeholder group is likely to have different levels of interest in the LTIM Project and want different type of information and different levels of technical detail. This plan outlines how we will engage with the different stakeholder groups to seek input and disseminate information throughout the course of the LTIM Project.

6.1.2 GBCMA's role in the project

The GB CMA's strong partnerships, communication networks and tools mean that it is well positioned to contribute to:

- Building and managing effective partnerships with stakeholders with interests in Commonwealth environmental watering including relevant Indigenous groups.
- Communicating monitoring and evaluation results to local environmental watering groups interested stakeholders and, where appropriate the broader community in a clear, consistent and timely manner.

6.1.3 Key messages

Key messages will be developed in consultation with the CEWO and will be the foundation to the planned communication work. The key messages will facilitate interactions with the media, the public and with stakeholders. With the number of partners and individuals involved in the project the key messages will importantly ensure consistency and continuity of information. During the course of the project key messages maybe refined or new key messages developed.

6.1.4 Communication and marketing resources & tools

The range of communication channels available continues to evolve. The key point is that the right channel(s) are used to communicate the right message(s) to the right people.

Among the tools available to promote the program are:

- media releases – targeting local print, radio and TV media – traditional but effective – builds on well-established, credible and well-used existing information networks;
- case studies – ranging in length and technical detail to be used for media articles, reviews, reporting, program improvement etc ;
- websites – we will create an LTIM Project project website, most likely as a sub-page to the Goulburn-Broken CMA website, with content current and accessible. This website will also provide a point of contact for external stakeholders to contact the Monitoring Provider, for both positive and negative feedback on the monitoring program;
- events – tours for stakeholders and media; presence at expos and field days; “milestone events” such as celebrating the completion of projects; submissions and presentations at industry awards ceremonies and conferences;
- face-to-face and one-on-one gatherings – attending community events; partnership meetings; keeping advisory groups in the loop so they can advocate on the program's behalf out in the community; and speaking directly to politicians (particularly local MPs);
- direct letters and emails;
- advertising (e.g. dedicated monthly column in Country News);
- brochures and flyers; and
- social media (facebook, twitter etc) and e-newsletters.

6.1.5 Audience

This communication plan will target five key audiences (stakeholder groups). Existing environmental watering forums are a part of this audience, including:

- Goulburn and Broken environmental water advisory groups
- Goulburn Broken Regional Water Quality Meeting
- Goulburn Broken Wetland Management Group
- RiverConnect
- Wetland Working Group (State-wide network attended by CMAs, DEPI, VEWH and Melb Water)
- the Environmental Water Reserve Officer Network (State-wide network attended by CMAs, DEPI, VEWH and Melb Water)

What, why, when and how we communicate to these different audience groups needs to be tailored to meet their roles and interests in the monitoring program, as outlined in Table 6.1 below.

6.1.6 Action plans

An annual action plan will be developed for each of these five key audience groups. These will be internal documents, and are not intended to be submitted to the CEWO.

The annual action plans will detail:

- Specific messaging to suit the groups.
- Timing of events and activities.
- Responsibilities.
- Resources needed.
- Measures/outcome.
- Protocols and codes of conduct to be followed including the LTIM Project Code of Conduct.

6.1.7 Evaluation

A log of communication activities and results will be kept and reported to the CEWO, as part of the annual evaluation report. This information will inform an annual evaluation of the external communication plan and the development of the annual action plans.

Table 6-1: summary of proposed communication plan for external stakeholders

Aim	Who (Audience)	What (Information to be communicated)	Why (Purpose)	When (Timing & frequency)	How (Communication tools)
<p style="text-align: center;">↑</p> <p style="text-align: center;">Scientific enquiry and review</p>	Scientists and scientific institutions (CSIRO, Tertiary Institutions, MDFRC)	Methodology and results	To interpret and critique the program and provide advice to the organisations making decisions about environmental water management (CEWH, GB CMA, and VEWH). Raise the profile of the CEWH and the LTIM Project	<ul style="list-style-type: none"> • after significant results/findings • annually and at end of program 	<ul style="list-style-type: none"> • scientific papers • progress and final reports • presentations at scientific forums/conferences • publications on websites
	E-Flow managers (CMA E-Water Staff/CEWO - CEWH communication officers/VEWH)	Results (particularly results related directly to the river systems they manage/deliver environmental water down)	To inform environmental water management decision making.	<ul style="list-style-type: none"> • biannual (to coincide with and inform the development and implementation of seasonal watering proposals – March to April) • after significant results/findings 	<ul style="list-style-type: none"> • progress reports/summaries highlighting results that may influence or inform current or future environmental water management decisions
<p style="text-align: center;">↓</p> <p style="text-align: center;">Inform management</p>	E-Flow Partners (G-MW/CMA Environmental Water Advisory Groups/PV/CMA Board/CMA River Health staff/MDBA River Murray/MDMA TLM/DEPI/Yorta Yorta)	Broad results and activities	To inform and educate: <ul style="list-style-type: none"> • on why and where we are using environmental water • on how the use of environmental water is achieving the desired outcomes • to increase their capacity to provide meaningful input into environmental water management decision making DEPI would also be interested in how the results can complement or feed into their VEFMAP program. Raise the profile of the CEWH and the LTIM Project.	<ul style="list-style-type: none"> • monthly/seasonal • after significant results/findings 	<ul style="list-style-type: none"> • fact sheets • e-newsletters • cultural heritage information day – information exchange on river values, management and goals • media releases celebrating milestones • YouTube Videos • progress reports/summaries
	River user groups (fishing clubs, tourism operators, environmental groups and irrigators, river diverters, Traditional owners, urban water authorities, RiverConnect)	Broad results and activities, and proposed changes in river flow that might impact use	To raise the understanding and appreciation of: <ul style="list-style-type: none"> • environmental water management • E-water monitoring programs • role of the Commonwealth and other partners in environmental water management and monitoring • how environmental water management is /could benefit their particular use • potential impacts of planned environmental water deliveries to their use (eg access restrictions, inundation of pumps) Raise the profile of the CEWH and the LTIM Project.	<ul style="list-style-type: none"> • monthly/seasonal • after significant results/findings 	<ul style="list-style-type: none"> • fact sheets • e-newsletters • media releases celebrating milestones • YouTube Videos • Field days/site visits (e.g. electro fishing) • GB CMA website • Facebook/twitter • Presentations • Articles in industry/user group publications
	General public (industry, education institutions, local government, elected representatives)	Broad results and activities, and proposed changes in river flow that might impact use	To raise the understanding and appreciation of: <ul style="list-style-type: none"> • environmental water management • E-water monitoring programs • role of the Commonwealth and other partners in environmental water management and monitoring • how environmental water management is /could benefit their particular use Raise the profile of the CEWH and the LTIM Project.	<ul style="list-style-type: none"> • monthly/seasonal • after significant results/findings 	<ul style="list-style-type: none"> • fact sheets • e-newsletters • media releases celebrating milestones • YouTube Videos • Facebook/twitter • Newspaper columns
<p style="text-align: center;">↓</p> <p style="text-align: center;">Inform and educate</p>					

6.2 Communicating / engagement as directed by the CEWO

We will adhere to the schedule of meetings and engagement requirements set out the CEWO in communications prior to the development of the draft plan and also set out in the Project Operations Manual. These requirements include

- **Project Meetings – CEWO and M&E Providers:** These are monthly phone meetings of 1 hr duration throughout the lifetime of the project.
- **LTIM Project Managers Group meetings:** These are twice-yearly half-day teleconferences designed to ensure collaboration and consistency among the seven selected areas in the implementation of monitoring.
- **Selected Area Working Group meetings:** We propose to continue these meetings using the format employed during Stage 1; 2-3 hr teleconferences with locally-based working group members meeting at the University of Melbourne. The main purpose of these meetings is information and knowledge exchange between the monitoring provider and environmental watering stakeholders. These meetings will be held quarterly.
- **M&E Provider Annual Workshops:** These will be 2-day meetings to be held annually in Sydney. Four members of the project scientific team will attend each year with attendees to rotate among years. The workshops will provide an opportunity to evaluate the standard methods, compare results, and be presented with the annual results of basin-scale evaluation.

6.3 Reporting to CEWO

We will adhere to the schedule of reporting set out by the CEWO in communications prior to the development of the draft plan and also set out in the Project Operations Manual. These requirements include

- **Annual area evaluation report:** This is the major reporting item from the Goulburn River LTIM Project. At the end of each monitoring season we will provide details on the monitoring conducted, the evaluation of monitoring data to address the key Selected Area evaluation questions, how the data may contribute to Basin-Scale evaluation questions, and the results of our annual self-evaluation exercise (see Section 5.3) to optimize program design. This is a major undertaking and we have budgeted for it appropriately.
- **Quarterly progress reports:** These are short reports that will be at a similar level of detail to the monthly reports submitted during Phase 1. They are designed to alert the CEWO to any issues that have arisen, how such issues can be resolved, and any other requirements of the Monitoring Provider.
- **Annual monitoring workplan:** We will provide an annual monitoring workplan in August each year that outlines which elements of the M&E Plan will be implemented over the coming water year, based on the M&E Plan and environmental watering action(s) that is likely to be undertaken.
- **Annual evaluation plan:** We will provide an annual evaluation plan in August each year that outlines what evaluation activities will be undertaken over the coming year, based on anticipated environmental watering actions monitoring data availability.
- **Monitoring data entry:** Processed monitoring data will be uploaded to the Monitoring Data Management System monthly, in accordance with data management protocols

7. Project management

7.1 Project governance

Our project team is a collaboration between the University of Melbourne, the Arthur Rylah Institute for Environmental Research, Monash University, the Goulburn Broken Catchment Management Authority, **Streamology** and Jacobs. The University of Melbourne Commercial will enter into a contract with the Commonwealth Department of Environment to deliver the LTIM Project for the lower Goulburn River and will engage project team members from other partner organisations through sub-contract arrangements.

Our project structure is organised around project administration, technical monitoring disciplines, and stakeholder engagement as shown in Figure 7-1.

Dr Angus Webb (University of Melbourne) will be the Program Leader for the lower Goulburn River Selected Area. He has a project administrative role and will also lead the data analysis and evaluation for the Selected Area monitoring objectives. In his administration role Angus will be the primary point of contact between the CEWO and the broader project team and will be responsible for delivering the LTIM Project as described in this M&E Plan. He will represent the project team at forums with Program Leaders from other Selected Areas, report to the Project Working Group at regular intervals and ensure that each of the sub-contracted discipline leads deliver against agreed project milestones and standards. Angus will also be the primary project contact for the M&E Advisor and will include Discipline Leads and other project team members in discussions with the M&E Advisor as needed.

Dr **Simon Treadwell** (Jacobs) will be the Program Co-ordinator. His main role will be to manage relationships within the consortium, facilitate annual meetings with the Discipline Leads and represent the project team at relevant stakeholder engagement events. He will help develop templates for reports that require standardised contributions from the Discipline Leads and will oversee the development and implementation of the annual monitoring plan. He will also oversee the internal project audits and review technical reports that are produced by the project team prior to submitting them to the CEWO. **Simon** will deputise for Angus at Program Leader meetings and Working Group meetings as needed.

We have separate discipline leads for our six technical disciplines:

- Wayne Koster (Arthur Rylah Institute for Environmental Research) is the discipline lead for Fish, which includes the Fish (River), Fish (Larvae) and Fish (Movement) Indicators.
- Dr Kay Morris (Arthur Rylah Institute for Environmental Research) is the discipline lead for Vegetation, which will focus on Vegetation Diversity on the river banks, and Tree Condition, should this activity be funded.
- Assoc. Professor Mike Grace (Monash University) is the discipline lead for Stream Metabolism.
- Dr Vin Pettigrove (RMIT University) is the discipline lead for Macroinvertebrates.
- Dr Geoff Vietz (Streamology) is the discipline lead for Physical Habitat, both 2D Hydraulic model and Bank condition.
- **Ben Baker** (Jacobs) is the discipline lead for Hydrology.

Each discipline lead has been actively involved in developing the monitoring plan for their particular indicators and will be responsible for managing sub-teams to safely implement the planned monitoring, collate and analyse the results and provide the agreed data to the CEWO for Basin scale analyses and to Angus for specific Selected Area analyses. The sub-teams to support each of the discipline leads will include trained assistants from their home organisation and staff from other partner organisations, especially the Goulburn Broken CMA, where practical.

Simon Casanelia and **Daniel Lovell** from the Goulburn Broken Catchment Management Authority will lead and implement the communication and engagement plan for the project, with implementation assistance from Fiona Lloyd. They will liaise with the technical discipline leads, Program Leader and the CEWO to determine the main messages to be communicated and the best way to communicate those messages to community groups and other interested stakeholders.

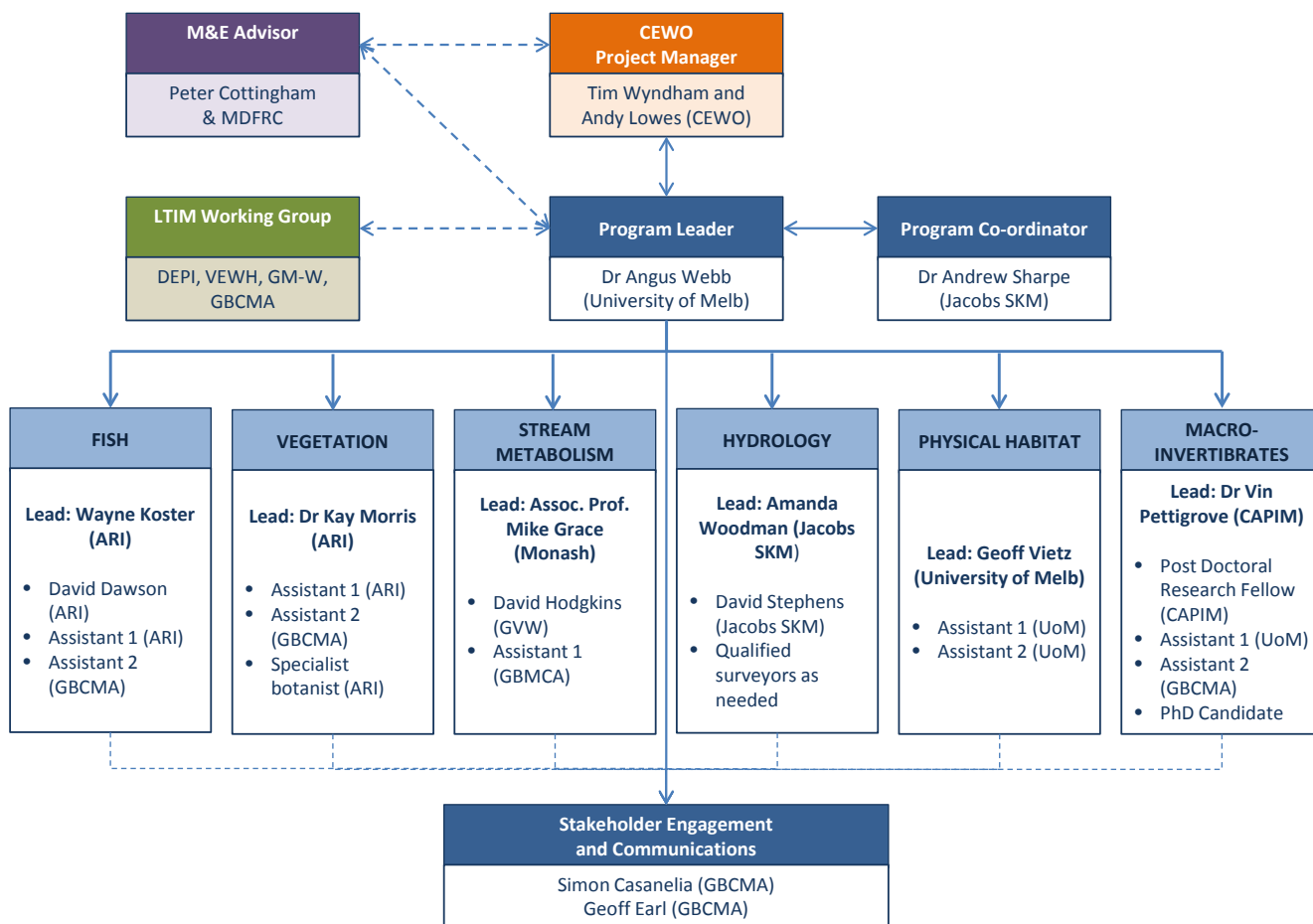


Figure 7-1: Lower Goulburn Selected Area Project Team structure. Please see sections above for contacts updated in 2018.

7.2 Risk Assessment

Prepare a risk assessment that is compliant with AS/NZ 31000:2009 Risk management – principles and guidelines. At a minimum, the risk assessment must cover risks to the success of the project, risks to the environment and risks to individuals. Additional information on the requirements for the risk assessment are provided in the Project Operations Manual.

Long-term monitoring projects that involve multi-disciplinary teams that are responsible for implementing different field programs and providing data to another individual or organisation have inherent risks. Those risks can be broadly grouped into four categories:

- 1) Risks to the success of the project (i.e. inability to deliver certain elements of the planned monitoring program, or inability of data to address specific monitoring objectives);
- 2) Risks to individuals working on the project (i.e. health and safety of people working on the project, especially those individuals undertaking fieldwork);
- 3) Risks to the environment (i.e. damage to flora, fauna or landforms due to field monitoring activities); and
- 4) Risks to stakeholders (i.e. adverse outcomes for local landowners and damage to professional reputations).

We have followed a four step process to identify and qualitatively evaluate risks in each of these categories as proposed in the *Project Risk Assessment and Mitigation Guidance Document*. Step 1 involves identifying potential risks. Step 2 assesses the likelihood that a particular risk will occur using the criteria presented in Table 7-1. Step 3 assesses the potential consequence that the risk poses to the project, individual or environment using the criteria presented in Table 7-2. Step 4 combines the likelihood and consequence categories identified in the previous steps to rate each risk as low, medium, high or severe using the matrix presented in Table 7-3.

Table 7-1: Criteria for categorising the likelihood that a particular risk will occur.

Category	Description / criteria
Almost certain	Is expected to occur in most circumstances
Likely	Will probably occur
Possible	Might occur at some time in the future
Unlikely	Not expected to occur
Rare	May occur under exceptional circumstances

Table 7-2: Criteria for categorising the consequence of a particular risk

Risk	Consequence				
	Negligible	Minor	Moderate	Major	Critical
Undertaking monitoring activities	Monitoring activities undertaken according to M&E Plan, with data from all planned samples available.	Minor disruption to the monitoring program with a small number of planned samples (<10%) not collected or data not available	More than 10% of planned samples not collected / available, however sufficient data available for planned analyses	Data from more than 50% of planned samples not collected / available. Limited monitoring outcomes reported	No useable data collected, analyses not possible, no monitoring outcomes reported
Environment	Negligible environmental damage	Short term, localised, reversible damage to the environment	Short term, widespread damage to the environment reversible to intensive effort	Long-term damage to the environment and/or risk of continuing environmental damage	Long-term, widespread, irreversible damage
Health and safety	Incident requiring first aid treatment	Minor incident requiring treatment by a medical practitioner	Moderate incident requiring short term hospitalisation	Serious incident requiring extensive hospitalisation	A fatality, permanent disability , or multiple people affected by a serious incident
Stakeholders	Short-term, isolated complaints from stakeholders	Sustained but isolated complaints from stakeholders Relationship with stakeholder temporarily affected	Sustained complaints from stakeholders Relationship with stakeholder damaged	Short-term but significant complaints from stakeholders Relationship with stakeholder significantly damaged	Sustained and significant complaints from stakeholder Relationship with critical stakeholder irreversible damaged
Project objectives	Short delay in achievement of project objectives	Delay in achievement of project objectives	Element or project objective not met	Project objectives not met	Project objectives harmed (negative impact)

Table 7-3: Risk assessment matrix

Likelihood	Consequence				
	Negligible	Minor	Moderate	Major	Critical
Almost certain	Low	Medium	High	Severe	Severe
Likely	Low	Medium	Medium	High	Severe
Possible	Low	Low	Medium	High	Severe
Unlikely	Low	Low	Low	Medium	High
Rare	Low	Low	Low	Medium	High

The known risks to the LTIM Project, project members and environment in the lower Goulburn River are presented in Table 7-4. The measures that the project team will implement to mitigate medium, high and severe risks to the project and the expected effectiveness of those measures in reducing the risk are presented in Table 7-5. Risks to the health and safety of people and the environment will be addressed specifically through EHS Plans and associated Job Safety Environment Assessments (see Section 7.4 of this M&E Plan).

The Risk Register (i.e. Table 7-4) and mitigated risk assessments presented in Table 7-5 and the JSEA will form the risk assessment document for the project. The risk assessment will be a live document that can be updated at any time throughout the project to include new risks as they are identified, and to modify existing, or introduce new, mitigation measures as needed. We will also formally review the risk assessment at our annual project workshop with all Discipline Leaders to ensure that it is current and relevant.

Table 7-4: Identified risks to the project, people, environment and stakeholders including an assessment of their likelihood, consequence and overall level of risk.

Description of risk	Likelihood	Consequence	Risk Level
Inability to meet project objectives			
Loss of key project staff (i.e. Discipline Leaders) due to role changes	Possible	Moderate Would need to find a suitable replacement within the discipline lead's organisation.	Medium
Loss of Program Leader due to role changes	Unlikely	Major Because Angus is also leading the specialised evaluation component of the program	Medium
Loss of other project staff due to role changes	Likely Because staff turnover in assistant roles is more common	Negligible Because other staff can be readily trained to replace them	Low
Competing time demands prevent key staff from working on project as planned	Possible	Minor	Low
Cost escalations over the course of the monitoring program that reduce the amount of monitoring and evaluation that can be done within the available budget.	Unlikely Because cost escalations have been considered in developing project budgets.	Moderate	Low
Breakdown in relationships and co-operation among consortium partners	Possible	Moderate	Medium
Lost or damaged equipment resulting in incomplete or inaccurate data.	Almost Certain	Moderate	High
Loss of data post collection due to improper storage of data or samples	Possible	Moderate	Medium
Inability to deliver and therefore measure responses to environmental water	Unlikely	Major	Medium
Natural events such as floods, drought or fires that alter the condition of the lower Goulburn River	Possible	Moderate	Medium
Toxic pollution event that changes condition of the lower Goulburn River	Rare	Moderate	Low
Planned monitoring activities are inadequate to evaluate effect of environmental flow releases.	Unlikely	Moderate	Low
Risks to health and safety of individual project team members			
Note – these risks will be described in detail and addressed in the Environment, Health and Safety Plan.			
Accidents associated with working on or in water (i.e. from boats or wading into the river)	Possible	Major	High

Description of risk	Likelihood	Consequence	Risk Level
Accidents associated with working on the river bank or woodland adjacent to the monitoring sites	Possible	Moderate	Medium
Exposure to adverse weather such as extremely hot or very wet and cold conditions.	Likely	Minor	Medium
Exposure to bushfire	Rare	Critical	High
Risks associated with fatigue	Possible	Moderate	Medium
Risks associated with manual handling	Possible	Moderate	Medium
Risks associated with bites and stings from wild animals and insects	Possible	Minor	Low
Risks associated with working in a remote location	Unlikely	Moderate	Low
Risks associated with driving to and from field sites	Unlikely	Critical	High
Risks to the environment			
Death or distress to animals caught as part of the monitoring program	Likely	Minor	Medium
Damage to native vegetation or bank condition associated with working on site, driving vehicles off road and launching boats	Likely	Negligible	Low
Spills of fuel or chemicals used in the monitoring program	Rare	Minor	Low
Risks to stakeholders and professional reputations			
Inconvenience or disturb local landowners during monitoring activities	Unlikely	Minor	Low
Field staff fail to take account of indigenous heritage values at monitoring sites	Rare	Minor	Low
Monitoring brings attention to environmental flow releases and provides a trigger for lobbying by environmental flow opponents.	Likely	Minor	Medium

Table 7-5: Preliminary assessment of medium and high risks to the project outcomes, mitigation measures to address those risks and a residual risk assessment assuming the mitigation is applied.

Risk description	Likelihood	Consequence	Preliminary Risk Level	Proposed mitigation	Residual Likelihood	Residual Consequence	Residual Risk Level
Loss of key project staff (i.e. Discipline Leaders) due to role changes	Possible	Moderate Would need to find a suitable replacement within the discipline lead's organisation.	Medium	Documented procedures for handover responsibility in the SOPs. Replacement will preferably come from within home organisation of original discipline lead.	Possible	Minor	Low
Loss of Program Leader due to role changes	Unlikely	Major Because Angus is also leading the specialised evaluation component of the program	Medium	Project administration could be transferred to Project Facilitator permanently or until suitable replacement found at the University of Melbourne Would need to recruit new person to undertake specialist Bayesian analysis and oversee evaluation	Unlikely	Moderate	Low
Breakdown in relationships and co-operation among consortium partners	Possible	Moderate	Medium	Program Co-ordinator has specific role to manage relationships among consortium members. Some disagreements are likely, but they should not jeopardise the program.	Unlikely	Minor	Low
Lost or damaged equipment resulting in incomplete or inaccurate data.	Almost Certain	Moderate	High	Costs to replace lost or damaged equipment have been included in the program budget. Regular monitoring events are planned to minimise period of lost data.	Almost Certain	Minor	Medium
Loss of data post collection due to improper storage of data or samples	Possible	Moderate	Medium	Detailed procedures for chain of custody, data storage and timely uploading of data to central databases are outlined in the SOPs. These actions will reduce the likelihood of data loss and reduce quantity of data loss.	Unlikely	Minor	Low
Inability to deliver and therefore measure responses to environmental water	Unlikely	Major	Medium	Climatic conditions will primarily determine availability of environmental water. Therefore difficult to mitigate this risk	Unlikely	Major	Medium
Natural events such as floods, drought or fires that alter the condition of the lower Goulburn River	Possible	Moderate	Medium	Cannot control natural events, but monitoring program has built in flexibility to measure responses to extreme events so those effects can be separated from environmental flow effects.	Possible	Minor	Low
Monitoring brings attention to environmental flow releases and provides a trigger for lobbying by environmental flow opponents.	Likely	Minor	Medium	The project communications plan will engage with stakeholders to inform them about the monitoring program and that the results will be used to adaptively manage the flows to maximise environmental outcomes and minimise impacts to the environment and public and private assets.	Likely	Negligible	Low

7.3 Quality plan

Prepare a Quality Assurance Plan to document quality control and quality assurance procedures for activities at the Selected Area. The following details the minimum requirements for Quality Plans, which should be developed in accordance with relevant standards such as AS/NZS ISO 10005:2006 Quality management systems - Guidelines for quality plans; and ANZECC and ARMCANZ (2000) Australian Guidelines for Water Quality Monitoring and Reporting.

7.3.1 Equipment

A list of the relevant field equipment that will be used throughout the LTIM Project for the lower Goulburn River and details about how that equipment will be calibrated and maintained is provided in Table 7-1.

Table 7-1: List of proposed equipment for use in the LTM Program including how the equipment will be maintained and where necessary calibrated. Any additional equipment required for the winter monitoring in 2018-19 is detailed in the Addendum document.

Equipment description			Equipment maintenance				Equipment calibration			
Monitoring discipline	Equipment description	Indicator or method the equipment that will be used for	How will equipment be maintained?	How frequently will maintenance work be conducted?	How will maintenance work be logged or recorded?	Who will be responsible for maintenance?	How will equipment be maintained?	How frequently will maintenance work be conducted?	How will maintenance work be logged or recorded?	Who will be responsible for maintenance?
Physical Habitat	Erosion pins	Bank Condition	Condition will be checked during inspections, and pins replaced where necessary	Pins will be re-inserted at every visit: twice per year	Field notes will be taken and data filed digitally	Dr Geoff Vietz	N/A	N/A	N/A	N/A
Physical Habitat	Total Station	2D Modelling	Will be maintained by University of Melbourne stores staff	Maintenance will be conducted on an annual basis	Maintenance is logged digitally by University of Melbourne stores staff	University of Melbourne stores staff	Calibrated in the field by University of Melbourne operations staff	Calibration is conducted as required (Sokkia systems contain a self calibrating function) and does not need to be returned for manufacturer calibration until June 2016 (new system)	Calibration will be noted in the field book	University of Melbourne operations staff
Physical Habitat	ADV or ADCP	2D Modelling	Will be maintained by University of Melbourne stores staff	Maintenance will be conducted on an annual basis	Maintenance is logged digitally by University of Melbourne stores staff	University of Melbourne stores staff	Current profilers undergo manufacturers calibration by Sontek	Calibration has been undertaken every two years (last calibrated July 2013)	Calibration is logged in hard copy in the case accompanying the equipment, and a certificate of calibration will be placed on digital file	University of Melbourne staff
Macroinvertebrates	Artificial Snags	Artificial Substrates	Regular collection of snag from study area	Annually	A maintenance book will be used	Dr V Pettigrove	Same standard snags will need to be used annually	Annually	Recorded in a book	CAPIM staff
Macroinvertebrates	Field nets, waders, boat	Field work generally	Regular inspection of equipment and cleaning after each field trip to prevent transfer of pests	Each sampling event	Routine	Dr V Pettigrove	Regularly cleaned, maintained and inspected	N/A	N/A	CAPIM staff
Stream Metabolism	DO/Temp Loggers	Stream Metabolism	Infield maintenance including battery replacement, cleaning, visual inspection	Every 4-6 weeks by field team	On prescribed field sheets	Senior Field Technician reporting to A/Prof Mike Grace	Infield 100% DO saturation check then recalibration if required	Every 4-6 weeks by field team	On prescribed field sheets, including any drift detected during 100% DO check	Senior Field Technician reporting to A/Prof Mike Grace
Stream Metabolism	PAR & Barometric Pressure Loggers	Stream Metabolism	Infield maintenance including battery replacement, cleaning, visual inspection	Every 4-6 weeks by field team	On prescribed field sheets	Senior Field Technician reporting to A/Prof Mike Grace	PAR logger calibrated in laboratory against standard light (PAR) fluxes. Barometer checked against Bureau of Meteorology readings.	Pror to first deployment	On initial equipment preparation file	Senior Field Technician reporting to A/Prof Mike Grace
Fish	Boat and motor	Fish - River	Boat serviced annually by Barry Lawrence Marine and whenever issue reported following field trip	Annually and whenever issue reported following field trip	Maintenance records kept at Arthur Rylah Institute	Arthur Rylah Institute (Andrew Pickworth)	N/A	N/A	N/A	N/A
Fish	Electrofishing equipment		Annual service by qualified electricians Berry Rewind Electrical	Annually, plus additional as needed	Maintenance records kept at Arthur Rylah Institute	Arthur Rylah Institute (Andrew Pickworth)				
Fish	Fyke nets	Fish - River	Checked for holes prior to each trip and repaired if needed. Also cleaned and dried between field trips to prevent transfer of pest species	Prior to each trip	Maintenance records kept at Arthur Rylah Institute	Arthur Rylah Institute (John Mahoney)	N/A	N/A	N/A	N/A
Fish	Scales	Fish - River	Checked for function	Prior to each trip	Maintenance records kept at Arthur Rylah Institute	Arthur Rylah Institute (John Mahoney)	Checked for accuracy	Annually	Maintenance records kept at Arthur Rylah Institute	Arthur Rylah Institute
Fish	Larval drift nets	Fish - Larvae	Checked for holes prior to each trip and repaired if needed. Also cleaned and dried between field trips to prevent transfer of pest species	Prior to each trip	Maintenance records kept at Arthur Rylah Institute	Arthur Rylah Institute (David Dawson)	N/A	N/A	N/A	N/A
Fish	Flow meters	Fish - Larvae	Cleaned at end of each trip	Fortnightly during sampling	Maintenance records kept at Arthur Rylah Institute	Arthur Rylah Institute (David Dawson)	Checked for accuracy	Annually	Maintenance records kept at Arthur Rylah Institute	Arthur Rylah Institute (David Dawson)

Fish	Water quality (turbidity) recorder	Fish - Larvae	Cleaned and air dried after each trip, sent to TPS for repair if any problem noted.	After each trip	Maintenance records kept at Arthur Rylah Institute	Arthur Rylah Institute (David Dawson)	Calibrated 6 monthly with a 90 NTU standard and zero calibration.		Maintenance records kept at Arthur Rylah Institute	Arthur Rylah Institute (David Dawson)
Fish	Acoustic listening stations	Fish - movement	Cleaned and repaired if needed at end of each trip	Quarterly on each download trip	Maintenance records kept at Arthur Rylah Institute	Arthur Rylah Institute	N/A	N/A	N/A	N/A
Vegetation	No specialist equipment needed									

7.3.2 Data collection (field and laboratory) – samples and measures

The QA/QC arrangements to ensure the collected data are of high quality are summarised in Table 7-2.

Table 7-2: Summary of QA/QC procedures that will apply to each type of data collected during the LTIM Program for the lower Goulburn River

Monitoring discipline	Data Type	What if any relevant Standard (e.g. ANZECC) will be followed or applied?	What type of field data sheets will be used? Who will develop field sheets, how will information entered to the sheets be checked and how will the field sheets be stored?	What Chain of custody procedures will be used for samples that need to be transported to the laboratory?	Will sample blanks or duplicates be used for QA/QC? If so what and when?	What are the proposed methods for transporting samples from field to laboratory and what are the maximum holding times before laboratory analyses will be undertaken?	What are the Laboratory accreditation requirements (e.g. NATA)?	What quality control methods are in place for laboratory work and how will QA/QC for laboratory work be reported?	Will samples or vouchers need to be kept and if so for how long and how will they be stored or registered?
Physical Habitat	Erosion Pin measurements (quantitative and qualitative)	N/A	Data recording sheets have been developed by Dr. Geoff Vietz. The information will be checked by the second staff on hand and the data will be entered into a spreadsheet upon return from the field. Scanned copies of field sheets to be stored on central LTIM Project server at the University of Melbourne.	N/A	N/A	N/A	N/A	N/A	N/A
Physical Habitat	Bathymetry Survey data	N/A	Results from the survey will be recorded by Dr. Geoff Vietz in the field and then transcribed to a spreadsheet. Scanned copies of field sheets to be stored on central LTIM Project server at the University of Melbourne.	N/A	N/A	N/A	N/A	N/A	N/A
Vegetation diversity	Cover of species, bare ground, ground cover, understorey, overstorey		Data recording sheets have been developed by Dr Kay Morris for the pin intercept method. All data sheets will be check for errors and completeness after each transects. Field sheets will be copied immediately upon return and stored separately in secure locations. Data will be entered into a spreadsheet upon return from the field and checked for errors. Scanned copies of field sheets to be stored on central LTIM Project server at the University of Melbourne.	Plant material for taxonomic identification will be transported by field staff back to ARI where the discipline lead (Kay Morris) will be responsible for preparing and storing the samples.	N/A	Plant material for taxonomic identification will be labelled and placed in a plant press for transport by field staff to ARI where the discipline lead (Kay Morris) will be responsible for preparing and storing the samples. Samples can be held indefinitely once dried.	N/A	N/A	For species that cannot be identified in the field, herbarium samples will be prepared to enable formal identification by experienced taxonomists. Samples will be held for the duration of the project for future reference.
Tree condition	Tree condition		Field data sheets provided in the standard methods will be used. All data sheets will be check for errors and completeness after each transects. Field sheets will be copied immediately upon return and stored separately in secure locations. Data will be entered onto spreadsheet upon return from the field and checked for errors. The spreadsheet will follow prescribed template outlined in the standard methods. Scanned copies of field sheets to be stored on central LTIM Project server at the University of Melbourne.	N/A	N/A	N/A	N/A	N/A	
Macroinvertebrates	Macroinvertebrates	LTIM monitoring data management system	Prepared using suggested format in macroinvertebrate protocol	A field sheet specifying the details of each sample (i.e. time and date of collection, sample type, replicate number, location, and who collected the sample) will be filled out after each sample collection and will be sent with the samples to the laboratory	N/A	Macroinvertebrates are stored in sampling jars in 70 % ethanol for preservation; jars given internal and external labels in waterproof and ethanol proof pen/pencil. Jars are securely transported to laboratory in esky or tub. There are no holding time requirements before samples are analysed.	N/A	N/A	Stored at Zoology for minimum of 5 years
Macroinvertebrates	Macroinvertebrate - species identification	Macroinvertebrate Protocol	Prepared using suggested format in macroinvertebrate protocol	Samples in the laboratory will be given a number from the macroinvertebrate database	N/A	N/A	N/A	10% of samples will be reprocessed by a second person according to EPA Victoria protocols	Stored on CAPIM database
Stream metabolism	DO & Temp readings from logger	n/a	field sheet as per LTIM SOP	n/a	n/a	n/a	n/a	n/a	n/a
Stream metabolism	PAR & Pressure readings from logger	n/a	field sheet as per LTIM SOP	n/a	n/a	n/a	n/a	n/a	n/a

Monitoring discipline	Data Type	What if any relevant Standard (e.g. ANZECC) will be followed or applied?	What type of field data sheets will be used? Who will develop field sheets, how will information entered to the sheets be checked and how will the field sheets be stored?	What Chain of custody procedures will be used for samples that need to be transported to the laboratory?	Will sample blanks or duplicates be used for QA/QC? If so what and when?	What are the proposed methods for transporting samples from field to laboratory and what are the maximum holding times before laboratory analyses will be undertaken?	What are the Laboratory accreditation requirements (e.g. NATA)?	What quality control methods are in place for laboratory work and how will QA/QC for laboratory work be reported?	Will samples or vouchers need to be kept and if so for how long and how will they be stored or registered?
Stream metabolism	Total P, Total N, NOx, FRP, NH4+, DOC	NATA-accredited protocol for analysis of these samples by Water Studies Centre (Monash University)	field sheet as per LTIM SOP	field sheet copy to accompany samples in transport to laboratory	as per NATA-accredited protocol for analysis of these samples by Water Studies Centre (Monash University)	Transportation in an esky over dry ice. Max time 24 hours.	NATA for all analytes listed	as per NATA-accredited protocol for analysis of these samples by Water Studies Centre (Monash University). Details of spike recoveries, duplicates, blanks and SRMs to be reported back to project team along with rest of results	As per NATA-accredited lab SOP
Stream metabolism	Chlorophyll-a	NATA-accredited protocol for analysis of these samples by Eastern Melbourne Laboratory (EML)	field sheet as per LTIM SOP	field sheet copy to accompany samples in transport to laboratory	as per NATA-accredited protocol for analysis of these samples by EML	Transportation in an esky over dry ice. Max time 24 hours.	NATA for chlorophyll-a	as per NATA-accredited protocol for analysis of these samples by EML. QC results to be reported back to project team along with rest of results	As per NATA-accredited lab SOP
Fish	Electrofishing and fyke net data	N/A	Field data sheets provided in the standard methods will be used. All data sheets will be check for errors and completeness after each survey. Field sheets will be copied immediately upon return and stored at ARI. Scanned copies will be loaded onto the LTIM Project Server hosted by the University of Melbourne. Data will be entered onto spreadsheet upon return from the field and checked for errors. The spreadsheet will follow prescribed template outlined in the standard methods.	N/A	N/A	N/A	N/A	N/A	No
Fish	Larval drift net and light trap data	N/A	Field data sheets provided in the standard methods will be used. All data sheets will be check for errors and completeness after each survey. Field sheets will be copied immediately upon return and stored at ARI. Scanned copies will be loaded onto the LTIM Project Server hosted by the University of Melbourne. Data will be entered onto spreadsheet upon return from the field and checked for errors. The spreadsheet will follow prescribed template outlined in the standard methods.	Label each sample vial in the field (labels inside and outside of vial). Also record on data sheet the vial number(s) that correspond to each net and site. In laboratory cross check vials with data sheets.	N/A	Larval samples collected in field and preserved in 90% ethanol. Transported to laboratory at Arthur Rylah Institute at the end of each sampling trip. Timing is not critical.	N/A	Samples will be sorted and identified by experienced staff. 5% of samples will be checked by another technician to confirm identification accuracy.	Not necessary to keep for QA, but will be stored at ARI.
Fish	Otolith samples	N/A	Field data sheets provided in the standard methods will be used. All data sheets will be check for errors and completeness after each survey. Field sheets will be copied immediately upon return and stored at ARI. Scanned copies will be loaded onto the LTIM Project Server hosted by the University of Melbourne. Data will be entered onto spreadsheet upon return from the field and checked for errors. The spreadsheet will follow prescribed template outlined in the standard methods.	Prepare an Excel spreadsheet identifying the species, sample number, site, date of collection, length and weight of each individual fish. Spreadsheet will be supplied to Fish Aging Services with otolith samples. Samples and completed data will be returned to ARI.	N/A	Otolith samples are placed in plastic vial or envelope in the field without any preserving agent (i.e. stored dry). Then transported to Fish Ageing Services (time not critical).	N/A	Each otolith will be double read (by separate technicians) to check for accuracy.	Otoliths will be returned to ARI for archiving.
Fish	Acoustic telemetry data	N/A	NA - data is downloaded and stored electronically	N/A	N/A	N/A	N/A	N/A	N/A

7.3.3 Data storage and management

The CEWO will develop a Data Management System for shared data to support evaluation. M&E Providers are to store and manage access to primary data for the duration of the LTIM Project. In doing so, they are to:

- Describe procedures for management of all primary (raw) data including governance, storage, backup, version control and custodianship.

Data will be stored on a secure server at the University of Melbourne in a staff folder controlled by project leader Webb. These servers are backed up regularly, providing security for the data. Discipline leads will transmit data to the University of Melbourne using a cloud service, uploading raw data to the cloud service at the same time as they upload processed data to the MDMS. The University of Melbourne Research Assistant will be responsible for timely transfer of data from the cloud service to the secure server. Data transfers and backups will be subject to spot audits as part of project internal audits to confirm that these procedures are being followed.

Each organisation within our project team will also save a duplicate copy of the data that is relevant to their particular monitoring activity on secure servers within their home organisations.

- Identify process for accessing archived primary data (e.g. if required to verify or recalculate derived data at a future date, or to support evaluation).

All discipline leads will be able to access primary data stored on the secure server described above by submitting a request to the University of Melbourne Research Assistant. The RA will save a copy of the data file/s to the same cloud service that is used to transmit data to the university. We cannot guarantee this service beyond the term of the LTIM Project, as staff will inevitably leave the university. We reiterate our earlier strong recommendation that the CEWO provide a 'dropbox' for raw data as part of the MDMS.

External requests for raw data will be handled by the Project Leader. Any request must be made in writing, and include a statement of the proposed use of the data. The contact address on the project website will provide the necessary point of contact for any external party interested in obtaining data. The Project Leader will clear all requests with the CEWO before providing data. Data will be provided by upload to a secure filesharing utility (e.g. hightail). All external requests for data that have not yet been published as part of the annual selected area or basin scale evaluation report will be subjected to a further permissions process as previously specified by the CEWO.

- All derived data submitted for shared evaluation needs must adhere to LTIM data standards and be traceable to raw data.

All processed data will conform to the LTIM data standards, and indeed will probably not be able to be uploaded to the MDMS if they do not.

- M&E Providers to submit their data that supports shared evaluation needs within 1 month of collection, and according to the protocols established by CEWO.

Discipline leads will be responsible for the timely upload of processed data, in accordance with CEWO requirements.

In addition to meeting data storage and management protocols and standards, M&E Providers are to state any additional standard, protocols or issues that may be relevant to the management and sharing of data for their Selected Area. In particular, M&E Providers should note issues of custodianship and data sharing arrangements that are to be addressed.

7.3.4 Document management

Outline relevant document control processes.

Storage: We will establish a document store on the secure server at the University of Melbourne (mentioned above). This will archive all reports, SOPs, etc. produced throughout the project. A hierarchical directory structure will be used to navigate the store, and a meta-data document will be used to provide details of all documents uploaded to the store.

Version numbers for evolving documents: Standard operating procedure documents (and potentially others) may evolve over the course of the monitoring program. SOPs will be assigned a version number (those attached this proposal will be 1.0 for each monitoring activity), with new version numbers assigned to reflect minor and major changes to procedures. A change in version number will demonstrate to the user that they should re-read the new document to be aware of changes in procedures. All previous versions will be archived as part of the project document store.

Version control during writing: The majority of reports produced for this project will be quite simple (e.g. quarterly progress reports, annual monitoring and evaluation plans). These documents will be primarily authored by a single individual, perhaps with minimal input from others. We do not foresee major version control problems for these documents.

The annual selected area evaluation report will be more complex. It will combine inputs from all discipline leads, the project leader, outputs of evaluation, appendices of project audits, etc. Moreover, it will undergo review and revision before being accepted by the CEWO. The Project Leader will be responsible for maintaining version control of this document. This will primarily be achieved by:

- Discipline leads write individual sections, rather than all working on the same document
- Project lead compiles those sections once they are ready for submission
- Following receipt of review comments from the CEWO and Monitoring Adviser, the Project Leader circulates comments for revision to the relevant discipline lead. The discipline lead works upon the previously written *individual section* rather than the full compiled copy
- Project lead re-compiles the revised individual sections as the final report.

Working documents for the annual report, and for other minor reports will be saved to a 'Dropbox'™ folder. This cloud storage service automatically archives a copy of every saved version of a file. If files become corrupted during writing, an earlier version of the file can be extracted from Dropbox. Once the report is complete, working documents will be removed from the visible Dropbox directory.

7.3.5 Training

The specific training requirements for certain monitoring activities are described below. All field staff must have a valid Level 2 (or higher) First Aid qualification.

Stream metabolism

Initial training or checking of capability in handling loggers (maintenance, downloading, calibration check & recalibration) and collecting the requisite water samples for specified analyses will be conducted by Assoc Prof Mike Grace in conjunction with the designated senior field technical officer. Subsequent training of new staff and annual checking will be the responsibility of the senior field technical officer (in consultation with Assoc Prof Grace if required)

Fish (River), Fish (larvae) and Fish (movement)

All staff undertaking electrofishing must be accredited operators and have completed the U.S. Fish and Wildlife Services Principles and Techniques of Electrofishing Program. No formal accreditation is required to undertake fyke netting or larval sampling, but all staff involved in the fish aspect of the field program must either have or be supervised by someone who has at least two years' experience with the sampling techniques. Staff must hold a valid Victorian Driver's licence and completed accredited 4WD training. From mid 2015, all boat operators must hold a Coxswains Certificate.

The fish Discipline Lead (Wayne Koster) will be responsible for inducting any new field staff to the program. The induction will follow six steps:

1. Describe the overall objectives and format of the program;
2. Outline and document the roles and responsibilities of each team member;
3. Provide them with a copy of the Standard Operating Procedure and talk them through each task;
4. Explain and discuss the project risk assessment and project safety requirements
5. Demonstrate the sampling methods in the field and supervise staff implementing the methods until satisfactory competency is demonstrated
6. Explain and demonstrate data collation, analysis, uploading procedures and assist staff in performing these tasks as required.

Vegetation diversity

No formal training or qualifications are required to undertake the vegetation diversity monitoring proposed for the project. However, the Vegetation Discipline Lead (Kay Morris) will supervise all fieldwork and be responsible for inducting new staff who will assist on the project. The induction will follow six steps:

1. Describe the overall objectives and format of the program;
2. Outline and document the roles and responsibilities of each team member;
3. Provide them with a copy of the Standard Operating Procedure and talk them through each task;
4. Explain and discuss the project risk assessment and project safety requirements
5. Demonstrate the sampling methods in the field and supervise staff implementing the methods until satisfactory competency is demonstrated
6. Explain and demonstrate data collation, analysis, uploading procedures and assist staff in performing these tasks as required.

Macroinvertebrates

The Macroinvertebrate Discipline Lead (Dr Vin Pettigrove) will oversee the planned monitoring. All fieldwork will be conducted by a qualified research assistant and an experienced CMA employee. Vin will induct all project staff to the project via the following six step process:

1. Describe the overall objectives and format of the program;
2. Outline and document the roles and responsibilities of each team member;
3. Provide them with a copy of the Standard Operating Procedure and talk them through each task;
4. Explain and discuss the project risk assessment and project safety requirements
5. Demonstrate the sampling methods in the field and supervise staff implementing the methods until satisfactory competency is demonstrated
6. Explain and demonstrate data collation, analysis, uploading procedures and assist staff in performing these tasks as required.

All staff must undertake a safety induction for the laboratory and be familiar with any Material Safety Data Sheets (MSDS) for chemicals used in the sampling (e.g. ethanol) as well as the location of MSDS hard copies, site risk assessments, and other safety information.

All staff involved in field work should have up-to-date first aid and CPR training. Staff driving vehicles must have a current Victorian Drivers Licence. Staff operating the boat must have a current Victorian Boat Licence and as of mid 2015 have a Coxswains Certificate. Staff involved in Replicated Edge Sweep Sampling (RESS) must have successfully completed the EPA Victorian AusRivAS and Rapid Biological Assessment Competency course or have a minimum of five years experience conducting sweep sampling or be supervised by someone with the above qualifications. Similarly, staff involved in sorting and identifying macroinvertebrates from RESS and Artificial Substrate Samplers must have successfully completed the EPA Victorian AusRivAS and Rapid Biological Assessment Competency course or have a minimum of five years experience conducting sweep sampling or be supervised by someone with the above qualifications.

2D hydraulic modelling and bank condition

The Discipline Leader for Physical Habitat (Dr Geoff Vietz) will undertake all Bathymetric surveying, 2D model development, and erosion pin measurement for the LTIM Project. He will directly supervise any assistants in the field and therefore no formal training is proposed.

7.4 Health, safety and environment plan

A Health, Safety and Environment Plan (HSEP) will be prepared that describes the procedures and requirements for minimising the risk of injury to persons and harm to the environment from the LTIM Project. The HSEP will be compliant with the [Work Health and Safety Act 2011](#), [Work Health and Safety Regulations 2011](#), [Work Health and Safety Codes of Practice 2011](#) and relevant Victorian legislation.

It is proposed that an overarching Health, Safety and Environment Plan (HSEP) will be developed centrally for the project. The format, structure and requirements of this plan will be based on those currently used by Jacobs SKM. The HSEP will include the following elements:

1. A risk register identifying the potential hazards (such as working in remote locations, working outdoors, working on or near water, travel to remote locations, manual handling);
2. An environmental hazard identification checklist
3. Details of any specific legislation and organisation procedures and work standards that must be followed.
4. A description of the relevant training, qualifications and competencies that field staff need to undertake the work
5. A Job Safety and Environment Assessment (JSEA) that describes how medium, high or severe hazards will be mitigated and any residual hazards managed.
6. A procedure for responding to emergency situations,
7. A procedure for reporting incidents and/or near misses; and
8. A procedure for checking in with daily contacts during fieldwork.

The overarching HSEP will specify minimum safety requirements such as the need to always have at least two people in the field, to wear an approved Personal Floatation Device (PFD) at all times while working on boats or wading in the river and current first aid qualifications (Level 2 or greater) for all field staff.

Sub-plans will be developed for each of the individual discipline project teams (i.e. fish team, vegetation team, macroinvertebrate team, stream metabolism team, physical habitat team and hydrology team), because each of the discipline leads has the best understanding of the planned field activities and risks associated with them. Moreover, it is critical that those people undertaking the fieldwork have been actively involved in identifying and mitigating risks associated with their work. The sub-plans will be developed in consultation with the relevant EHS managers in each of the partner organisations.

Each partner organisation has its own specific safety plan requirements and formats. We will allow each partner organisation to prepare their safety plans using their own templates. Each of the sub-plans will be submitted to the Project Facilitator (**Simon Treadwell**) or a nominated specialist in EHS Risk Management for review to ensure that they are compatible with the overarching HSIP. Any items or mitigation measures that are not covered by the home organisation's safety plans will need to be added to ensure the minimum standard is applied across the whole LTIM Project. Formal endorsement of the respective sub-plans and the HSIP by the project coordinator will take place prior to any fieldwork commencing.

Each discipline lead will be responsible for implementing their respective sub-plan inclusive of the whole of project requirements (the HSIP) and the safety planning requirements of their home organisation.

Safety audits will be conducted at various times during the project by EHS representatives from the relevant discipline home organisation, the Program Co-ordinator or EHS managers from the GBCMA to ensure safety plans are being followed in the field.

7.4.1 Incident Reporting

The first priority in the event of a health and safety incident and/or near miss will be to care for those affected and to ensure the safety of others. Once this can be guaranteed a formal process for the reporting of the incident and/or near miss will be implemented.

The reporting of all incidents and/or near misses is a critical first step in identifying causal factors and taking action to prevent recurrence of similar incidents and in identifying trends that may have broader implication. All incidents and/or near misses will be reported so that they can be investigated to the appropriate level.

The discipline lead of the person notifying the incident and/or near miss will be responsible for submitting a formal report to both the relevant EHS managers in each of the partner organisations and the Program Leader (Dr Angus Webb) within 24 hours of occurrence. A project specific incident reporting form will be developed and be used to report the incident. An individual form is to be used for each incident type; for example, if two staff are injured, there is to be a separate incident form submitted for each injured person.

The Program Leader (Dr Angus Webb) will notify Andy Lowes or another designated representative from the CEWO within 48 hours of the incident.

An investigation into the health and safety incident and/or near miss will be conducted by the EHS manager in the relevant partner organisations and the Program Leader (Dr Angus Webb) or his delegate. The outcome of the investigation will be communicated to all relevant staff within the partner organisations and the CEWO and will include both lessons learned and any proposed modifications to work practices to further mitigate any residual health and safety risk.

7.5 Auditing

A comprehensive approach to self-auditing of project quality is proposed. Implementation of this plan will ensure that key elements of the quality and safety plans for the project are successfully implemented. The proposed audit method will include an annual program of spot audits and embed quality assurance processes within key project activities.

7.5.1 Audit Approach

It is proposed that a series of spot audits of the individual project teams (i.e. fish team, vegetation team, macroinvertebrate team, stream metabolism team, physical habitat team and hydrology team) will be undertaken over the project term. This will be a rolling program that will ensure that all individual project teams are the subject of at least one spot audit during the project term.

The Program Co-ordinator (Dr **Simon Treadwell**) or an approved delegate will conduct the spot audits. The audits will consider field, laboratory and office based activities and will focus on the quality assurance and EHS elements of the project.

It is anticipated that the spot audit framework will include the following:

- Are all personnel undertaking the monitoring activities properly trained in all assigned sampling activities?
- Are all samples being collected as per the nominated and agreed methodology?
- Are all samples being correctly labelled and preserved as per the agreed methodology?
- Are all samples being collected at the correct locations and/or are sample locations being correctly recorded?
- Are all chain of custody procedures for samples being accurately completed and adhered to?
- Has all relevant sampling equipment been maintained and calibrated as per the nominated schedules?
- Have all personnel undertaking the monitoring activities been properly inducted into the JSEA?
- Are all personnel undertaking the monitoring activities completing those activities according to the agreed work method statement?
- Are all EHS risk management/mitigation measures nominated in the JSEA being implemented by personnel undertaking the monitoring activities?
- Have all scheduled notifications (check ins) with home locations been undertaken as per agreed schedule?

The spot audit framework will be reviewed annually to ensure that the proposed audit activities are meaningful and are contributing to a quality project outcome.

7.5.2 Verification of Field and Analytical Data

A series of steps are proposed to verify all field and analytical data generated through the project:

- 1) Visual Checking – A visual check of all data will be undertaken to ensure that there are no obvious errors in data.
- 2) Regular QA/QC Reports and Audits – regular QA/QC Reports will be prepared by the discipline leads and submitted to the project coordinator to flag whether there are potential errors in data due to deficiencies in instrument calibrations, procedures etc.

7.5.3 Annual Compliance Report

At the completion of each monitoring season, each of the discipline leads will prepare a compliance (acquittal) report and submit to the Program Leader (Dr Angus Webb) or Program Co-ordinator (Dr **Simon Treadwell**) confirming that they followed the planned methods and schedules exactly and also documenting any deviations from planned approach including justification for such deviations. The compliance report will also include relevant information in relation to the following:

- Details of compliance with maintenance schedule for all nominated equipment
- Details of compliance with calibration schedule for all nominated equipment
- Details confirming adherence to chain of custody requirements for nominated samples
- Details confirming ongoing NATA accreditation for nominated laboratories undertaking sample analysis
- Training records confirming that all staff undertaking field sampling and/or sample identification are appropriately qualified and have undertaken relevant training

The outcomes of the annual spot audit program will be combined with the compliance reports and a summary of this information will be included as a section in the project annual report.

8. References

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Appendix A. Standard Operating Procedures for proposed monitoring activities.

This appendix contains Standard Operating Procedures for the following monitoring activities:

1. Fish (River)
2. Fish (Larvae)
3. Fish (Movement)
4. Vegetation Diversity
5. Macroinvertebrates
6. Stream Metabolism
7. Physical Habitat (Two Dimensional Modelling)
8. Physical Habitat (Bank Condition).

A SOP has not been prepared for Hydrology, because we are proposing to use existing flow gauges.

Appendix B.

Addendum to the Long-Term Intervention Monitoring Program for the lower Goulburn River: winter monitoring 2018–19
