Commonwealth Environmental Water Office

Long-Term Intervention Monitoring Project

Lower Murray River Selected Area

Monitoring and Evaluation Plan

Prepared by the South Australian Consortium:

SARDI, University of Adelaide, CSIRO, EPA, DEWNR and In Fusion

August 2014

This monitoring project was commissioned and funded by Commonwealth Environmental Water Office with additional in-kind support from South Australian Research and Development Institute, South Australian Department of Environment, Water and Natural Resources and Environment Protection Authority, South Australia.

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Summary

This document is the Monitoring and Evaluation Plan (M&E Plan) for the Lower Murray River Selected Area. It forms part of a national Long-Term Intervention Monitoring Project (LTIM Project) of the Murray–Darling Basin that is being coordinated and funded by the Commonwealth Environmental Water Office (CEWO). The LTIM Project will be implemented at seven Selected Areas over a five year period from 2014–15 to 2018–19, aiming to monitor and evaluate the ecological outcomes of Commonwealth environmental watering. This M&E Plan has been prepared by a South Australian consortium of agencies: South Australian Research and Development Institute, the University of Adelaide, the Commonwealth Scientific and Industrial Research Organisation, the Department of Environment, Water and Natural Resources, the Environment Protection Authority and In Fusion Consulting.

The authors of this M&E Plan have followed the guidelines and format required by the CEWO. The authors have proposed a set of evaluation questions to address Selected Area and Basin evaluation objectives for environmental watering. To address these evaluation questions, the M&E Plan proposes a range of indicators for measurement, and describes the methodologies and purpose of each indicator. The M&E Plan also outlines the communications and engagement strategy and the project management arrangements for implementing the plan. Appendix A (removed from public version) summarises the budget for all activities, including for the proposed indicators, project management, stakeholder and community engagement, synthesis reporting and evaluation.

This M&E Plan has been assessed and agreed by the CEWO. It will inform the implementation of the five-year LTIM Project in the Lower Murray River Selected Area, commencing in 2014–15.

1 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 (MDB), 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 in meeting 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 MDB 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.

1.1 The M&E Plan

A Monitoring, Evaluation, Reporting and Improvement (MERI) Framework (CoA, 2009) will be implemented through the LTIM Project to facilitate the adaptive management of Commonwealth environmental water holdings. This will include an evaluation at the Basin-scale and in seven Selected Areas within the Basin. The Basin-scale evaluation will use monitoring data collected at each of the seven Selected Areas. Details of the Basin-scale monitoring requirements and evaluation are presented in a Logic and Rationale document (Gawne *et al*. 2013b) and evaluation plan (Gawne *et al*. 2014), respectively.

The Lower Murray River (LMR) is one the seven Selected Areas for the LTIM Project. As such, a long-term (five-year) Monitoring and Evaluation Plan (M&E Plan) is required for the LMR Selected Area. The monitoring and evaluation for the LMR Selected Area will be conducted through implementation of the M&E Plan described here. The plan details the monitoring and evaluation activities that will be implemented under the LTIM Project for the LMR Selected Area. The M&E Plan includes:

- A description of the Selected Area
- 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.

2 Lower Murray River Selected Area

A detailed description of the LMR Selected Area is provided in Ecological Associates (2010) and summarised here. For the purposes of this study, the LMR Selected Area incorporates the length of the Murray River between the South Australian border and Wellington (Figure 2.1). The LMR Selected Area includes in-stream, connected wetland, floodplain and temporary non-connected wetland habitats up to the 60,000 megalitres per day (ML/day) extent, but excludes The Living Murray icon sites (Chowilla and Lake Alexandrina, Lake Albert and the Coorong).

The natural flow regime of the LMR Selected Area is highly variable because of the variable rainfall within the MDB associated with the El Niño Southern Oscillation and other atmospheric phenomena (McMahon *et al.* 1992). The LMR Selected Area has very low grades, so travel times are typically slow, with significant flows required for floodplain inundation. The biota of the LMR Selected Area has evolved to flourish under hydraulic variability, with both floods and droughts acting as intermediate disturbances that maintain biodiversity (Bunn *et al*. 2006). However, the hydrology of the Murray River in South Australia has been altered significantly by regulation and diversions (Maheshwari *et al.* 1995). The ecologically significant effects of regulation and diversions are:

- Loss of flowing water habitat
- Permanent inundation of wetlands, the river channel and low-lying floodplain areas in the vicinity of the weir pools
- Reduction in the frequency of inundation in higher wetlands and floodplain areas.

Despite these changes, the LMR Selected Area has high habitat and biological diversity and includes important habitat for a number of listed species, including:

- Southern bell frog (nationally threatened, *Environment Protection and Biodiversity Conservation Act 1999* – EPBC Act)
- Listed migratory waterbirds (EPBC Act)
- Numerous state and nationally listed waterbird species
- Large-bodied native fish (Murray cod, freshwater catfish, silver perch)
- Small-bodied native fish (Murray hardyhead, unspecked hardyhead, dwarf flathead gudgeon, Murray rainbowfish).

The South Australian Murray River remains in recovery phase from the impacts of prolonged drought prior to 2010–11. High flow peaks of 93,000 and 60,000 ML/day in the 2010–11 and 2011–12 water years respectively, followed by moderate flow years have assisted the recovery process (Ye *et al*. 2013a).

For the purpose of this study, the LMR Selected Area is considered to have three major geomorphic zones (Figure 2.1): the Floodplain (Border to Lock 3), the Gorge (Lock 3 to Mannum), and the Swamplands (Mannum to Wellington), which are described below.

2.1 The Floodplain

The Floodplain is between the South Australian border and Lock 3. Here the river meanders through a broad floodplain up to 8 kilometres wide, with high geomorphic diversity including anabranches, backwaters and wetlands (Walker and Thoms 1993). The Floodplain section includes the Riverland Ramsar site and a number of large wetlands, including Lake Bonney, Wachtels Lagoon, Gurra Lakes, Lake Merreti, Lake Woolpolool, Coombool Swamp, Clover Lake, Lake Littra and Bulyong Island. Small wetlands, less than 50 hectares in area, make up the majority of total wetland area. Under regulated conditions, 70 percent of wetlands (approximately 7,000 hectares) are permanently inundated. Increasing river flow does not significantly increase the inundation of the floodplain area (including floodplain vegetation communities) until flows of approximately 55,000 ML/day are reached.

2.2 The Gorge

The Gorge is between Lock 3 (Overland Corner) and Mannum. Here, the channel is characterised by long, straight reaches within a 30 metre deep limestone gorge with a narrow floodplain (2–3 kilometres wide) with geomorphology that is largely undisturbed. The Gorge section includes numerous wetlands including the Banrock Station Ramsar site. Just under half of the total wetland area is permanently inundated, with most of the remaining area inundated at flows of 30,000 ML/day. As in the Floodplain, significant floodplain inundation commences at flows above 55,000 ML/day.

2.3 The Swamplands

The Swamplands are between Mannum and Wellington. Here, the river corridor remains confined within the gorge with a narrow floodplain (1–2 kilometres wide), but a large proportion of the floodplain has been developed for irrigated agriculture with levee banks constructed that have largely isolated the floodplain from the main river channel. This has resulted in a loss of floodplain habitat, native vegetation and natural geomorphic characteristics. There are eight wetlands more than 50 hectares in size and these represent approximately two-thirds of the total wetland area, but less than 10 percent of the total number of wetlands. Most wetlands are permanently inundated, with a small additional area inundated by flows exceeding 30,000 ML/day. Greater floodplain inundation commences at flows exceeding 55,000 ML/day.

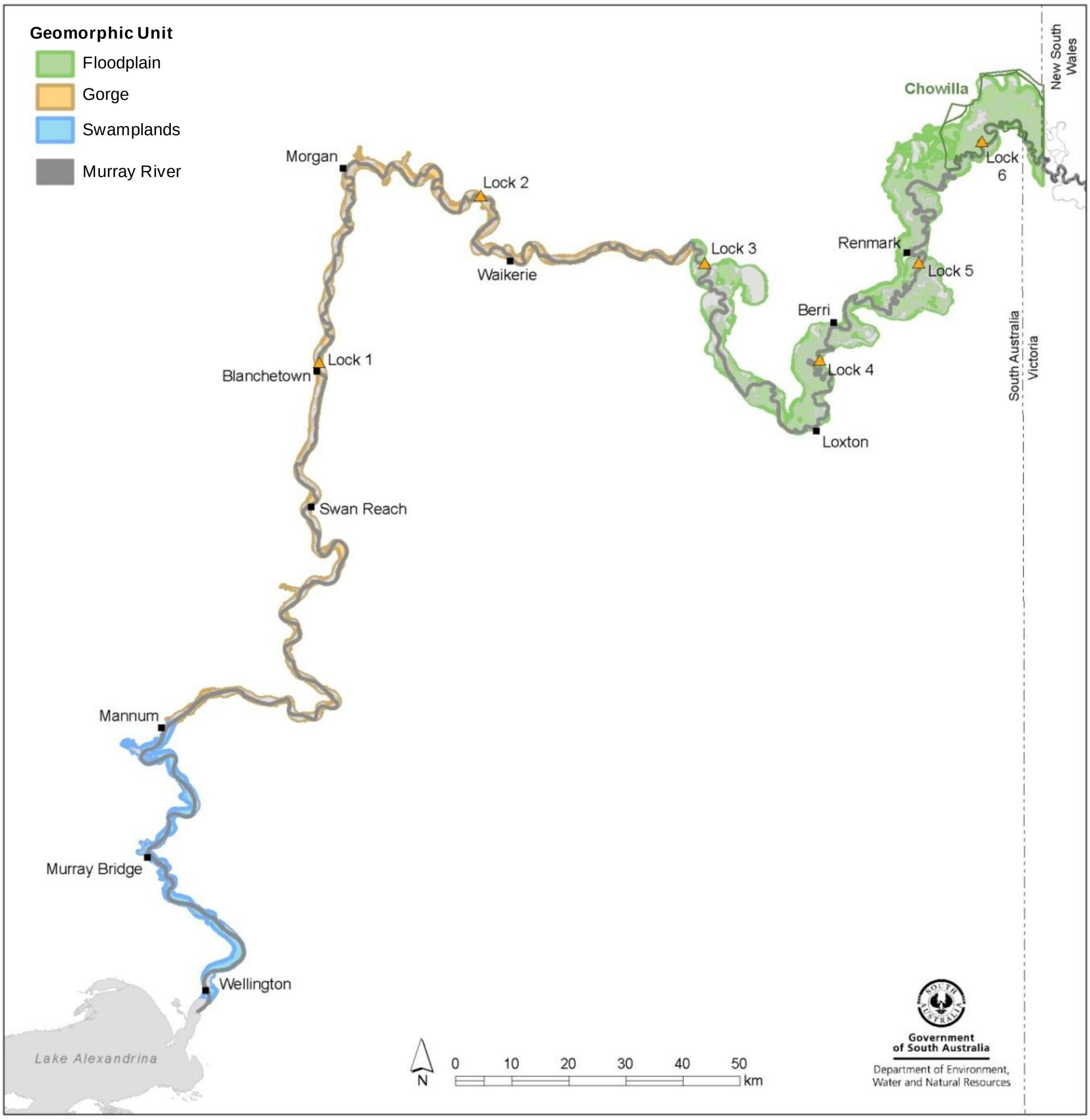

Figure 2.1. Map of the LMR Selected Area, including the locations of the three major geomorphic zones (Floodplain, Gorge and Swamplands), locks and major towns.

3 Commonwealth environmental watering

3.1 What types of watering are proposed?

The MDB Plan and Gawne *et al*. (2013a) outline a number of generalised flow types, illustrated in Figure 3.1. *Cease-to-flow* events do not occur in the LMR Selected Area, as minimum water levels and flows are maintained by river regulation and South Australian entitlement flows. Thus, *base flows* in the LMR Selected Area also cannot be significantly influenced by environmental water provisions. *Freshes* and *bankfull flows* can largely be considered as equivalent within the LMR Selected Area, because they will both result in an increase in stream velocities and only minor additional inundated area. Herein, *freshes* and *bankfull flows* are both described as *freshes*.

Within the five year monitoring and evaluation period, it is expected that a majority of the Commonwealth environmental water provisions within the LMR Selected Area will be used to contribute to freshes. These Commonwealth environmental water provisions will be used to complement *natural freshes* and in doing so increase the magnitude or duration of an event. However, freshes may also be created solely through the provision of Commonwealth environmental water. Should suitable climatic and hydrological conditions transpire during the five year period, Commonwealth environmental water provisions may also be used to complement *natural overbank flows* and in doing so increase the magnitude or duration of these events.

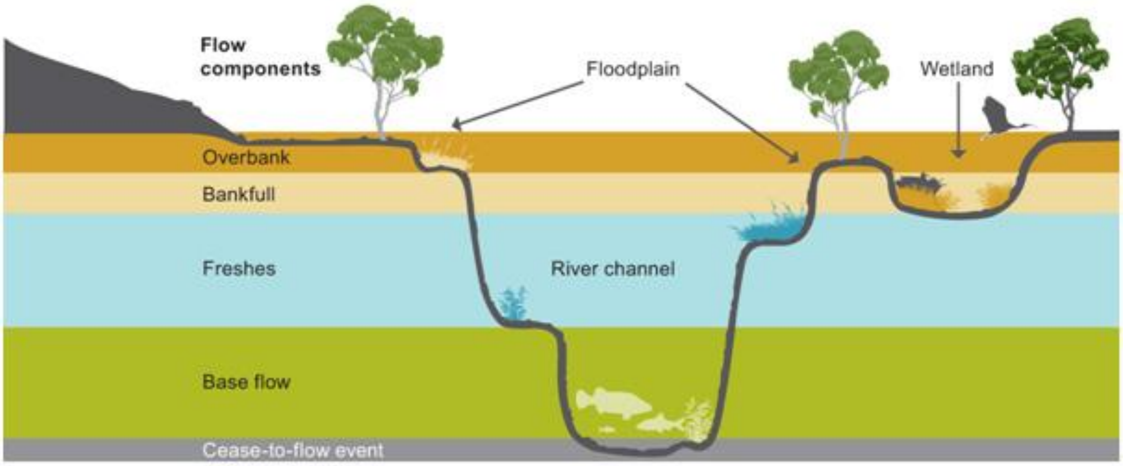

Figure 3.1. The various flow types as described by the Murray–Darling Basin Plan and Gawne *et al*. (2013a).

3.2 Practicalities of watering

Environmental water provisions to the LMR Selected Area are sourced from multiple locations, including tributary storages and natural inflows. The environmental water will be delivered across the South Australian border in addition to the South Australian entitlement flows. Commonwealth environmental water available for use in the LMR Selected Area will depend on the inflow scenarios, water available in the Commonwealth environmental water holdings, and delivery constraints.

The volumes of environmental water delivered to the LMR Selected Area is constrained by risks associated with the flooding of property and infrastructure, impacts to river and floodplain work programs, and the practical feasibility of contributing water to natural high flow events. The MDBA is developing a constraints management strategy, but over the five year evaluation period it is expected that environmental flow provisions would be limited to events of less than 60,000 ML/day, and that a maximum of 10,000 ML/day would be added to a natural event (see Gawne *et al*. 2013a for further details).

Commonwealth environmental water provision to the LMR Selected Area may be complemented with other sources of environmental water, which are detailed in Gawne *et al*. (2013a). They include water held by The Living Murray Program and the South Australian Department of Environment, Water and Natural Resources (DEWNR). In addition to the environmental flow provisions, environmental water may be used for other complementary management actions aimed at achieving environmental outcomes within the LMR Selected Area (e.g. weir pool manipulation, operation of environmental regulators, pumping).

The implementation of watering options in the LMR Selected Area is undertaken through the coordination of river operations across the Southern Connected Basin, in negotiation between DEWNR, CEWO, MDBA and other jurisdictional operations units. To effectively implement the LMR Selected Area M&E Plan, a proposed hydrograph of flow to South Australia would need to be available to the project team, with regular updates provided as information becomes available.

3.3 What are the expected outcomes?

The provision of Commonwealth environmental water to increase the magnitude or duration of natural freshes and overbank flows is expected to make significant contributions to environmental outcomes within the LMR Selected Area, through changes to the main channel and floodplain (including wetland) habitats. A consolidated view of the expected outcomes for the main channel is presented in Figure 3.2 below.

As identified previously, within the five year monitoring and evaluation period it is expected that a majority of the Commonwealth environmental water provisions to the LMR Selected Area will be used to contribute to freshes. It is anticipated that these provisions will: increase stream velocity, mixing and dilution; increase variability in water levels; and increase the inundated area of low-lying wetlands, channels and floodplains. These changes to hydrological conditions within the LMR Selected Area are expected to lead to:

- Increased larval abundance of flow-dependent fish species due to the provision of flow-cues for spawning and increased larval drift and dispersion
- Increased recruitment of flow-dependent fish species due to increased spawning and larval drift, and enhanced survival rate due to increased productivity.
- Increased productivity and transport of organic material downstream
- Increased transport of dissolved and particulate matter (salt and nutrients) downstream due to mobilisation and discharge
- Increased microinvertebrate diversity and abundance

It is anticipated that these outcomes will be reflective of broader environmental outcomes within the LMR Selected Area.

Indicators in this M&E Plan were chosen on the basis of their capacity to assess various Basin-scale and LMR Selected Area evaluation questions. There are specific evaluation questions for each indicator (see Section 4). The overall key evaluation questions for the plan are, what did Commonwealth environmental water provision contribute to:

- Increased ecosystem productivity
- Increased spawning and recruitment of flow-dependent fish species
- Increased transport of dissolved and particulate matter
- Increased microinvertebrate diversity and abundance

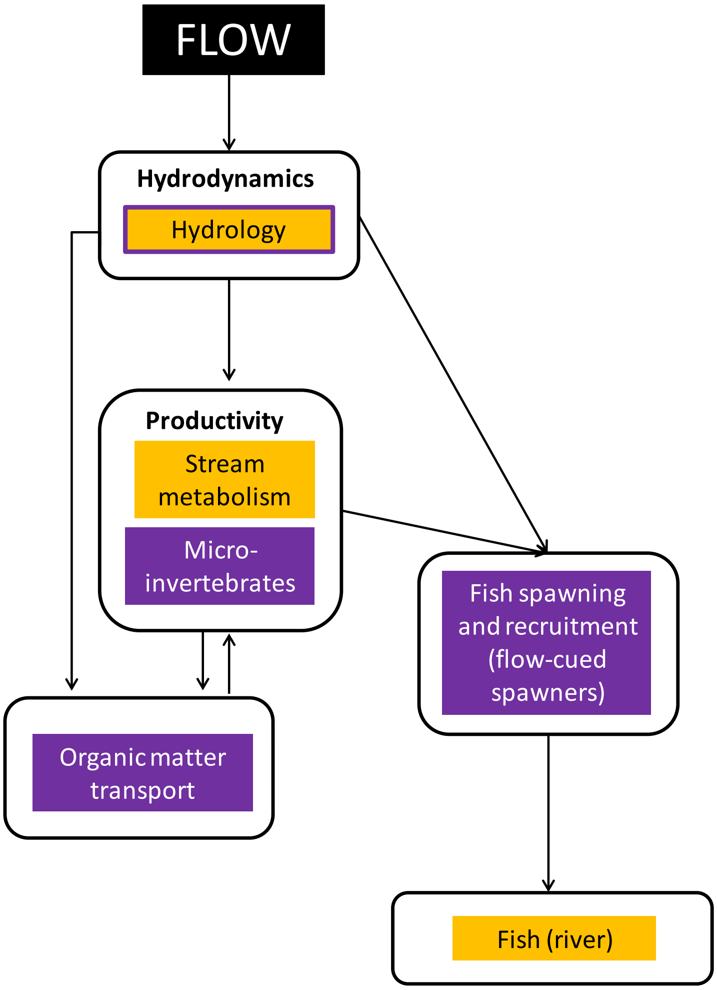

Figure 3.2. Cause and effect diagram of flow for the main channel of the LMR Selected Area with respect to the proposed category indicators. Category 1 indicators are highlighted in orange and category 3 indicators in purple. Magnitude, timing and duration are factors of flow (in black).

4 Indicators

A number of indicators from categories 1 and 3 have been identified for the LMR Selected Area, in line with Commonwealth environmental watering evaluation needs for the Basin and Selected Area. Category 1 indicators are mandatory indicators with standard protocols, and are required to inform quantitative Basin evaluation. Category 3 indicators are those proposed by the project team for targeted investigations and hypothesis-driven monitoring of flow-related ecological responses in the LMR Selected Area, aiming to evaluate ecological outcomes and support adaptive management for Commonwealth environmental watering. Monitoring these different categories of indicators will enable the effects of Commonwealth environmental watering to be evaluated in the local hydrological, geomorphological and ecological setting.

Category 1 indicators for the LMR Selected Area are:

- Stream metabolism
- Fish (River)
- Hydrology (River).

Category 3 indicators for the LMR Selected Area are:

- Fish spawning and recruitment (flow-cued spawners)
- Dissolved organic and particulate matter transport
- Hydrological regime
- Microinvertebrate diversity.

Ecosystem type (validation) (Category 1 indicator for the LMR Selected Area) is the field validation of the ANAE classification that is required for Basin-scale evaluation of ecosystem diversity for the LTIM Project. For the LMR Selected Area, the field sampling will be focused on channel habitats, which have already been classified as permanent lowland rivers. As the river typology that applies to all in-channel sites is very coarse; there is no need to undertake the validation activity during the current LTIM project. The cause and effect diagram for the LMR Selected Area (Figure 3.2) and those for selected indicators in Sections 4.1 and 4.2 (Figure 4.2,Figure 4.3, Figure 4.5, Figure 4.6,Figure 4.8) illustrate our conceptual understanding of the ecological processes and life histories of relevant biota, and the expected responses from Commonwealth environmental water delivery. Hypotheses are based on these concepts, and monitoring is designed to assess flow responses and ecological outcomes. This intervention monitoring approach allows strong inferences to be drawn regarding the contribution of Commonwealth environmental water to ecological outcomes in the LMR Selected Area. Data and knowledge developed from intervention monitoring will also underpin adaptive environmental flow management.

Table 4.1 below provides a summary of the indicators proposed for the LTIM Project in the LMR Selected Area. It includes indicator categories, objectives and hypotheses, and a brief comment about the strength or limitation of each indicator.

The following sections (Sections 4.1 and 4.2) provide further details for each indicator, including background, cause and effect diagrams, objectives and hypotheses, general methodologies, outputs and key staff involved. More details are available in the Standard Operating Procedures (SOPs) for each indicator in Appendix B. An annual budget for each indicator, along with a more detailed breakdown of the budget is available in Appendix A. A matrix table linking indicators to the ecological objectives for the Basin Plan, CEWO and Selected Area and the one and five year evaluation questions is presented in Appendix C. Note that colour schemes for cause and effect diagrams are taken from MDFRC (2013) (Figure 4.1).

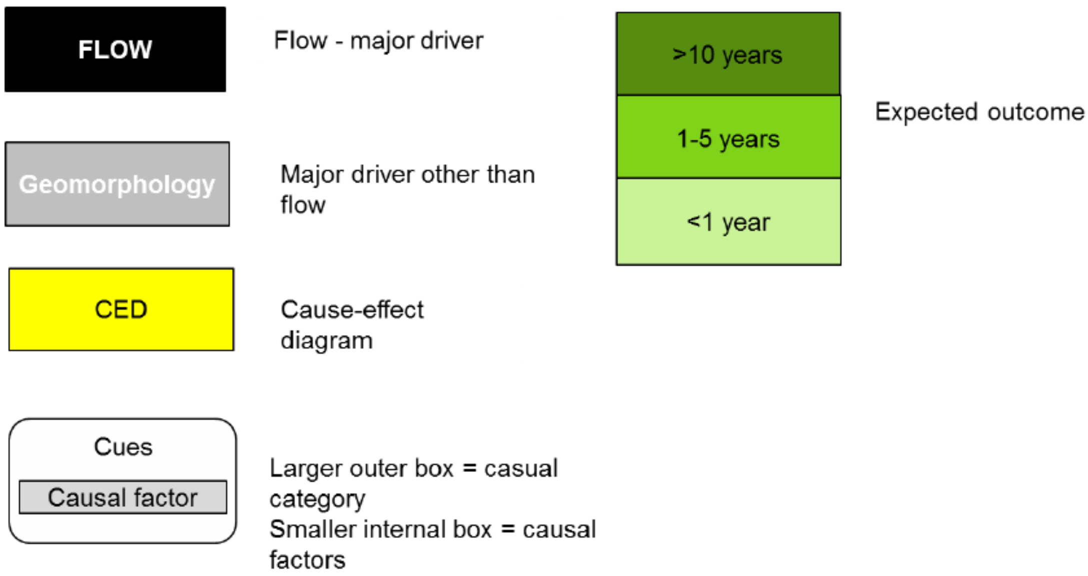

Figure 4.1. Key for cause and effect diagrams (taken from MDFRC 2013) that are provided in Sections 4.1 and 4.2.

Table 4.1. Category 1 and 3 indicators for the LMR Selected Area for the LTIM Project with evaluation questions, objectives and hypotheses. Short-term (one-year) and long-term (five-year) evaluation questions are the CEWO Basin-scale questions.

Cat	Indicator	Evaluation questions	Objectives and hypotheses	Comments
1	Stream metabolism	Short-term and long-term questions: • What did CEW contribute to patterns and rates of decomposition? • What did CEW contribute to patterns and rates of primary productivity? • What did CEW contribute to dissolved oxygen levels?	Objective: • Assess how environmental water influences primary production and ecosystem respiration in the river channel. Hypotheses: • During in-channel flows, the transport of organic material from the floodplain is low and autochthonous carbon is the major source of energy to the aquatic food webs. • Water quality influences the growth of plants (microalgae and macrophytes) by modifying light and nutrient availability, and influences the supply of autochthonous organic carbon to food webs. • Increasing flow better connects the channel with riparian, wetland or floodplain areas and enhances the supply of allochthonous organic carbon to the river channel, leading to increased energy supplies and enhanced ecosystem respiration rates due to decomposition. • Excessive loads of organic carbon increase respiration and decomposition rates and reduce dissolved oxygen concentrations to levels below those required by aquatic organisms, with potentially lethal effects. • Increased energy supply leads to increased food web size and complexity that can support larger populations of organisms that are dependent on aquatic systems for food supplies.	Important component of Basin-scale outcome evaluation, and strong capacity to infer outcomes across the LMR Selected Area

Cat	Indicator	Evaluation questions	Objectives and hypotheses	Comments
1	Fish (River)	Short-term questions: • What did CEW contribute to native fish community resilience? • What did CEW contribute to native fish survival? Long-term questions: • What did CEW contribute to native fish populations? • What did CEW contribute to native fish diversity?	Objective: • Determine presence or absence, relative abundance and age or size structure for certain key species.	Designed for Basin-scale evaluation, but will not provide a direct relationship with flow and will not answer evaluation questions for CEW in the LMR Selected Area
1	Hydrology (River)	This method does not include any short or long-term evaluation questions. However, this indicator contributes to the evaluation of a broad range of questions.	Objective: • Provide discharge and water level data to inform other indicators. Hypothesis: • N/A	Incorporates monitoring of daily discharge

Cat	Indicator	Evaluation questions	Objectives and hypotheses	Comments
3	Fish spawning and recruitment (flow-cued spawners)	Short-term questions: • What did CEW contribute to native fish reproduction? • What did CEW contribute to native larval fish growth and survival? Long-term questions: • What did CEW contribute to native fish populations? • What did CEW contribute to fish population/community resilience? • What did CEW contribute to native fish survival?	Objectives: • Compare and contrast spawning response to various environmental water deliveries • Compare and contrast recruitment success in response to various CEW deliveries • Compare and contrast the timing of spawning and source (i.e. natal origin) of new recruits in response to various environmental water deliveries • Identify potential associations between reproduction (spawning and recruitment) and environmental water delivery (e.g. magnitude, timing and source) • Determine population connectivity between regions (e.g. whether larvae spawned in the Goulburn recruiting to LMR Selected Area populations). Hypotheses: • Increases in flow above regulated entitlement flow (in-channel or overbank) in spring–summer will promote the spawning and recruitment (to YOY) of golden perch and silver perch. • Multiple years of enhanced spring–summer flow will increase the resilience of golden perch and sliver perch populations in the LMR	Enables the explicit association of fish spawning and recruitment with flow Provides complementary information at different life stages on three time scales (near real-time, yearly and 5-yearly) to inform adaptive management. Historical data from SARDI will provide extended temporal interpretation Allows evaluation of CEW at both local and Basin-scale, and addresses both Selected Area and Basin-wide ecological objectives Larval abundance data obtained by tows may complement Category 2 indicators in other Selected Areas

Cat	Indicator	Evaluation questions	Objectives and hypotheses	Comments
3	Dissolved organic and particulate matter transport*	Short-term and long-term questions: • What did Commonwealth environmental water contribute to nutrient and carbon cycling? • What did Commonwealth environmental water contribute to salinity regimes? • What did Commonwealth environmental water contribute to sediment transport? • What did Commonwealth environmental water contribute to patterns and rates of primary productivity? • What did Commonwealth environmental water contribute to ecosystem function? • What did Commonwealth environmental water contribute to water quality?	Objectives: • Assess whether CEW has increased the transport and export of salt, nutrients and suspended solids through the LMR Selected Area. Hypotheses: • CEW will increase the mobilisation of salts from the Basin and increase the transport of salt passing from Lock 1 through the LMR Selected Area (and through the Lower Lakes and Murray Mouth). • CEW will increase the mobilisation of nutrients from the Basin and increase nutrient loads passing from Lock 1 through the LMR Selected Area (and through the Lower Lakes and Murray Mouth). • CEW will increase suspended solid loads (including phytoplankton biomass) passing from Lock 1 through the LMR Selected Area (and through the Lower Lakes and Murray Mouth).	Responsive to flow and capacity to directly evaluate contributions of CEW
3	Hydrological regime	Short-term question: • What did CEW contribute to help increase hydraulic diversity within weir pools? • What did CEW contribute to temperature regimes? Long-term question: • What did CEW contribute to hydrological connectivity? • What did CEW contribute to temperature regimes?	Objective: • Assess how CEW has contributed to an increase in discharge, velocity and depth of flow at a high spatial and temporal resolution. Inundated area will also be reported if overbank flows occur. Hypothesis: • CEW will increase metrics representing desirable conditions, for example increased velocities and increased variability in water levels.	Includes modelling to assess CEW contribution Outputs will also input to other indicators

Cat	Indicator	Evaluation questions	Objectives and hypotheses	Comments
3	Microinvertebrate diversity*	Short-term question: • What did CEW contribute to microinvertebrate diversity?	Objectives: • Compare and contrast potamoplankton assemblages pre- and post-CEW. • Compare and contrast littoral microcrustacean assemblages pre- and post -CEW. • Identify dietary items of juvenile fish collected concurrently with microinvertebrate samples. • Compare dietary item proportions to ambient microinvertebrate composition to determine selectivity of feeding. Hypotheses: • Microinvertebrate taxonomic diversity will increase in inundated habitats due to increases in available habitat by triggering propagules deposited in sediments. • Microinvertebrate abundance will increase in inundated habitats in response to increased egg production by resident or transported populations. • Microinvertebrate assemblage responses will be reflected in the dietary components of larval/juvenile fish.	Follows the standard method developed by Jenkins (2014).

*Category 3 Matter transport and Microinvertebrate diversity indicators have additional Selected Area scale evaluation questions, which are presented in Section 4.2 (pgs 34 and 40) and Appendix B (pgs 120 and 127).

4.1 Category 1

4.1.1 Stream metabolism

Indicators

Dissolved oxygen concentrations and diel oxygen fluctuations to assess the influence of environmental flows on:

- River dissolved oxygen concentrations supportive of biota
- Rates of photosynthesis
- Rates of ecosystem respiration including decomposition.

Concentrations of phytoplankton, nutrients, and organic carbon to identify:

- Phytoplankton contributions to photosynthesis and respiration
- Influence of organic carbon concentrations on ecosystem respiration
- Nutrient, phytoplankton and metabolism links to environmental flows

Background

Under the LTIM Project, stream metabolism is measured for two purposes (Hale *et al*. 2014):

- Inform the Basin-scale quantitative evaluation of fish responses to Commonwealth environmental water (see LTIM Standard Protocol: Fish (River))
- Detect changes in primary productivity and decomposition in the river in response to Commonwealth environmental water.

River metabolism measurements estimate the in-stream rates of photosynthesis and respiration and provide information on the energy processed through river food webs (Odum 1956, Young and Huryn 1996, Oliver and Merrick 2006). Metabolism measurements help identify whether the sources of organic material that provide the food resources have come from within the river (autochthonous) or from the surrounding landscape (allochthonous).

Stream metabolism can be measured by monitoring rates of change in the dissolved oxygen concentration over sequences of day and night cycles (diel changes). These changes in concentration are caused by the balance between photosynthetic oxygen production which occurs in the light, and oxygen depletion by respiration which occurs continuously. Suitable concentrations of dissolved oxygen are required for aquatic organisms to survive. Monitoring can inform on the mean oxygen levels, their changes in response to environmental flows, and likely impacts on the biota.

In conjunction with water quality data, the metabolism measurements can indicate whether photosynthetic production was associated with phytoplankton or other aquatic plants. By estimating the magnitude of the total energy transfers relative to the supply from in-stream photosynthesis, the role played by other sources of organic carbon can be identified.

Measurements of stream metabolism describe the fundamental trophic energy connections that characterise different food web types (e.g. detrital, autotrophic, planktonic). They indicate the size of the food web and its capacity to support higher trophic levels including fish and water birds (Odum 1956, Young and Huryn 1996, Oliver and Merrick 2006).

Cause and effect diagram

The cause and effect diagrams and background information presented in MDFRC (2013) for primary productivity and decomposition are applicable to this investigation. Refer to MDFRC (2013) for further details.

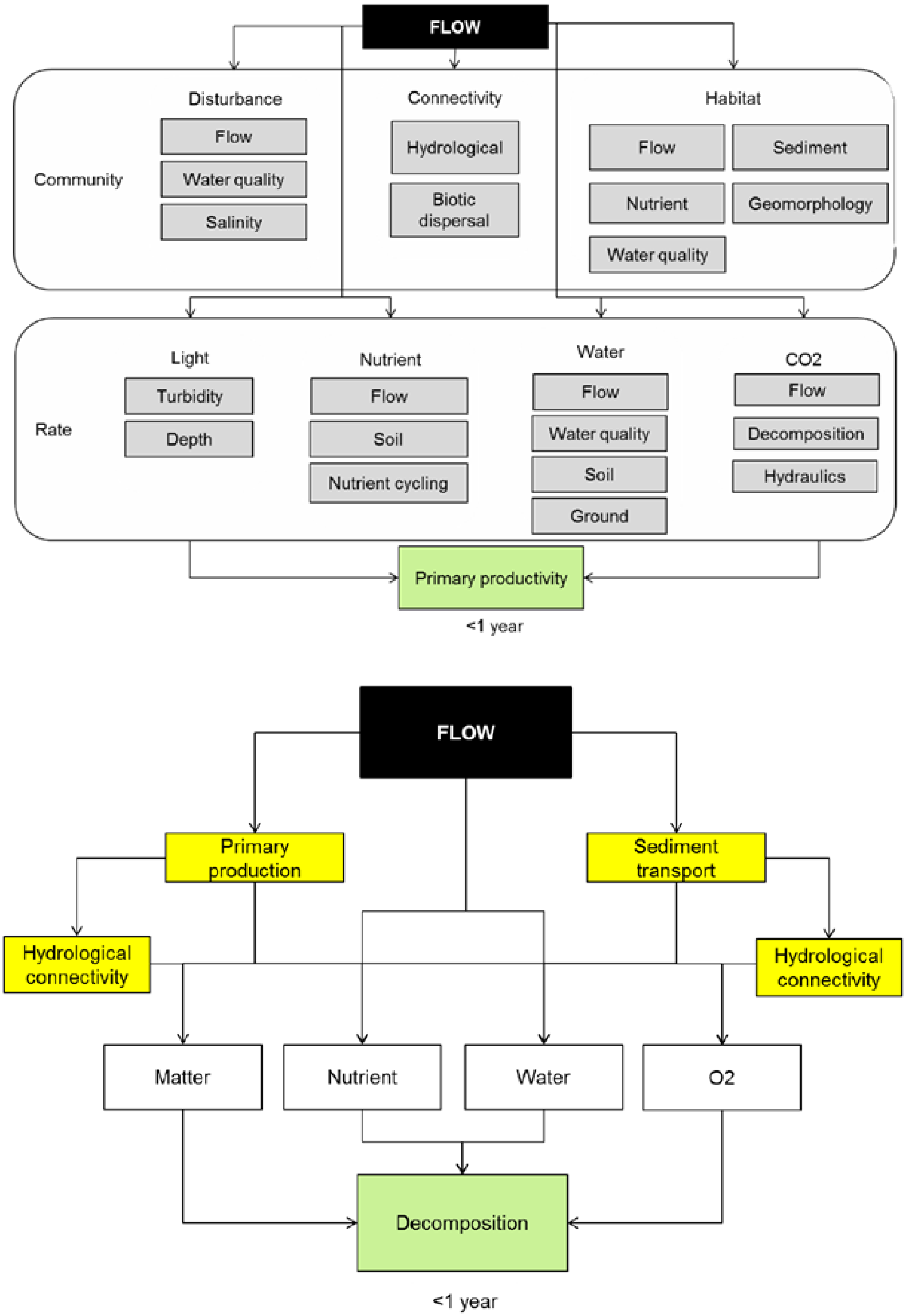

Figure 4.2. Cause and effect diagrams depicting the influence of flow on the components of stream metabolism, on primary productivity (top) and decomposition (bottom) (MDFRC 2013). Magnitude, timing and duration are factors of flow (in black).

Key evaluation questions

Short-term (one-year) and long-term (five-year) Basin and Selected Area questions (Hale *et al.* 2014):

- 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?
- What did Commonwealth environmental water contribute to dissolved oxygen levels?

Objectives and hypotheses

The objective of this indicator is to:

- Assess how environmental water influences primary production and ecosystem respiration in the river channel.

Major hypotheses are:

- During in-channel flows the transport of organic material from the floodplain is low and autochthonous carbon captured in-stream through photosynthesis is the major source of energy to the aquatic food webs.
- Water quality influences the growth of aquatic plants (microalgae and macrophytes) by modifying light and nutrient availability and influences the supply of autochthonous organic carbon to food webs.
- Increasing flow better connects the channel with riparian, wetland or floodplain areas and enhances the supply of allochthonous organic carbon to the river channel, leading to increased energy supplies and enhanced ecosystem respiration rates due to decomposition.
- Excessive loads of organic carbon increase respiration and decomposition rates and reduce dissolved oxygen concentrations to levels below those required by aquatic organisms, with potentially lethal effects.
- Increased energy supply due to enhanced aquatic photosynthetic production or enhanced supply of externally sourced organic carbon leads to increased food web size and complexity that can support larger populations of organisms dependent on aquatic systems for food supplies.

General methodology

This protocol is based on the single station open water stream metabolism method as detailed in Oliver and Merrick (2006), Oliver and Lorenz (2010) and Grace and Imberger (2006).

Measurements of water level and stream characteristics including water velocity, channel cross-sectional area and average depth of sampling sites will be provided from established gauging stations in the LMR in conjunction with site measurements during sampling trips. Discrete water quality samples will be collected for the analyses of chlorophyll-*a*, total nitrogen, NO_X, NH_4, total phosphorus, PO_4, and dissolved organic carbon. *In situ* logging of the dissolved oxygen concentration and temperature will provide data for estimating stream metabolism at the two sampling sites selected to represent the two zones (Gorge and Floodplain) of the LMR Selected Area. A terrestrial station logging photosynthetically active radiation (PAR) and barometric pressure to match the stream metabolism measurements will be established in a suitable nearby location.

Refer to the LMR Selected Area SOP for Category 1 Stream metabolism (Appendix B, pg 86) for more information on the sampling protocol including sites, timing and equipment, and on data analysis and evaluation, data management and quality assurance/quality control measures. Refer to Section 5 for timing of monitoring activities and more information on sampling sites and zones.

Outputs

- Annual reports on the stream metabolism in response to flow regime, including environmental water delivery, in the LMR Selected Area. The report will include:
    - Evaluation of the benefits of environmental flows to oxygen concentrations, primary production and ecosystem respiration
    - Assessment of the influences of water quality and connectivity on stream metabolism as related to environmental water
- Measurements of river metabolism suitable for Basin-wide comparisons
- Measurements of metabolism suitable for comparison with other aquatic indicators, especially fish population changes in response to environmental water.

Staff

Dr Rod Oliver ***CSIRO***

Rod Oliver is a senior Principal Research Scientist and the Research Program Leader for Catchment Biogeochemistry and Aquatic Ecology in CSIRO Land and Water. He has 25 years experience in aquatic ecology working on reservoirs, lakes, rivers and wetlands. His research is aimed at understanding the effects of physical and chemical conditions on the population dynamics and community composition of phytoplankton, and how these interactions influence water quality, aquatic food webs, and ecosystem function. His current research is focussed on developing methods for assessing changes in the composition and activity of the micro-biota of riverine food webs using eco-physiological and molecular tools. This has included extensive use of stream metabolism measurements. He has numerous publications, including journal papers, articles, and book chapters.

Zygmunt Lorenz ***CSIRO***

Zygmunt Lorenz has an MSc in aquatic systems measurement and modelling with over 15 years experience working in the MDB. He recently played a critical role in the analysis of the Coorong Lower Lakes and Murray Mouth monitoring data for DEWNR through his computing and data management skills. The areas of direct research experience that are relevant to the LTIM Project are:

- Detailed knowledge of deploying, maintaining and managing electronic monitoring equipment including sensor systems, data loggers, GPS mapping, and remote communications. Experienced with design and construction of associated mounting frames and incubation chambers
- Experienced in aquatic sampling protocols for biota, water quality and physical attributes with extended experience measuring river metabolism and phytoplankton eco-physiology
- Extensive experience in planning and running complex field trips including operation of boats, vehicles, and sampling equipment
- Excellent computer programming skills in multiple languages including 'R', with experience in development and maintenance of large databases, large-scale statistical data analyses, and preparation of publication quality material
- Experienced with ecohydrological analyses of hydrographs and description of watering regimes (spell analyses, peak flows etc.).

Field Assistant ***CSIRO***

An experienced aquatic systems field assistant with the necessary vehicle (4WD) and boat licences and training to meet CSIRO health and safety standards. Has a working knowledge of logging and sensor systems, their deployment, maintenance, calibration and data downloading and handling. Experienced with water sampling techniques, sample integrity, storage and transport requirements. Collates, stores and maintains raw data records and undertakes basic statistical analyses. Essential support for Zygmunt Lorenz on aquatic field trips as it is mandatory for CSIRO that two experienced personnel participate when working on water.

4.1.2 Fish (River)

Indicators

- Fish diversity
- Fish population dynamics.

Background

River regulation and flow modification have a profound impact on ecosystem processes and aquatic biota, including fish populations. In the MDB, many native fish species have suffered significant declines in abundance and distribution in the last hundred years due to river regulation and other anthropogenic perturbations (MDBC 2013). This study was designed by the M&E Advisers (MDFRC) of the CEWO to address Basin-scale evaluation of the response of river fish (large- and small-bodied) to Commonwealth environmental water (for details see Hale *et al*. 2014).

Cause and effect diagram

The cause and effect diagram and background information presented in MDFRC (2013) for landscape fish diversity is applicable to this investigation (Figure 4.3). Refer to MDFRC (2013) for further details.

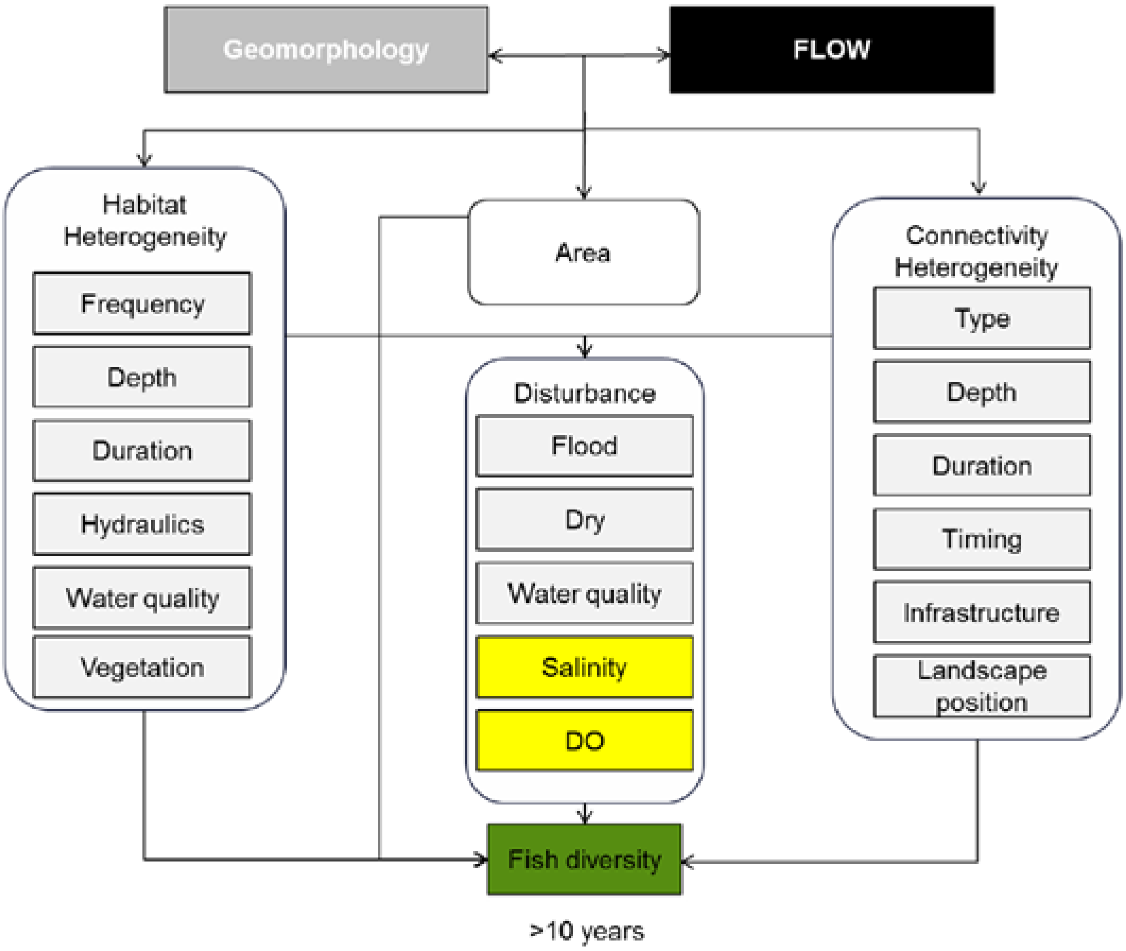

Figure 4.3. Fish (River) cause and effect diagram (MDFRC 2013). Magnitude, timing and duration are factors of flow (in black).

Key evaluation questions

Short-term (one-year) Basin and Selected Area question (Hale *et al.* 2014):

- What did Commonwealth environmental water contribute to native fish reproduction?
- What did Commonwealth environmental water contribute to native fish survival?

Long-term (five-year) Basin and Selected Area questions (Hale *et al.* 2014):

- What did Commonwealth environmental water contribute to native fish populations?
- What did Commonwealth environmental water contribute to native fish diversity?

Objective

The objective of this indicator is to:

- Determine presence or absence, relative abundance and age or size class structure for certain key species.

General methodology

This protocol follows the methods outlined in Hale *et al.* (2014). Sampling will occur in the Gorge zone each year using electrofishing (active sampling) and small-meshed fyke nets (passive sampling) to measure catch-per-unit-effort (CPUE) of fish species. Population structure (i.e. length, weight and age structure) data will be collected for target species. Target species include two equilibrium (Murray cod and freshwater catfish), two periodic (golden perch and silver perch) and two opportunistic (carp gudgeon and Murray rainbowfish) life-history species.

Refer to the LMR Selected Area SOP for Category 1 Fish (River) (Appendix B, pg 97) for more information on the sampling protocol including sites, timing and equipment, and on data analysis and evaluation, data management and quality assurance/quality control measures. Refer to Section 5 for timing of monitoring activities and more information on sampling sites within the zone.

Outputs

- Relative abundance estimation, population structure and community data will be submitted as described in Hale *et al*. (2014), complying with data standards as per Brooks and Wealands (2014).
- A brief section will be included in annual M&E report about Fish (River) activity, with basic summary statistics.

Staff

Dr Qifeng Ye ***SARDI***

Qifeng Ye is the principal scientist and science leader for the SARDI Inland Waters and Catchment Ecology research program. She has a range of skills and extensive research experience in fish and fishery biology and ecology and population dynamics, accumulated through 20 years of environmental and fishery related work. This has been done in freshwater, marine and estuarine systems in several countries. Qifeng has an excellent knowledge of the biology and habitat and environmental water requirements of native fish and the potential ecological impacts of river regulation. She has led and played a substantial role in a number of significant environmental flow related projects, particularly in the MDB and the South East region of South Australia. Qifeng represented South Australia on the MDBA Fish Advisory Panel. She is a member of a number of science and management committees at state and national levels, including the national Murray Cod Fishery Management Group and CLLMM Science Advisory Group.

Brenton Zampatti ***SARDI***

Brenton Zampatti is a senior research scientist at SARDI Aquatic Sciences and has been conducting research on the flow related ecology of freshwater and estuarine fish for the past 18 years. Brenton has a broad understanding of the ecology and hydrology of rivers in the MDB and has published extensively on the ecology of fish throughout south-eastern Australia. Brenton has played a key role in a number of multi-disciplinary and cross-jurisdictional environmental water requirement (EWR) projects, including development of a multi-disciplinary technique for the establishment of EWRs for rivers in south-eastern Australian (FLOWS) for the Victorian Government, and a review of environmental requirements for managing fish recruitment in the Murray River for the MDBA. Brenton is currently undertaking large-scale research projects on the ecology of fish throughout the lower Murray and Darling Rivers, including the Chowilla, Katarapko and Pike Anabranch systems and the Coorong Lower Lakes region in South Australia. These projects are directly informing the management of water resources and river operations, including the delivery of environmental water by the MDBA and CEWO.

Dr Juan Livore ***SARDI***

Juan Livore completed his PhD in ecology at The University of Adelaide. He has 10 years of research experience in ecology. From his work he has authored or co-authored nine research articles in international journals. Juan's research interests focus on the dynamics of aquatic ecosystems in relation to environmental variables, particularly on how species and ensuing communities respond to changes in their environment. This knowledge allows for better management of impacted ecosystems by providing the capacity to predict the direction and magnitude of community shifts as a consequence of environmental changes. Since 2011 he has worked within the Inland Waters and Catchment Ecology program at SARDI on several projects related to Murray River and the Coorong, he has collaborated with field, lab and reporting duties.

Luciana Bucater ***SARDI***

Luciana Bucater is an experienced fisheries ecologist, and has worked on a range of research over the past 12 years. She is particularly interested in fish biology, early life history of fish, and the application of GIS in fisheries research. She migrated from Brazil in 2004 and since then she has been involved in research both in NSW and SA. Since 2007 she has been part of the Inland Waters and Catchment Ecology team at SARDI Aquatic Sciences, having been involved in various projects assessing changes in fish assemblage associated with different flow scenarios in the Lower River Murray, Lakes and Coorong. Information generated from these work has been used extensively by the state government agencies in management of the region.

Phillipa Wilson ***SARDI***

Phillipa Wilson is a research officer with the Fish Ecology Sub-program of Inland Waters and Catchment Ecology Program at SARDI. She graduated from Flinders University in 2005 and has since worked at SARDI Aquatic Sciences and the Western Australian Department of Environment and Conservation. Phillipa has a great knowledge of MDB fish and the methods used to study them both in the field and the laboratory.

Ian Magraith ***SARDI***

Ian Magraith is a senior technical services officer who has been working in the field of environmental research for over 20 years. Ian worked for the University of Adelaide Zoology and Botany Departments as a technical officer throughout the 1990s and early 2000s before joining SARDI in 2003. Ian is a highly experienced technical officer offering many skills and expertise in boating and fieldwork operations.

David Short ***SARDI***

David Short is a Senior Research Services Officer who has been working in the field of fisheries and environmental research for 20 years. David is a highly experienced technical officer offering expertise in a large variety of fish sampling techniques including electrofishing, gill netting, seine netting and fyke netting, and holds a coxswains qualification. David is also highly skilled in database management and laboratory techniques including fish ageing and reproductive analysis. Over the last ten years, he has been the key technical officer for a number of important projects in the SA MDB, including the Coorong fish research and monitoring projects, the Sustainable Rivers Audit Project and Murray Fishway Program.

Arron Strawbridge ***SARDI***

Arron Strawbridge is an experienced senior technical officer who has worked in the field of aquatic ecology and aquaculture for over 20 years. He has extensive experience running field, laboratory and mesocosm studies and has provided technical and field leadership on numerous projects including vegetation condition and intervention monitoring, seed bank assessments, electrofishing, fish condition monitoring and fish passage assessment. Arron also manages all project databases, field and laboratory equipment, vehicles and boats for the Plant Ecology Sub-program.

David Fleer ***SARDI***

David Fleer is a senior research services officer who has been working in the field of fisheries and environmental research for over 25 years. David is a highly experienced technical officer offering many skills and expertise in boating, fieldwork operations, and laboratory analyses including fish ageing and reproductive analysis. In the last six years, he has been the key technical support staff for the larval fish recruitment dynamics study, native fish monitoring and Murray River wetland surveys in the Lower Murray River for the Inland Waters research team.

George Giatas ***SARDI***

George Giatas has worked at SARDI Aquatic Sciences since 2012 after finishing his honours study at Flinders University, investigating fish diet in the Murray River estuary and Coorong. At SARDI he has been involved in various fish monitoring projects throughout the Lower Murray River and the Coorong. George has also worked as a research assistant in the benthic ecology lab at Flinders University, which is involved in the monitoring of macrobenthic invertebrates in the Coorong, Lower Lakes and Murray Mouth region.

4.1.3 Hydrology (River)

Indicators

- Recorded daily discharge over each Lock
- Recorded daily discharge at further existing stations if appropriate for the Commonwealth environmental water event (e.g. Katarapko Creek, Morgan (low flows) or Overland Corner (high flows).

Background

The Hydrology (River) protocol describes a stage-based rating curve to determine daily discharge, using velocity measurements to derive the rating curve and the relationship between stage and discharge. The highly regulated LMR Selected Area it is not a free-flowing system where the downstream water level influences the discharge, so this approach is generally not appropriate. CEWO have advised that another approach can be used if the necessary accuracy can be achieved.

Daily discharge is currently calculated at all weirs (Locks 1–6) in South Australia within the necessary accuracy (within 10 percent), based on upstream and downstream water levels. A further station has recently been constructed on Katarapko Creek, and other sites may provide the necessary accuracy depending on the flow event, such as at Morgan (low flows) or Overland Corner (high flows). Monitoring stations in the LMR Selected Area that record water level, discharge or salinity at least daily can be seen in Figure 4.4. Given this existing coverage of stations, and the limited locations suitable for further stations to be installed, no further discharge stations are proposed as part of the LTIM Project.

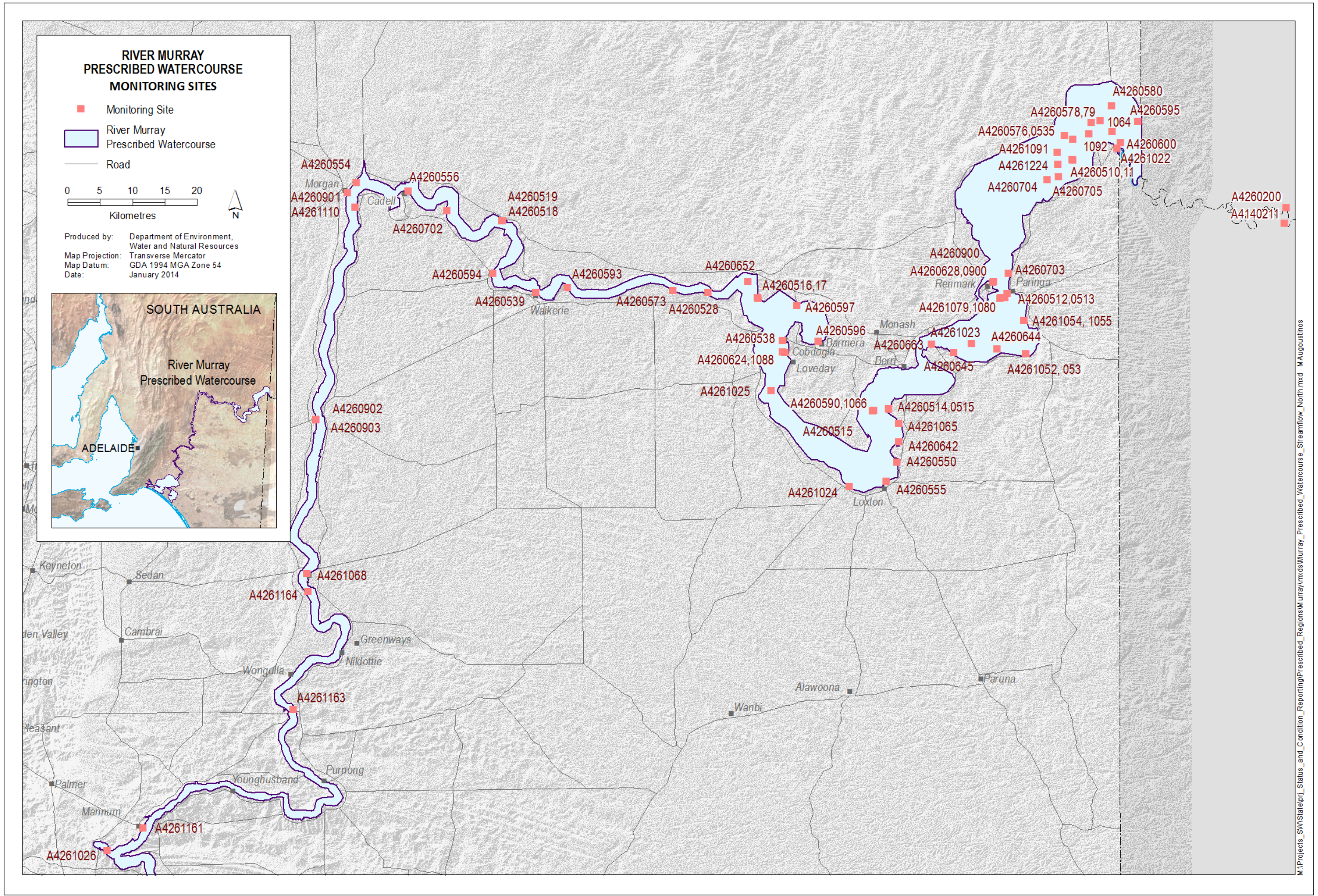

Figure 4.4. Monitoring stations in the LMR Selected Area (SA border to Mannum). Most stations record level and salinity, and only some stations record daily discharge.

Cause and effect diagram

No cause and effect diagram is provided for Hydrology (River). Instead, hydrology can be seen to be present as a cause in all cause and effect diagrams and will be reported on as part of each indicator.

Key evaluation questions

This indicator does not directly address specific evaluation questions but is important, providing fundamental information for analysis and evaluation of monitoring outcomes against hydrological conditions and environmental watering for all indicators. It indirectly addresses the following Basin scale evaluation questions:

Short-term (one-year) Basin and Selected Area questions (Hale *et al.* 2014):

- What did Commonwealth environmental water contribute to native fish reproduction?
- What did Commonwealth environmental water contribute to native larval fish growth and survival?

Long-term (five-year) Basin and Selected Area questions (Hale *et al.* 2014):

- What did Commonwealth environmental water contribute to hydrological connectivity?
- What did Commonwealth environmental water contribute to native fish species diversity
- What did Commonwealth environmental water contribute to fish community resilience?

Short-term (one-year) and long-term (five-year) Basin and Selected Area questions (Hale *et al.* 2014):

- 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?
- What did Commonwealth environmental water contribute to temperature regimes?
- What did Commonwealth environmental water contribute to pH levels?
- What did Commonwealth environmental water contribute to turbidity regimes?
- What did Commonwealth environmental water contribute to salinity regimes?
- What did Commonwealth environmental water contribute to dissolved oxygen levels?

Objective

- The recorded daily discharge will inform the assessment of other indicators and evaluation.

General methodology

Daily discharge will be monitored at each existing station using existing methods that provide the necessary level of accuracy (within 10 percent). Hydrological information collected from this part of the project will be used as an input for the analysis of many other indicators.

Refer to the LMR Selected Area SOP for Category 1 Hydrology (River) (Appendix B, pg 109) for more information on the sampling protocol including sites, timing and equipment, and on data analysis and evaluation, data management and quality assurance/quality control measures. Refer to Section 5 for timing of monitoring activities and more information on sampling sites and zones.

Outputs

- A database of recorded daily discharge, provided if necessary. This data is already held in publicly available databases.

Staff

Senior Hydrologist ***DEWNR/University of Adelaide***

Dr Matt Gibbs ***University of Adelaide***

Matt Gibbs holds a joint position as Principal Hydrologist at DEWNR and Postdoctoral Fellow at the University of Adelaide. At DEWNR he is involved in modelling and advice to support Murray River policy and operations. Matt's current research is investigating methods to forecast flows in the drains in the South East of South Australia to inform decision-making on the best use of the water resource available. He has undertaken numerous consulting research projects for the South Australian Government on applied hydrological modelling.

4.2 Category 3

4.2.1 Fish spawning and recruitment (flow-cued spawners)

Indicators

- Reproduction of flow-cued spawners
  - Presence of eggs and larvae of golden perch
  - Recruitment of golden perch (presence of young of the year (YOY))
  - Natal origin of larval and YOY golden perch
  - Age structure of golden perch populations.

Note that reproduction is defined as 'the natural process among organisms by which new individuals are generated (e.g. spawning) and the species perpetuated (e.g. recruitment)'.

Background

Flow regulation may impact fish directly through loss of spawning cues and barriers to migration and dispersion, and indirectly through effects on fish habitat and food resources (Figure 4.5). Understanding the influence of flow and the mechanisms that facilitate fish reproduction will inform how environmental water provision and flow management may be used to restore native fish populations.

Within the southern MDB, golden perch and silver perch are the only two fish species considered to require increased discharge to initiate spawning (Mallen-Cooper and Stuart 2003). In particular, golden perch spawning and recruitment in the LMR Selected Area has been associated with both increases in in-channel flow and overbank flooding (Zampatti and Leigh 2013a, 2013b). Importantly, in-channel flows of a magnitude that may elicit a positive spawning and recruitment response from golden perch are absent from the contemporary flow regime of the LMR Selected Area, but are achievable through Commonwealth environmental water delivery.

The presence of golden perch eggs or larvae has previously been used as an indicator of spawning, and subsequently associated with flow, including environmental water allocations (Ye *et al.* 2013b). Golden perch are pelagic spawners. In lotic ecosystems eggs and developing larvae may drift in the water column for many days, and early stage juveniles may continue to passively or actively move downstream (Gehrke 1990). These individuals may have been spawned in the LMR Selected Area or considerable distances upstream, under hydrological and physicochemical conditions which may vary markedly from those where they were collected.

The spawning and recruitment (i.e. survival) of golden perch in the LMR Selected Area will be investigated to assess the potential benefit of Commonwealth environmental water to native fish populations. To explicitly relate the spawning and recruitment of flow-cued spawning fish to flow, knowledge of hydrological conditions at the time and place of spawning is fundamental. This can be achieved by collecting drifting eggs, and determining the spatio-temporal provenance (i.e. when and where a fish was spawned through otolith microstructure and microchemistry analyses) of early life stages (e.g. larvae), juveniles or adults. This information will inform future environmental water delivery, including the influence of water from different sources, on the reproductive success and population dynamics of golden perch.

The complementary components of this indicator, i.e. larval sampling, YOY sampling, aging and natal origin of larvae and YOY, and the age structure and natal origin of the broader population, provide a complete story of the population resilience of flow-cued spawning species. Importantly, this method allows monitoring and direct investigation of cause and effect mechanisms in relation to flow and fish recruitment, to evaluate ecological outcomes of Commonwealth environmental water delivery. It will provide results at various time-scales from close to real-time information on the presence of eggs and larvae, mid-term information (evidence of annual reproduction) and long-term (five-year) information on the influence of Commonwealth environmental water delivery on fish recruitment and population resilience. It will also incorporate historical data from other projects, providing a broader interpretation and better understanding of the potential links between environmental water delivery and reproduction in order to support adaptive management.

Cause and effect diagram

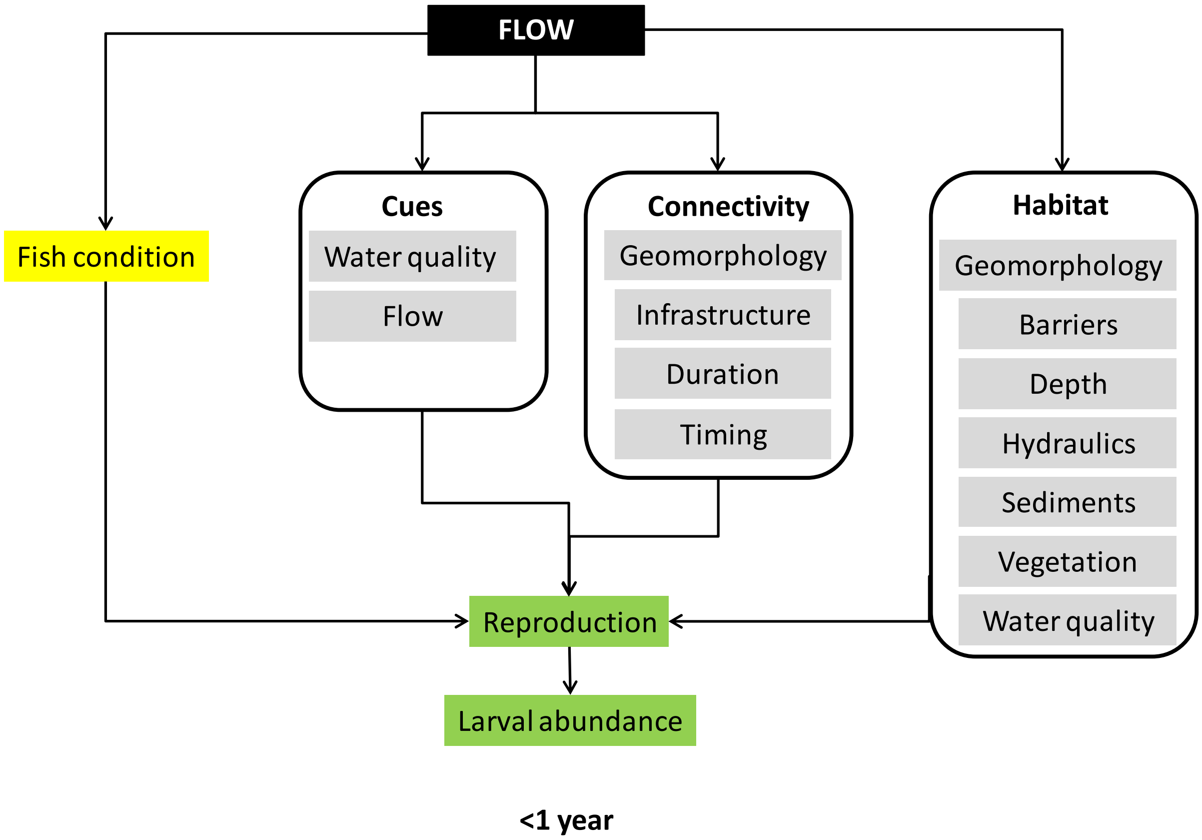

Figure 4.5. Fish spawning and recruitment (flow-cued spawners) cause and effect diagram (MDFRC 2013). Magnitude, timing and duration are factors of flow (in black).

Key evaluation questions

Short-term (one-year) Basin and Selected Area questions (Hale *et al.* 2014):

- What did Commonwealth environmental water contribute to native fish reproduction?
- What did Commonwealth environmental water contribute to native larval fish growth and survival?

Long-term (five-year) Basin and Selected Area questions (Hale *et al.* 2014):

- What did Commonwealth environmental water contribute to native fish populations?
- What did Commonwealth environmental water contribute to fish population/community resilience?
- What did Commonwealth environmental water contribute to native fish survival?

Objectives and hypotheses

The objectives of this indicator are to:

- Compare and contrast spawning response to various environmental water deliveries

- Compare and contrast recruitment success in response to various environmental water deliveries
- Compare and contrast the timing of spawning and source (i.e. natal origin) of successful recruits in response to various environmental water deliveries
- Identify potential associations between reproduction (spawning and recruitment) and environmental water delivery (e.g. magnitude, timing and source)
- Determine population connectivity between regions (e.g. larvae spawned in the Goulburn recruiting to LMR Selected Area populations).

Major hypotheses are:

- Increases in flow above regulated entitlement flow (in-channel or overbank) in spring–summer will promote the spawning and recruitment (to YOY) of golden perch and silver perch
- Multiple years of enhanced spring–summer flow will increase the resilience of golden perch and silver perch populations in the LMR.

General methodology

This Category 3 method will be used in place of the Category 2 Fish (larvae) method (Hale *et al.* 2014) because it takes a more holistic approach to identifying causal links between environmental water delivery and fish spawning and recruitment in the LMR Selected Area. Sampling for larval fish will be conducted in the main channel of the LMR in the Gorge and Floodplain zones using net tows to estimate larval fish abundances (mean CPUE). The collection of larval fish will differ from Category 2 Fish (larvae) as light traps will not be used in this section of the river as they have proven to be inefficient in the main channel habitat and will not collect large amounts of larvae of flow-cued spawning species.

Juvenile golden perch will be obtained through Category 1 Fish (River) sampling in the Gorge zone and complementary electrofishing in the Floodplain zone. Spawn date and location of larval and YOY golden perch will be determined by analysing otolith microstructure and chemistry (strontium isotope ratios).

Refer to the LMR Selected Area SOP for Category 3 Fish spawning and recruitment (Appendix B, pg 113) for more information on the sampling protocol including sites, timing and equipment, and on data analysis and evaluation, data management and quality assurance/quality control measures. Refer to Section 5 for timing of monitoring activities and more information on sampling sites and zones.

Outputs

- Annual report on the reproduction of golden perch in response to flow regime, including environmental water delivery, in the LMR Selected Area from 2014–15 to 2017–18. The report will include:
    - Comparison with existing data on the reproduction of flow-cued spawning species, collected during entitlement, in-channel and overbank flow events
    - Data interpretation that considers the current conceptual understanding of the life history, spawning and recruitment of key fish species in the LMR Selected Area.

Staff

Dr Qifeng Ye	***SARDI***
Brenton Zampatti	***SARDI***
Dr Juan Livore	***SARDI***
Luciana Bucater	***SARDI***
Phillipa Wilson	***SARDI***
Ian Magraith	***SARDI***
David Short	***SARDI***
Arron Strawbridge	***SARDI***
David Fleer	***SARDI***
George Giatas	***SARDI***

Refer to Section 4.1.2 for staff capabilities.

4.2.2 Dissolved organic and particulate matter transport

Indicator

Concentrations and transport (loads) of:

- Salt
- Dissolved and particulate nutrients
- Suspended solids, including phytoplankton biomass (chlorophyll *a*).

Background

Flow provides habitat and resources for aquatic organisms by altering the concentrations and transport of dissolved and particulate matter. Ultimately this governs the physiology, distribution and abundance of organisms. Here we consider dissolved and particulate matter to include:

- Salinity, which is a measure of total dissolved salts and is a particularly important parameter governing the distribution and abundance of aquatic biota. Salinity is strongly influenced by flow through the alteration of groundwater inputs, evapoconcentration and in estuarine habitats, incursions of seawater (Brookes *et al.* 2009, Aldridge *et al.* 2011, Aldridge *et al.* 2012, Mosley *et al.* 2012).
- Dissolved inorganic nutrients, which are readily assimilated by biota and are essential resources for growth and survival (Poff *et al.* 1997). Nitrogen, phosphorus and silica are particularly important because they often control the productivity of aquatic ecosystems. Flow results in the mobilisation and transport of dissolved nutrients through the leaching of nutrients from dried sediments and dead organic matter.
- Particulate organic nutrients (phosphorus and nitrogen), which are those nutrients incorporated into the tissue of living and dead organisms. Flow can influence particulate organic nutrient concentrations and transport through a number of mechanisms, including through increased productivity associated with elevated dissolved nutrient concentrations.
- Chlorophyll *a*, which is a measure of phytoplankton biomass, with phytoplankton being an important primary producer of riverine ecosystems. Flow can influence chlorophyll *a* concentrations and transport through increased phytoplankton productivity.
- Total suspended solids, which is a measure of the total amount of inorganic and organic particulate matter. It has a strong influence on light availability, which is important for structuring aquatic ecosystems (Geddes 1984a, 1984b). It is influenced by flow through increased productivity, as well as the mobilisation of inorganic matter from the floodplain and river channel (i.e. resuspension).

Altering the flow regime of riverine systems has significant consequences for the concentrations and transport of dissolved and particulate matter (Aldridge *et al.* 2012). For example, reduced flow can result in: salinisation through evapoconcentration and the intrusion of saline water; reduced sediment transport and increased sedimentation; reduced nutrient concentrations due to decreased mobilisation of nutrients from the floodplain; and reduced primary productivity because of nutrient limitation, leading to reduced secondary productivity. Such observations have been made in the Lower Murray, including the LMR Selected Area, Lower Lakes and Coorong (Brookes *et al.* 2009, Aldridge *et al.* 2011, Aldridge *et al.* 2012, Mosley *et al.* 2012). Environmental flow provisions may be used to reinstate some of the natural processes that control the concentrations and transport of dissolved and particulate matter, and may provide ecological benefits by doing so.

Relationships between flow and the transport of dissolved and particulate matter are relatively well established within the LMR Selected Area (Brookes *et al.* 2009, Aldridge *et al.* 2011, Aldridge *et al.* 2012, Mosley *et al.* 2012). Increased flows will lead to the mobilisation of dissolved and particulate matter from local and upstream sources through the inundation of the floodplain and resuspension of riverbed matter (Figure 4.6). This will influence dissolved oxygen levels, salinity levels, rates of nutrient and carbon cycling, primary production, decomposition and the occurrence of algal blooms (Aldridge *et al.* 2012). Increased flows will also lead to increased channel mixing and flow velocities, which will transport this matter to downstream ecosystems (Figure 4.6).

Cause and effect diagram

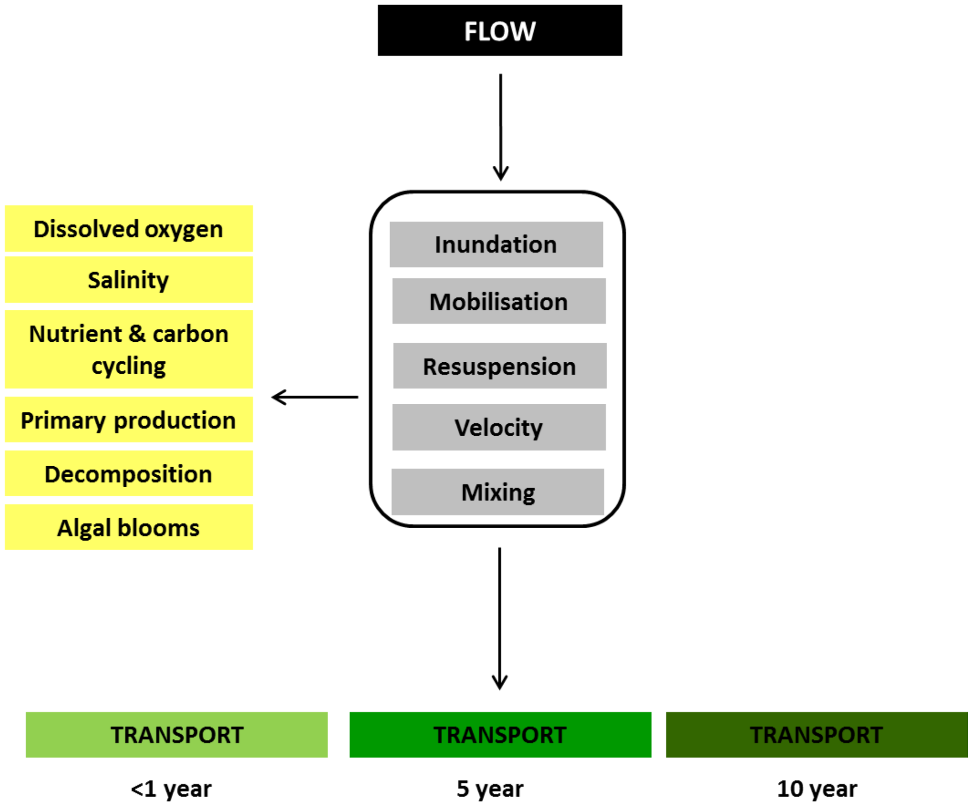

Figure 4.6. Dissolved organic and particulate matter transport cause and effect diagram. Magnitude, timing and duration are factors of flow (in black).

Key evaluation questions

Short-term (one-year) and long-term (five-year) Basin and Selected Area questions (Hale *et al.* 2014):

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

Additional short-term (one-year) and long-term (five-year) Selected Area questions:

- What did Commonwealth environmental water contribute to nutrient and carbon cycling?
- What did Commonwealth environmental water contribute to sediment transport?
- What did Commonwealth environmental water contribute to ecosystem function?
- What did Commonwealth environmental water contribute to water quality?

Objectives and hypotheses

The objective of this indicator is to:

- Assess whether Commonwealth environmental water has increased the transport and export of salt, nutrients and suspended solids through the LMR Selected Area.

Major hypotheses are:

- Commonwealth environmental water will increase the mobilisation of salts from the Basin and increase the transport of salt passing from Lock 1 through the LMR Selected Area (and through the Lower Lakes and Murray Mouth)
- Commonwealth environmental water will increase the mobilisation of nutrients from the Basin and increase nutrient loads passing from Lock 1 through the LMR Selected Area (and through the Lower Lakes and Murray Mouth)
- Commonwealth environmental water will increase suspended solid loads (including phytoplankton biomass) passing from Lock 1 through the LMR Selected Area (and through the Lower Lakes and Murray Mouth).

General methodology

This component will use a 3D hydrodynamic–biogeochemical model that has been developed and used extensively in the region (Aldridge *et al.* 2013, Hipsey and Busch 2012a, 2012b). For detailed information on the proposed modelling approach refer to Aldridge *et al.* (2013). Two interlinked modelling platforms that represent the area between Lock 1 and the Southern Ocean will be used. One model is for the LMR Selected Area below Lock 1, and another is for Coorong, Lower Lakes and Murray Mouth, with the former used as an input to the latter. Although outside of the LMR Selected Area, incorporation of Coorong, Lower Lakes and Murray Mouth increases the capacity of the LTIM Project to demonstrate outcomes within other areas and allows an assessment of exports to the Southern Ocean.

No data will be collected through this indicator, but validation of the models will rely solely on monitoring data (i.e. water temperature, electrical conductivity, dissolved oxygen, pH and turbidity, and water samples to be analysed for nutrients) that will be collected by complementary monitoring programs.

Refer to the LMR Selected Area SOP for Category 3 Matter transport (Appendix B, pg 120) for more information on the sampling protocol including sites, timing and equipment, and on data analysis and evaluation, data management and quality assurance/quality control measures. Refer to Section 5 for timing of monitoring activities and more information on sampling sites and zones.

Outputs

- Annual reports describing changes in dissolved and suspended matter associated with river flows and environmental conditions between Lock 1 and the Southern Ocean, and an assessment of the contribution of Commonwealth environmental water delivery to those changes
- A database to assess the response of dissolved and particulate matter to flows from Lock 1 to the Southern Ocean
- A validated hydrodynamic–biogeochemical model from Lock 1 to the Southern Ocean.

Staff

Dr Kane Aldridge ***University of Adelaide***

Kane Aldridge is a limnologist with a broad interest in the biogeochemistry, primary productivity, phytoplankton and macrophyte ecology, and the ecological functioning of stream, lake and estuarine ecosystems. Kane's research focuses on human impacts upon natural inland water ecosystems and on providing tools for better management of these systems. In 2006 Kane began a Postdoctoral Fellowship at the University of Adelaide on the Land and Water Australia funded project entitled Flow requirements and resource delivery to the Lower Murray Lakes and Northern Coorong. Kane has also been involved in numerous projects assessing changes in water quality in the LMR Selected

Area associated with river flows. Information generated from this work has been used extensively by state government agencies in management of the region.

***Assoc. Prof. Matt Hipsey		University of Western Australia***

Matt Hipsey is an Associate Professor at the University of Western Australia and leads a research group active in the area of aquatic system modelling. He has a long history of developing coupled hydrodynamic–biogeochemical–ecological model platforms, particularly for lakes, rivers and estuarine environments. Since 2008 he has had an active role in developing 3D model systems for the region from Lock 1 to the Coorong, including assessing the impacts of drought and floods on water quality parameters such as nutrients, phytoplankton and geochemistry. These models have been used by state government agencies to manage the region and will be built upon for the LTIM Project.

***Brendan Busch		University of Western Australia***

Brenton Busch is a Senior Research Engineer at the University of Western Australia. Brendan manages field and remote sensing data, and setup and assessment of computer models for the Aquatic Ecodynamic Research group (AED). His expertise was developed from extensive experience in the design and implementation of monitoring programs, which started as the Field Operations Manager for the Centre for Water Research (UWA) in 2006. In his current role, Brendan is also responsible for the design and creation of the AED group's data and model processing platforms, specialising in data analysis within the MATLAB computing environment.

***Assoc. Prof. Justin Brookes	University of Adelaide***

Justin Brookes has broad research interests in limnology and water treatment. His primary research focus is coupling between hydrodynamics, biology and water quality contaminants such as cyanobacteria and pathogens. Justin currently leads several large inter-institutional projects examining degradation of chemical contaminants of concern (endocrine disruptors, pharmaceuticals), carbon cycling in lakes and rivers and the ecology of the Coorong and Lower Lakes of the River Murray.

***Dr Luke Mosley		EPA***

Luke Mosley is the Principal Scientific Officer Water Quality at the Environment Protection Authority (EPA) in South Australia. He has worked for the EPA on Murray River water quality and environmental management issues for over 10 years. Over the last 5 years he has focused on assessing, predicting and managing water quality risks associated with a severe drought and acid sulfate soil exposure in the Lower Murray River and Lower Lakes. Dr Mosley was recognised with a South Australian Premier's award in 2010 for this work. Dr Mosley has published several scientific papers and reports on the water quality of the Lower Murray River and Lower Lakes, including papers in international journals on the impact of the recent drought.

4.2.3 Hydrological regime

Indicators

- Modelled daily discharge with and without Commonwealth environmental water
- Modelled daily velocity (cross section average) with and without Commonwealth environmental water
- Modelled daily depth with and without Commonwealth environmental water
- Modelled area inundated at different durations with and without Commonwealth environmental water if appropriate (e.g. substantial overbank flows, exceeding 40,000 ML/day).

Background

Ecological indicators that are likely to have detectable change in response to hydrological regime have been intentionally selected as part of this M&E Plan. As such, detailed spatial and temporal information on the change in hydrological regime due to Commonwealth environmental water contribution is beneficial to report on hydrological indicators as well as to inform the assessment of the ecological indicators.

Modelling will be used to upscale monitoring to the regional scale, to provide other variables such as velocity, and to simulate conditions with and without Commonwealth environmental water. Hydrodynamic (MIKE FLOOD) models upstream of Lock 1 will be used to simulate the Commonwealth environmental water events that occur, simulating discharge, stage and velocity at a high spatial and temporal resolution, and filling any gaps in monitoring with modelled data. Below Lock 1, modelling will be resourced as part of the matter transport indicator. The models can then be used to simulate events without Commonwealth environmental water, with the difference providing a direct indication of the contribution of that water to the hydrological regime. This information can be reported directly as hydrological metrics (i.e. proportion of the reach in different velocity or depth classes), as well as an input to the assessment of outcomes for other ecological indicators.

Cause and effect diagram

No individual cause and effect diagram is provided for hydrological regime. Instead, the hydrological regime can be seen to be present as a cause in all cause and effect diagrams.

Key evaluation questions

Short-term (one-year) Basin and Selected Area questions (Hale *et al.* 2014):

- What did Commonwealth environmental water contribute to help increase hydraulic diversity within weir pools?
- What did Commonwealth environmental water contribute to temperature regimes?

Long-term (five-year) Basin and Selected Area questions (Hale *et al.* 2014):

- What did Commonwealth environmental water contribute to hydrological connectivity?
- What did Commonwealth environmental water contribute to temperature regimes?

Objective and hypothesis

The objective of this indicator is:

- Assess how Commonwealth environmental water has contributed to an increase in discharge, velocity and depth of flow at a high spatial and temporal resolution. Inundated area will also be reported if overbank flows occur.

The hypothesis is:

- Commonwealth environmental water will increase metrics representing desirable conditions, for example increased velocities and increased variability in water levels.

General methodology

This indicator will make use of MIKE FLOOD hydrodynamic models that have been developed and used in the region (e.g. Macky and Bloss 2012, McCullough 2013, Wallace 2014). The models will be validated against monitored water levels and flows during environmental watering events, with recalibration of model parameters to accurately simulate the recorded data if required. The models provide level, area, velocity and flow at a high spatial scale (variable between 1D cross sections and 2D 15 to 30 metre grid models) and temporal scale (sub-daily). Validation data will be provided by the stations in Figure 4.4.

Once validated, the models will be re-run without the Commonwealth environmental water provision, to allow a direct comparison between the hydrological variables with and without the environmental water. Metrics such as those calculated in Wallace (2014), based on different velocity and water level classes, will be reported in a way that allows for interpretation for the different ecological indicators in this project. This method will include quantitative analysis and relative comparisons between with and without Commonwealth environmental water provisions as the analysis method, using maps and ecologically relevant metrics. As it is not possible to replicate the scenarios, no statistical analyses are possible and so validation of the model outputs is essential.

Refer to the LMR Selected Area SOP for Category 3 Hydrological regime (Appendix B, pg 127) for more information on the sampling protocol including sites, timing and equipment, and on data analysis and evaluation, data management and quality assurance/quality control measures. Refer to Section 5 for timing of monitoring activities and more information on sampling sites and zones.

Outputs

- Annual reports including an assessment of the contribution of Commonwealth environmental water provisions to the variables above, presented as ecologically meaningful metrics (proportion of the reach in different velocity classes and variability in water level in association with discharge)
- A database to report the modelled discharge, depth, velocity and area with and without the provision of Commonwealth environmental water.

Staff

Senior Hydrologist ***DEWNR/University of Adelaide***

Dr Matt Gibbs ***University of Adelaide***

Refer to Section 4.1.3 for staff capabilities.

4.2.4 Microinvertebrate diversity

Indicators

- Microinvertebrate diversity
- Microinvertebrate contribution to larval/juvenile fish diet.

Background

Aquatic microinvertebrates (protists, rotifers and microcrustaceans) are rapid responders to environmental flows. Upper Murray floodplain billabong plankton communities respond within hours of inundation, with egg production stimulated, resting propagules triggered, and resulting emergence changing the species composition and diversity of the resident assemblage within days (Tan and Shiel 1993). Prolonged overbank inundation and throughflow transport this assemblage back to the parent river (e.g. Barmah–Millewa, Gigney *et al.* 2006, Chowilla, Furst *et al.* 2014), where it persists, with the component organisms reproducing into downstream reaches of the LMR Selected Area and the Lower Lakes.

To date, more than 200 species of planktonic and littoral microinvertebrates have been identified in the LMR Selected Area and Lower Lakes, at densities up to 10,000 individuals per litre, where they provide a significant link in aquatic food webs between bacteria and algae and higher-order consumers such as macroinvertebrates, fish and birds (Shiel *et al.* 1982, Lock 2011, Shiel and Aldridge 2011, Shiel and Tan 2013a, 2013b). During the 2010–11 floods, prolonged inundation of the LMR Selected Area floodplain returned exceptional production of littoral and pelagic microinvertebrates to the main channel. A fourfold increase in density and diversity, relative to the main channel, was recorded at Illawonga, near Swan Reach (Shiel unpublished data), with more than 6 tonnes of plankton exported daily from the Chowilla floodplain to the downstream river (Figure 4.7, from Furst *et al.* 2014).

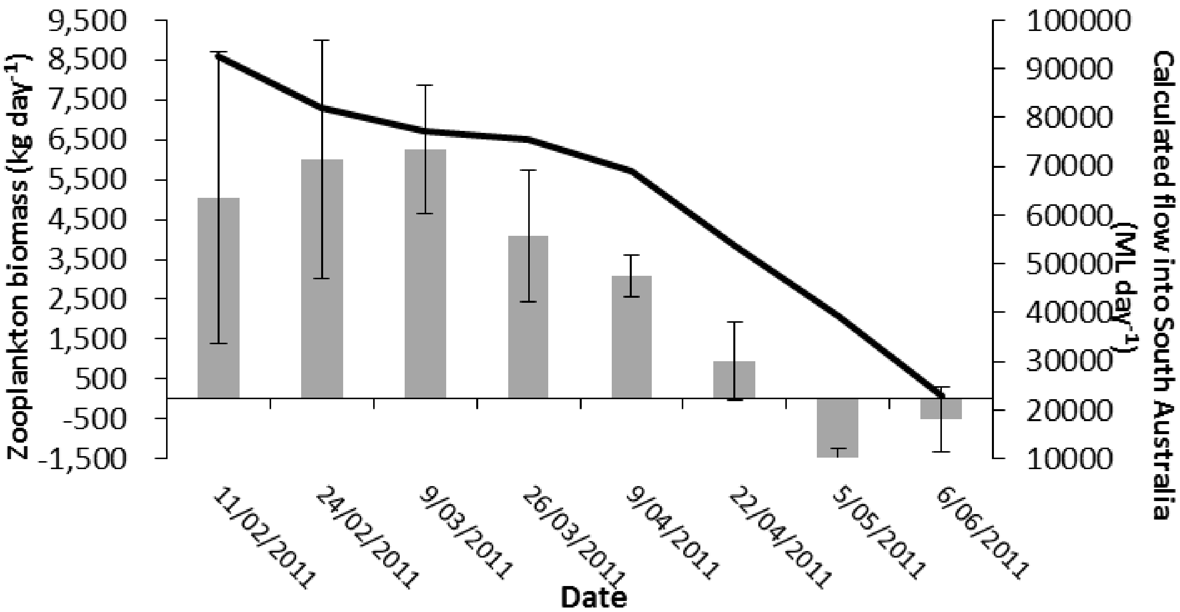

Figure 4.7. The estimated total zooplankton biomass (kg/day) coming from the Chowilla Floodplain (grey bars). Secondary x-axis shows the calculated flows into South Australia (black line). Vertical bars represent ± 1 S.D.

This assemblage provides a resource for higher order consumers, as demonstrated recently by a study of native versus exotic small fish dietary composition. Murray hardyhead preyed on pelagic rotifers and microcrustaceans, with up to 1,500 individuals of *Brachionus plicatilis* in the foregut of some individual juvenile fish. Rotifer and copepod eggs were strongly selected food items (Wedderburn *et al.* 2013).

To determine the responses of the microinvertebrate community to Commonwealth environmental water releases, it is proposed to quantify the assemblage(s) present before, during and after Commonwealth environmental water releases. Production of eggs and ephippia can also be quantified from littoral or pelagic samples, enabling the assessment of contributions to propagule banks (i.e. resilience of egg banks).

Microinvertebrate sampling will be concurrent with larval and juvenile fish sampling (golden and silver perch), enabling assessment of the microinvertebrate dietary components across a suite of larval and juvenile fish available at the time of collection, which will respond to Commonwealth environmental water releases. Changes in the microinvertebrate community associated with environmental water are likely to lead to changes in larval and juvenile fish diet. Establishing the diets of larval fish is a key element in understanding the processes that led to a successful recruitment. Very few studies have attempted to describe the natural diet of golden perch larvae. Golden perch larvae are particularly small at first feeding and face difficulties in survival due to lack of zooplankton of appropriate size (Arumugam and Geddes 1987). Their feeding is limited by the size of their mouth gape. Therefore the abundance of food items of appropriate sizes at different times of early development may determine their survival (Arumugam and Geddes 1987).

Quantitative sampling of planktonic and littoral micoinvertebrates pre- and post-supply of Commonwealth environmental water permits community responses to 'new water' to be identified. Triggering of propagule emergence is known to occur on the day water arrives (Tan and Shiel 1993). Dry floodplain sediments flooded in experimental conditions have produced protists, rotifers and nauplii of the conchostracan *Eulimnadia* within 24 hours of wetting (Shiel unpublished data). The concurrent analysis of microinvertebrate communities and larval fish gut content will allow the comparison between available and ingested microinvertebrate species. Recent studies of environmental flow responses in wetlands upstream of Renmark have made passing reference to microcrustaceans, but have not identified responses of the microinvertebrate assemblage *in toto* (Beesley *et al.* 2014a, 2014b)

Commonwealth environmental water flows provide for several pathways triggering microinvertebrate reproduction and stimulating increases in density and diversity. On the left of Figure 4.8, overbank flows trigger emergence of the resident propagule bank in heterogeneous floodplain habitats. Depending on upstream sources, assemblages transported in the flows may contribute new planktonic and littoral assemblages into these floodplain habitats, to become stranded there on recession of the flows. While water is present they will reproduce, adding cysts, resting eggs and ephippia to the floodplain egg bank. The persistence of these propagules is not known with any accuracy for MDB floodplains, but could be expected to be at least several years. With longer retention time on the floodplain, resident microinvertebrate assemblages change from rotifer-dominated to microcrustacean dominated, providing a range of food items for juvenile fish as gape size increases with age. As demonstrated by Furst *et al.* (2014), this mixed assemblage is transported back to the parent river during high flows. By analysing the gut contents of concurrently sampled larval and juvenile golden and silver perch, the use of this resource can be quantified at the study sites.

Cause and effect diagram

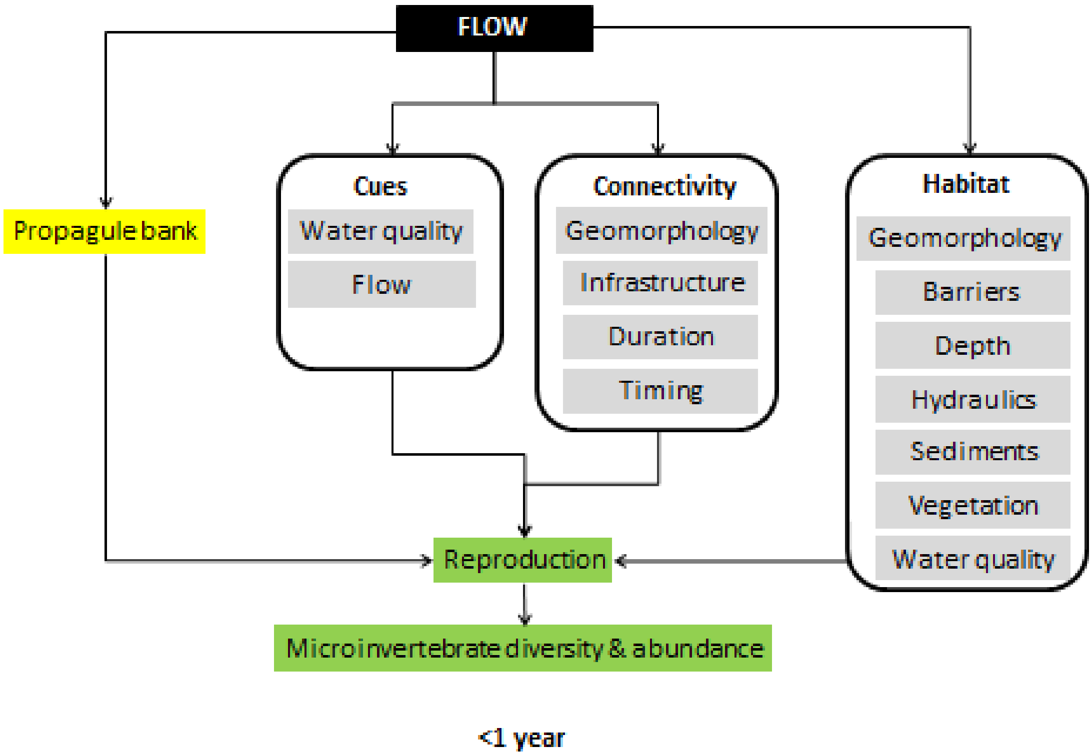

Figure 4.8. Microinvertebrate diversity cause and effect diagram. Magnitude, timing and duration are factors of flow (in black).

Key evaluation question

Short-term (one-year) Basin and Selected Area question (Hale *et al.* 2014):

- What did Commonwealth environmental water contribute to microinvertebrate diversity?

Additional short-term (one-year) Selected Area questions:

- What did Commonwealth environmental water contribute via upstream connectivity to microinvertebrate communities of the LMR Selected Area?
- What did Commonwealth environmental water contribute to the timing of microinvertebrate productivity and presence of key species in relation to diet of golden perch larvae?

Additional long-term (five-year) Selected Area questions:

- What did Commonwealth environmental water contribute to microinvertebrate productivity?
- What did Commonwealth environmental water contribute to microinvertebrate community composition?
- What did Commonwealth environmental water contribute to resilience of microinvertebrate egg banks? (comparing year 1 to 5)

Objectives and hypotheses

The objectives of this indicator are to:

- Compare and contrast potamoplankton assemblages pre- and post-Commonwealth environmental water deliveries
- Compare and contrast littoral microcrustacean assemblages pre- and post-Commonwealth environmental water deliveries
- Compare and contrast propagule deposition (egg-bank) in riparian sediments post-environmental deliveries
- Identify pre- and post-Commonwealth environmental water delivery dietary items of juvenile fish collected concurrently with microinvertebrate samples
- Compare pre- and post-Commonwealth environmental water delivery dietary item proportions to ambient microinvertebrate composition to determine selectivity of feeding.

Major hypotheses are:

- Microinvertebrate taxonomic diversity will increase in inundated habitats due to increases in available habitat by triggering propagules deposited in sediments
- Microinvertebrate abundance will increase in inundated habitats in response to increased egg production by resident or transported populations
- Microinvertebrate propagule density and diversity in riparian sediments will increase post environmental water delivery
- Microinvertebrate assemblage responses will be reflected in the dietary components of fish larvae (golden perch).

General methodology

Sampling for potamoplankton and riparian microcrustaceans will occur in the Gorge and Floodplain zones of the LMR Selected Area. Sampling times will coincide with Category 3 Fish spawning and recruitment sampling. Pelagic sampling for potamoplankton will be conducted with a Haney trap (quantitative) and a pelagic plankton net tow (qualitative). Riparian microcrustaceans will be collected using benthic corers. Abundances and diversity of microinvertebrates will be calculated.

Golden perch larvae collected as part of the Category 3 Fish spawning and recruitment will be processed for diet content to identify potential selectivity in the feeding of golden perch larvae.

Refer to the LMR Selected Area SOP for Category 3 Microinvertebrates (Appendix B, pg 132) for more information on the sampling protocol including sites, timing and equipment, and on data analysis and evaluation, data management and quality assurance/quality control measures. Refer to Section 5 for timing of monitoring activities and more information on sampling sites and zones.

Outputs

Annual reports on the changes in microinvertebrate community and diet of golden perch larvae in response to flow regime, including environmental water delivery, in the LMR Selected Area from 2014–15 to 2017–18. The report will include:

  - Diversity and abundance of microinvertebrates pre- and post-Commonwealth environmental water deliveries
  - Data interpretation that considers the current conceptual understanding of the changes in relative abundance of microinvertebrate species in the Selected Area with particular reference to community responses to environmental water
  - Diet composition of golden perch larvae pre- and post-Commonwealth environmental water deliveries.

Staff

Dr Russell Shiel ***University of Adelaide/Wetland Research & Management***

Russell Shiel completed a PhD on Murray River plankton ecology at the University of Adelaide in 1981, and has 30 years experience researching zooplankton taxonomy and ecology, resulting in 170 publications and technical reports. Most recent projects have been:

- Monitoring zooplankton responses to the 2010–2012 Murray–Darling floods into the Lower Lakes and Coorong Lagoons for DEWNR (South Australia)
- Investigating impacts of mining on zooplankton in the Kimberley in Western Australia for ERISS (Northern Territory)
- Investigating zooplankton responses to salinisation of wetlands in the Lower Muir region of the southwest of Western Australia for the Department of Parks and Wildlife, WA.
- Investigating the downstream effects of the Ok Tedi mine in Papua New Guinea on Fly River oxbow microinvertebrate diversity for Wetland Research & Management, WA.

Dr Lorwai Tan ***University of Adelaide/Wetland Research & Management***

Lorwai Tan completed her PhD Taxonomy, Microspatial and Temporal Variation of Freshwater Testate Amoebae (Protozoa: Rhizopoda) on the Submergent Macrophyte *Vallisneria gigantea* in a Murray River Floodplain Billabong in 1998 (La Trobe University). The principal research areas were: identification of testate species by light and scanning electron microscopy; data analysis by multivariate statistical analysis; and interpretation of the ecological significance of heterogeneous species distribution to billabong flooding. Lorwai collaborated on contract research for the Department of Lands, Parks & Wildlife in Tasmania on water chemistry, planktonic and littoral microfauna for the World Heritage Area Directed Research Programme. More recent contracts include monitoring the temporal effects of water release on microfaunal distribution in the Lower Murray River region.

Susan Davies ***Principal Environmental Consultant, WRM***

Sue Davies has more than 25 years experience in coordinating and undertaking research projects, and in the monitoring and assessment of aquatic invertebrate and fish populations, in particular, the analysis of structure and change in invertebrate populations as indicators of ecosystem health. Since graduating with a BSc (Hons) from The University of Western Australia (UWA) in 1983, Sue has worked as a biologist for both academic and government organisations in Western Australia, New South Wales and overseas (Caltech, California, USA). She has worked as an aquatic biologist with WRM for the last 10 years. Sue has considerable knowledge of threatening processes to aquatic ecosystems including alteration to natural hydrology, salinisation and sedimentation. Sue has extensive experience in aquatic ecology and in univariate and multivariate analysis and interpretation of biological data. Sue has also been closely involved with the development, implementation and refinement of system-specific operational water quality guidelines for a number of Pilbara and Kimberley mine sites, in accordance with ANZECC/ARMCANZ (2000) protocols. Sue has authored more than 90 project reports and nine peer-reviewed scientific journal articles.

Dr Qifeng Ye ***SARDI***

Dr Juan Livore ***SARDI***

See Section 4.1.2 for staff capabilities.

5 Selected Area monitoring schedule

5.1 Overview of monitoring

This plan proposes seven indicators for the LMR Selected Area, including three Category 1 and four Category 3 indicators. It is expected that Commonwealth environmental water delivery to the LMR Selected Area over the next five years will be limited to events of less than 60,000 ML/day, therefore the monitoring activities in this Selected Area will be focused on the in-stream environment for all indicators. Whilst the indicators proposed are complementary, field sampling regimes are aligned, within the constraints of CEWO standard methods/protocols, and sampling activities will be coordinated to maximise efficiencies. Further details of the monitoring schedule and sampling zones and sites are provided below.

5.2 Monitoring schedule

Table 5.1 provides a detailed monitoring schedule (timing, duration and sampling frequency) for all indicators for the LMR Selected Area from July 2014 to September 2019. Sampling sites and zones for each indicator are shown in Table 5.2. For three of the indicators, monitoring will not be confined to any specified schedule: Hydrology (River), matter transport and hydrological regime.

5.2.1 Stream metabolism

Stream metabolism measurements will be conducted annually between September and February below Lock 1 in the Gorge zone and below Lock 6 in the Floodplain zone (Table 5.1 and Table 5.2). The *in-situ* water quality (WQ) monitoring station will be deployed notionally in September to ensure that stream metabolism measurements are acquired prior to increased flows through the system (Hale *et al*. 2014). Start and end dates are flexible and will be assessed each year depending on the forecast flow conditions.

Ten field trips are planned for the deployment period so that on average the WQ monitoring stations will be maintained (batteries changed, mountings checked, sensors cleaned and re-calibrated) and data downloaded every 4 weeks. Light and barometric pressure loggers will also be downloaded and maintained and water quality samples taken.

Although field trips are planned to be an average 4 weeks apart, their actual timing will depend on the delivery of environmental flows. Event monitoring will be instituted in response to environmental flows to ensure that the major components of an event sequence (before, rising, peak, falling and following) are captured. This is necessary because of the rapid changes in stream metabolism in response to flow. Flexibility is required in case there are multiple or extended flow events. Despite changes in sampling frequency to capture flow events, field trips will not be longer than 6 weeks apart to ensure the reliability of data from the logging systems.

Equipment will be retrieved at the end of February unless further environmental flows are forecast, in which case monitoring will continue as long as resources are available to support the associated field trips. The resources available will depend on the prior sampling effort.

5.2.2 Fish (River)

Annual sampling will take place during autumn as described in Hale *et al.* (2014) and in the SOP (Appendix B, pg 97) (Table 5.1). The Gorge is the chosen zone for this indicator, and sampling (electrofishing and fyke-netting) will be conducted at 10 sites within an approximately 100 kilometre reach between Locks 1 and 3 (Table 5.2). Ageing of target species will be carried out following Hale *et al*. (2014), including annual ageing for opportunistic species for the first four years and ageing for periodic and equilibrium species in the first and fourth year. Details are provided in the SOP (Appendix B, pg 97).

5.2.3 Fish spawning and recruitment (flow-cued spawners)

Larval fish sampling (flow-cued spawners and other species) will be conducted using a method adapted from Hale *et al.* (2014) for Category 2 Fish (Larvae). Three sites will be located in each of the Floodplain and Gorge zones, 5 to 15 kilometres downstream of Lock 6 and Lock 1 respectively (Table 5.2). Eight sampling trips will be conducted from October to January (2014–15 to 2017–18), the spawning season for golden perch and silver perch in the LMR Selected Area (Table 5.1). Age and Strontium (Sr) ratios in larval golden perch and silver perch otoliths will be determined in order to investigate natal origin (i.e. the time and place of spawning).

Sampling of golden perch for assessing recruitment to young of the year (YOY), their natal origin and population age structure will be conducted in autumn. YOY fish will be collected in the Gorge zone as part of the Category 1 Fish (River) electrofishing in autumn each year from 2014–15 to 2017–18. Additional electrofishing will be conducted each year to collect golden perch from the Floodplain zone.

5.2.4 Microinvertebrate diversity

Microinvertebrate sampling will be conducted using methods adapted from Jenkins (2014) and Shiel and Tan (2013a, 2013b). Sites will be located in the Floodplain and Gorge zones, 5 to 15 kilometres downstream of Lock 6 and Lock 1 respectively (Table 5.2). Eight sampling trips will be conducted from October to January from 2014/15 to 2017/18, at the same time as sampling for the fish spawning and recruitment indicator (Section 5.2.3). Larval and juvenile fish collected at those sites will be analysed for microinvertebrate dietary intake.

Table 5.1. LTIM Project monitoring schedule for category 1 and 3 indicators in the LMR Selected Area from September 2014 to October 2019.

		2014				2015											
Indicator	**Activities**	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Category 1																	
Stream metabolism	Deploy equipment	■												■			
	Data logging/water quality sampling	■	■	■	■	■	■	■						■	■	■	■
	Equipment maintenance & data download		■	■	■	■	■								■	■	■
	Collect equipment							■									
	Data entry, analysis & reporting			■	■	■	■	■	■	■	■	■				■	■
Fish (River)	Planning						■										
	Field sampling (electrofishing)							■	■								
	Field sampling (fyke netting)							■	■								
	Lab fish ageing (small-bodied)									■	■						
	Lab fish ageing (large-bodied)									■	■						
	Data entry, analysis & reporting								■	■	■	■					
Hydrology (River)	Modelling	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Reporting								■	■	■	■					
Category 3																	
Fish spawning and recruitment	Planning	■												■			
	Water sample collection	■	■	■	■	■								■	■	■	■
	Field sampling (larvae)		■	■	■	■									■	■	■
	Lab larval sorting and id				■	■	■	■	■	■							■
	Field sampling (e-fishing YOY)								■								
	Lab ageing/otolith chem (larvae and YOY)									■	■						
	Data entry, analysis & reporting							■	■	■	■	■	■				
Matter transport	Physical–chemical data collection	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Modelling and scenario runs											■	■				
	Reporting											■	■				
Hydrological regime	Field sampling	■	■	■										■	■	■	
	Modelling	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Reporting											■	■				
Micro-invertebrate diversity	Planning	■												■			
	Field sampling (with larval fish)		■	■	■	■									■	■	■
	Lab sample sorting and id						■	■	■	■							
	Lab analysis (larval fish diet)									■	■						
	Data entry, analysis & reporting							■	■	■	■	■					

		2016												2017											
Indicator	**Activities**	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Category 1																									
Stream metabolism	Deploy equipment									■												■			
	Data logging/water quality sampling	■	■	■						■	■	■	■	■	■	■						■	■	■	■
	Equipment maintenance & data download	■	■								■	■	■	■	■								■	■	■
	Collect equipment			■												■									
	Data entry, analysis & reporting	■	■	■	■	■	■	■				■	■	■	■	■	■	■	■	■				■	■
Fish (River)	Planning		■												■										
	Field sampling (electrofishing)			■	■											■	■								
	Field sampling (fyke netting)			■	■											■	■								
	Lab fish ageing (small-bodied)					■	■											■	■						
	Lab fish ageing (large-bodied)																								
	Data entry, analysis & reporting				■	■	■	■									■	■	■	■					
Hydrology (River)	Modelling	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Reporting				■	■	■	■									■	■	■	■					
Category 3																									
Fish spawning and recruitment	Planning									■												■			
	Water sample collection	■								■	■	■	■	■								■	■	■	■
	Field sampling (larvae)	■									■	■	■	■									■	■	■
	Lab larval sorting and id	■	■	■	■	■							■	■	■	■	■	■							■
	Field sampling (e-fishing YOY)				■												■								
	Lab ageing/otolith chem (larvae and YOY)					■	■											■	■						
	Data entry, analysis & reporting			■	■	■	■	■	■							■	■	■	■	■	■				
Matter transport	Physical-chemical data collection	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Modelling and scenario runs							■	■											■	■				
	Reporting							■	■											■	■				
Hydrological regime	Field sampling									■	■	■										■	■	■	
	Modelling	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Reporting							■	■											■	■				
Micro-invertebrate diversity	Planning									■												■			
	Field sampling (with larval fish)	■									■	■	■	■									■	■	■
	Lab sample sorting and id		■	■	■	■									■	■	■	■							
	Lab analysis (larval fish diet)					■	■											■	■						
	Data entry, analysis & reporting			■	■	■	■	■								■	■	■	■	■					

Indicator	Activities	2018												2019									
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O
Category 1																							
Stream metabolism	Deploy equipment																						
	Data logging/water quality sampling																						
	Equipment maintenance & data download																						
	Collect equipment																						
	Data entry, analysis & reporting																						
Fish (River)	Planning																						
	Field sampling (electrofishing)																						
	Field sampling (fyke netting)																						
	Lab fish ageing (small-bodied)																						
	Lab fish ageing (large-bodied)																						
	Data entry, analysis & reporting																						
Hydrology (River)	Modelling																						
	Reporting																						
Category 3																							
Fish spawning and recruitment	Planning																						
	Water sample collection																						
	Field sampling (larvae)																						
	Lab larval sorting and id																						
	Field sampling (e-fishing YOY)																						
	Lab ageing/otolith chem (larvae and YOY)																						
	Data entry, analysis & reporting																						
Matter transport	Physical–chemical data collection																						
	Modelling and scenario runs																						
	Reporting																						
Hydrological regime	Field sampling																						
	Modelling																						
	Reporting																						
Micro-invertebrate diversity	Planning																						
	Field sampling (with larval fish)																						
	Lab sample sorting and id																						
	Lab analysis (larval fish diet)																						
	Data entry, analysis & reporting																						

*larval fish sampling is partially event-based, and microinvertebrate sampling will be conducted in conjunction with larval fish sampling.

Table 5.2. Summary of sampling sites and zones for category (Cat.) 1 and 3 indicators for the LTIM Project in the LMR Selected Area from July 2014 to June 2019.

Cat.	Indicator	Zones			Sites	Comments
		Floodplain	Gorge	Swamplands		
1	Stream metabolism	Y	Y		2	Methods follow Hale *et al.* 2014 (1 continuously recording station per site)
1	Fish (River)		Y		10	Follow Hale *et al.* 2014
1	Hydrology (River)	Y	Y		6–9	Add other sites depending on flow event
3	Fish a) spawning	Y	Y		3/zone	Larval sampling sites approx. 5 km below Lock 1 and Lock 6, in the Gorge and Floodplain zones respectively
	b) recruitment	Y	Y		>6/zone	Sites spread throughout Gorge and Floodplain zones
3	Matter transport*		Y	Y	N/A	Model covers Lock 1 to Wellington, the Coorong and Lower Lakes
3	Hydrological regime	Y	Y	Y	1–2 as needed	Swamplands covered by matter transport modelling
3	Micro-invertebrate diversity	Y	Y		3/zone	This will be conducted in conjunction with larval sampling at sites approx. 5 km below Lock 1 and Lock 6, in the Gorge and Floodplain zones respectively

*Matter transport also includes the Lower Lakes and Coorong.

6 Evaluation

6.1 Evaluation questions

Indicators presented within this M&E Plan were chosen on the basis of their capacity to assess various Basin-scale and Selected Area evaluation questions. For each indicator a series of specific evaluation questions have been developed (see Section 4). The overall key evaluation questions for this plan are below.

Within the LMR Selected Area, did Commonwealth environmental water delivery contribute to:

- Increased ecosystem productivity
- Increased transport of dissolved and particulate matter
- Increased microinvertebrate diversity and abundance
- Increased spawning and recruitment of flow-dependent fish species

The indicators have also been aligned with objectives and evaluation questions that have previously been developed by CEWO and DEWNR to facilitate reporting on environmental outcomes of the Basin Plan in the LMR Selected Area. This was achieved through the development of an evaluation framework (Appendix C), a summary of which is presented in Table 6.1. This framework will be continually refined through the implementation of monitoring and evaluation activities. The framework is expected to allow for monitoring data to be evaluated at the LMR Selected Area scale and aggregated to the Basin-scale. The Basin-scale questions that can be evaluated for the LMR Selected Area are described below.

One-year evaluation questions:

- What did Commonwealth environmental water contribute to:
    - Native fish reproduction
    - Larval fish growth and survival
    - Temperature regimes
    - Salinity regimes
    - Dissolved oxygen levels
    - Patterns and rates of primary productivity
    - Patterns and rates of decomposition
    - Hydraulic diversity within weir pools
    - Microinvertebrate diversity

Five-year evaluation questions:

- What did Commonwealth environmental water contribute to:
    - Native fish populations
    - Native fish species diversity
    - Fish community resilience
    - Native fish survival
    - Sustainable ecosystem diversity
    - Temperature regimes
    - Salinity regimes
    - Dissolved oxygen levels
    - Patterns and rates of decomposition
    - Patterns and rates of primary productivity
    - Hydrological connectivity
- Were ecosystems to which Commonwealth environmental water was allocated sustained?

The evaluation framework was initially populated by identifying South Australian ecological objectives and evaluation questions for the LMR Selected Area from South Australian technical reports and notes, and then adjusted to acknowledge Commonwealth environmental water contributions and the Commonwealth environmental water monitoring and evaluation requirements for the LMR Selected Area[1]. South Australian objectives were arranged into three levels in the evaluation framework (see Appendix C) to help with aligning to Commonwealth environmental water outcomes, as per the Commonwealth environmental water environmental outcomes framework. Duplicate objectives and objectives that could not be aligned with Commonwealth environmental water outcomes for the LMR Selected Area were removed, and relevant indicators were assigned to each of the remaining objectives. One and five-year evaluation questions for the Basin-scale were developed from the Commonwealth environmental water environmental outcomes framework.

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[1] **Wallace (2014) RM Channel EWR – Ecological Objectives and Targets, Goyder Institute, Project E.1.9. pp. 29–32**
Bloss *et al.* (2012) DFW Technical Report 2012/11, Hydro-ecological analysis of the proposed Basin Plan – SA Floodplain
Gibbs *et al.* (2012) DFW Technical Note 2012/01, Science review of MDBA modelling, pp. 21–22
Gawne *et al.* (2013a) LTIM – Monitoring and evaluation requirements, LMR (RTF Sched 5), pp. 23–26

Table 6.1. DEWNR Selected Area and CEWO Basin-scale evaluation questions by indicator. Evaluation questions are sourced from the documents as indicated.

Cat.	Indicator	DEWNR Selected Area Key 1-year evaluation question*	CEWO Basin-scale Key 1-year evaluation question#	DEWNR Selected Area Key 5-year evaluation question*	CEWO Basin-scale 5-year evaluation question#
1	Stream metabolism	What did CEW contribute to channel primary productivity during Sep–Mar as indicated by a temporary shift from near zero or autotrophic dominance towards heterotrophic conditions?	What did CEW contribute to patterns and rates of primary productivity? What did CEW contribute to patterns and rates of decomposition? What did CEW contribute to dissolved oxygen levels?	What did CEW contribute to channel primary productivity as indicated by a persistent shift from near zero or autotrophic dominance towards heterotrophic conditions?	What did CEW contribute to patterns and rates of primary productivity? What did CEW contribute to patterns and rates of decomposition? What did CEW contribute to dissolved oxygen levels?
1	Fish (River)	None identified	What did CEW contribute to native fish reproduction?	None identified	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?
3	Fish spawning and recruitment	What did CEW contribute to the recruitment of golden perch and silver perch?	What did CEW contribute to native fish reproduction? What did CEW contribute to native larval fish growth and survival?	What did CEW contribute to the abundance of golden perch and silver perch? What did CEW contribute to the population age structure for golden perch and silver perch?	What did CEW contribute to native fish populations? What did CEW contribute to fish population/community resilience? What did CEW contribute to native fish survival?
3	Matter transport	What did CEW contribute to help increase the transport of salt from the Murray River to the Southern Ocean? What did CEW contribute to the maintenance of water quality suitable for aquatic ecosystems?	What did CEW contribute to patterns and rates of primary productivity? What did CEW contribute to salinity regimes?	What did CEW contribute to help increase the transport of salt from the Murray River to the Southern Ocean? What did CEW contribute to the maintenance of water quality suitable for aquatic ecosystems?	What did CEW contribute to patterns and rates of primary productivity? What did CEW contribute to salinity regimes?

Cat.	Indicator	DEWNR Selected Area Key 1-year evaluation question*	CEWO Basin-scale Key 1-year evaluation question#	DEWNR Selected Area Key 5-year evaluation question*	CEWO Basin-scale 5-year evaluation question#
3	Hydrological regime	What did CEW contribute to habitat (incorporating the full range of velocity classes present in the lower third of weir pools, particularly in the period spanning Sep–Mar)?	What did CEW contribute to hydraulic diversity within weir pools? What did CEW contribute to temperature regimes?	What did CEW contribute to habitat (incorporating the full range of velocity classes present in the lower third of weir pools, particularly in the period spanning Sep–Mar)?	What did CEW contribute to hydrological connectivity? What did CEW contribute to temperature regimes?
3	Micro-invertebrate diversity	What did CEW contribute to microinvertebrate abundance and diversity?	What did CEW contribute to microinvertebrate diversity?	What did CEW contribute to microinvertebrate diversity?	None identified

*Sourced and/or adapted from Bloss *et al*. (2012), Gibbs *et al*. (2012), and Wallace (2014). #Sourced from Gawne *et al*. (2013a)

6.2 Evaluation process

Each year, data collected through the LTIM Project will be analysed in detail, reporting and evaluation conducted for each indicator (see details for indicator outputs in Section 4) and a synthesis report produced, consolidating indicator outputs and describing the ecological outcomes of Commonwealth environmental watering within the LMR Selected Area. In synthesising the results, potential linkages between key indicators will also be identified in context of cause and effect of flow for the ecological responses in the LMR Selected Area as illustrated in Figure 3.2. Through the above, the evaluation is conducted for the contribution of Commonwealth environmental watering to the ecological objectives of the LMR Selected Area.

As previously indicated, the LTIM in the LMR Selected Area over the next five years will mainly focus on the main channel given the likely flow scenario of Commonwealth environmental watering being within-channel freshes. The indicators for the LMR Selected Area include:

- Hydrology (River) (Category 1)
- Hydrological regime (Category 3)
- Dissolved organic and particulate matter transport (Category 3)
- Stream metabolism (Category 1)
- Microinvertebrate diversity (Category 3)
- Fish spawning and recruitment (flow-cued spawners) (Category 3)
- Fish (River) (Category 1)

It is anticipated that Commonwealth environmental water delivery will improve hydrological conditions (including flow magnitude, variability and hydraulic diversity) within the LMR Selected Area. These are expected to lead to: increased transport of dissolved and particulate matter downstream and salt and nutrient export out of the Murray Mouth; increased productivity and transport of organic material downstream; increased microinvertebrate diversity and abundance (food resources); enhanced recruitment of flow-cued spawning fish species due to increased spawning and/or facilitating larval drift, and improved survival rate due to increased productivity and food resources (microinvertebrates); and improved resilience of key native fish populations. These outcomes will be evaluated and potential linkages identified in context of broader environmental outcomes within the LMR Selected Area.

The evaluation questions for the LMR Selected Area will be analysed, with results provided in simple evaluation tables, similar to Table 6.2. The questions identified in this table may be modified iteratively. This is an important component of the adaptive management process, allowing knowledge developed in the detailed monitoring program to inform management of Commonwealth environmental water, the monitoring program, and our understanding of ecosystem response to environmental watering within the MDB.

Table 6.2. Example table for summarising the evaluation for the LMR Selected Area, adapted from Gawne *et al*. (2014).

Evaluation question	Objective 1	Objective 2	Objective 3
What was expected?			
What was observed?			
What worked in achieving outcomes?			
What didn't work in achieving outcomes?			
Are there any suggested improvements to delivery of environmental water			
Are there any suggested changes to the monitoring design			
Does system understanding need to be updated?			

In addition to the monitoring activities outlined in this plan, a number of complementary monitoring programs are undertaken with the South Australian MDB (Table 6.3). The monitoring programs listed in Table 6.3 were identified by DEWNR for the MDB Monitoring, Evaluation and Information Coordination project, and through contact with the relevant staff. In many cases, achievement of environmental outcomes from Commonwealth environmental water will depend on management actions and monitoring in these programs. The outputs of these programs may be used to increase the capacity of the LTIM Project to evaluate environmental outcomes within LMR Selected Area and the South Australian area of the MDB more broadly.

Data collected in the complementary monitoring programs is a potential data source for the LTIM Project, but it will have some limitations. Many of the programs have limited security or short timeframes, or indicators are not yet known (see Table 6.3). The data produced may not be consistent with LTIM Project requirements, and collation and analysis of this data for LTIM Project purposes may consume significant resources. It is therefore unlikely that the raw data from these programs will be used. It is likely however, that the evaluation framework will be reassessed and updated with indicators and evaluation questions that can be addressed by complementary monitoring programs, and that reports from these programs will be interpreted to inform the evaluation of environmental outcomes of Commonwealth environmental water as part of LTIM Project annual reporting. The potential for this will be explored as further information about the programs becomes available, and this will be resourced within the evaluation component of the LTIM Project.

The exception is water quality monitoring by SA Water, MDBA, DEWNR and the EPA. These data sources are suitable for use within the dissolved and particulate matter transport component of this project. However, funding sources for these programs are not secure. The risk management under such circumstances has been addressed in Table 8.2.

Table 6.3. Complementary monitoring programs for potential use in evaluating ecological outcomes in the LMR Selected Area associated with Commonwealth environmental water.

Funding source	Description of site(s)	Indicators	Planned monitoring timeframe	Security of funding	Contact person
SA MDB NRM Board	Approximately 50 wetlands along the LMR Selected Area that are actively managed through operation of regulators or pumping	Site (wetland) specific, dependent on objectives. Includes water quality, groundwater, frogs, macroinvertebrates, birds, vegetation, fish	Ongoing	Unknown	Rebecca Turner
The Living Murray (TLM)	Chowilla	Water quality, vegetation, fish, birds	Ongoing	Funding significantly reduced in 2014-15; Unknown for future years	Jan Whittle
TLM	Coorong, Lower Lakes and Murray Mouth	Vegetation, fish, birds, macro-invertebrates	Ongoing	Funding significantly reduced in 2014-15; Unknown for future years	Adrienne Rumbelow
Riverine Recovery Project (RRP)	Approximately 60 wetlands along the LMR Selected Area that are actively managed through operation of regulators	Not finalised. Site (wetland) specific, dependent on objectives. Includes vegetation, fish, birds, frogs, water quality	2014–2016	Unknown	Tumi Bjornsson
RRP	Weir pool manipulation	Inundation extent, flow velocity, vegetation, biofilms, macroinvertebrates	2014–2016	Funded	Tumi Bjornsson
RRP	Pike Floodplain	Numerous, focus on fish	2012–2016	Funded	Tumi Bjornsson
Goyder Institute	Murray River: Lock 6 and Lock 5 weir pool and Chowilla Anabranch (creeks and floodplain)	Water quality and open water metabolism: dissolved oxygen, BOD, dissolved organic carbon, nutrients	Feb 2014–May 2015	Funded	Todd Wallace
SA Water and MDBA (selected sites and parameters)	Lock 9, Lake Victoria Outlet, Murray River (MR) DS Rufus River Gauging Weir, MR 8 km downstream of Lock 6, MR Renmark, Lock 5, MR Berri, MR Loxton, MR Moorook, MR Cobdogla, MR Woolpunda, MR Waikerie,	Key parameters include phytoplankton count, chlorophyll *a*, metals, basic phys/chem., colour, DOC, DO, nutrients, colifoms/*E. Coli*, turbidity. Not all of these are monitored at each site	Ongoing	Not guaranteed (annual review)	Thorsten Mosisch

Funding source	Description of site(s)	Indicators	Planned monitoring timeframe	Security of funding	Contact person
	MR Cadell, MR Morgan, MR Lock 1, MR Swan Reach, MR Cowirra, MR Mypolonga, MR Mannum, MR Murray Bridge, MR Tailem Bend, Goolwa Barrage u/s, Lake Alexandrina – Milang				
Murray Futures (DEWNR, EPA)	Lower Lakes and Coorong	Water quality, phytoplankton, zooplankton Fish, macroinvertebrates	2014–2016 2010–2015	Secure until 2016 Secure until 2015	Ann-Marie Jolley Liz Barnett
Lower Murray Reclaimed Irrigation Area (LMRIA – EPA)	Lower Murray – Mannum to Wellington	Water quality, volumes and river impacts from LMRIA drainage channels.	2013–2014	Unfunded beyond June 2014	Like VanRoosmalen

7 Communication and engagement

7.1 Stakeholder engagement

The Stakeholder Engagement Plan is designed to ensure appropriate information exchange between parties involved in environmental watering and monitoring. Engagement with the broader community will be through existing stakeholder engagement processes of CEWO and the consortium partners.

The Stakeholder Engagement Plan aims for parties involved in environmental watering and monitoring in the LMR Selected Area to be aware of the project and its outputs, and to contribute data, advice and feedback for the monitoring and evaluation activities where appropriate.

The objectives of the Stakeholder Engagement Plan are to:

- Engage effectively with stakeholder agencies and organisations in the Australian and South Australian Governments
- Deliver communications in a targeted, relevant, timely, accurate and appropriate manner
- Respond to the emerging and changing needs of information delivery as they arise.

The Stakeholder Engagement Plan is guided by the International Association for Public Participation's (IAP2) Public Participation Spectrum.

7.1.1 Protocols for communicating information about the project

Community and stakeholder engagement requires a strong foundation. To create this foundation the LMR Selected Area consortium has adopted the seven principles outlined within 'Better Together: Principles of Engagement', developed by the South Australian Government to provide a consistent approach to community engagement. It has been developed using the values and practices of IAP2.

- We begin early.
- We know what we want to achieve and we communicate it clearly.
- We know who to engage.
- We know the background and history.
- We are genuine.
- We recognise and celebrate.
- We are creative, relevant and engaging.

7.1.2 Protocols for consistent messaging

While it is important to allow robust internal debate and discussion about processes, methodologies and interpretation, it is important for the credibility of the overall monitoring and evaluation program that messages delivered by the project team publicly are positive, internally consistent and consistent with messages from CEWO and the South Australian Government.

To this end, all key messages will be agreed by the Executive Committee before being made public. If there are any messages that could be construed as criticisms of or concerns about the LTIM Project, they will be discussed between CEWO Project Management Team area leader and the Project Leader to gain agreement on appropriate language.

The Project Leader will advise CEWO Project Management Team area leader of any meetings she organises, and offer the area leader the opportunity to contribute to relevant discussions.

Any written recording of meetings should accurately reflect the content of the discussion, but remove any emotive language.

It is important that complaints can be made. Any complaints by clients should be made to CEWO Project Management Team area leader in writing, by the Project Leader. Any complaints or concerns raised by stakeholders will be communicated to the area leader through the Project Leader. It is expected that any concerns presented to CEWO will be responded to in a timely manner, through the Project Leader back to the complainant.

All requests for media communications will be referred to the Director with oversight of the Lower Murray River LTIM Project within CEWO.

In all communications related to the LTIM Project (both operational and external), the LMR Selected Area consortium members agree to comply with the Code of Conduct developed by CEWO.

7.1.3 Stakeholder groups

Clients

Clients are those who are affected by the outcomes of the Project and are critical to the success of the Project.

Table 7.1. Clients for engagement

Client	Role and benefit to the project	Primary method of engagement
Commonwealth Environmental Water Office (CEWO)	Purchasing client Defines the deliverables Approves milestone payments	Contract with SARDI Reporting (see section 7.2) Meetings of the Selected Area Working Group
M&E Adviser	Provides technical advice on the design of the monitoring program	Communication through CEWO
Partner agencies of the project consortium	Support for project participants	Sub-Contracts Meetings of the Selected Area Working Group

Stakeholders

Stakeholders are those whose input or involvement may be required for the Project to be successful, or who are likely to play a key role in supporting the outcomes of the Project.

Table 7.2. Stakeholders for engagement

Stakeholder	Role and benefit to the project	Primary method of engagement
Department of Environment, Water and Natural Resources (DEWNR)	Identify monitoring and evaluation requirements for the South Australian Government Data curation Advice on engagement Knowledge adoption in adaptive management of environmental flows	Membership on the Selected Area Working Group Membership on the project delivery team during Stage 1
SA Water	Identify monitoring and evaluation requirements for the effective operation of the River	Membership on the Selected Area Working Group

Stakeholder	Role and benefit to the project	Primary method of engagement
EPA	Identify monitoring and evaluation requirements Contributing relevant water quality data for evaluation Responsible for SA State of Environment Report	Membership on the Selected Area Working Group Membership on the project delivery team during Stage 1
South Australian Murray–Darling Basin Natural Resources, DEWNR Local Action Planning	Provide advice on monitoring and evaluation needs of community stakeholders in the Lower Murray River region Community engagement	Membership on the Selected Area Working Group Membership on the project delivery team during Stage 1
First Nations	Identify monitoring and evaluation requirements of First Nations	Membership on the Selected Area environmental watering group
Affected landholders	Provide access to land for project delivery Supportive landholders ensure strong community support for the monitoring and evaluation program	Work with all affected landholders to agree on protocols for access and behaviour while on their land Engagement and interaction with affected landholders will comply with the Code of Conduct developed by CEWO

Interested communities

Interested communities are the broader public and community groups that may have an interest in the Project, but do not have significant influence or impact on the outcomes.

Table 7.3. Interested communities for engagement

Interested Communities	Desired Relationship	Primary Method of Engagement
Community of people who have a connection to the River	Support for and interest in the Program Promotion of the Program	External communication and engagement activities will be through existing engagement processes related to the management of environmental water. The primary engagement pathway will be the Selected Area environmental watering group
Media	Promotion of the Program	
Broader community	Support for and interest in the Program Promotion of the Program	

Table 7.4. Operational communications plan

Activity	Purpose	Timing / frequency	Responsibility	Indicative attendees
Project Meetings – CEWO and M&E Providers	*Project progress and outcomes* Regular meetings between CEWO and the M&E Providers will serve to monitor project progress, ensure the project remains on track to deliver against the project outcomes and to discuss and resolve project risks, issues and actions.	Monthly during Stage 1 Quarterly during Stage 2	SARDI	CEWO M&E Provider (Project Leader plus others as required)
M&E Adviser to M&E Provider meetings (with CEWO)	*Project approach, methods and technical guidance* Consistency in monitoring and evaluation approach is required across all Selected Areas. The approach must be aligned with the Logic and Rationale document and monitoring for Basin-scale interests must be undertaken in a consistent manner (some flexibility may be possible in monitoring and evaluation of area-scale interests). The purpose of these meetings will be: for the M&E Advisers to brief the M&E Providers on the project approach and methods; and for the M&E Providers to seek technical guidance.	Initial briefing workshop – 5 & 6 Dec 2013 Others as required	SARDI	CEWO M&E Advisers (Project Leader plus Task Leaders) M&E Providers (Project Leader plus Task Leaders)
LTIM Project Leaders Group meetings	*Collaboration and consistency* Consistency across all Selected Areas is essential. Regular meetings between the M&E Provider Project Leaders for each Selected Area and CEWO will help achieve this. Such meetings will also provide an opportunity for the Project Leaders to collaborate and share knowledge and experiences.	Monthly during Stage 1 Biannually from 2014–15	SARDI	CEWO M&E Provider Project Leaders for each Selected Area
Selected Area Working Group meetings	*Information and knowledge exchange* The Selected Area Working Group meetings will provide a forum for all parties involved in environmental water delivery to exchange knowledge, information and observations.	At least 2 times during Stage 1 Quarterly from 2014–15	SARDI	Selected Area Working Group members
M&E Provider annual workshops	*Technical collaboration* As monitoring and evaluation activities proceed, adaptations will be required in response to practical experiences. Annual workshops will provide a forum to discuss lessons learned and collaborate on adapting the monitoring and evaluation activities. The workshops will also help to build relationships between the M&E Providers and create opportunities for efficiencies.	Annually	CEWO	CEWO M&E Advisers (Project Leader plus Task Leaders) M&E Providers (Project Leader plus Task Leaders)

Activity	Purpose	Timing / frequency	Responsibility	Indicative attendees
Selected Area environmental watering group workshop	*Update on LTIM Project* Combined with one Selected Area Workshop in Year 2 and Year 5, other members of the environmental watering group will be invited to be kept up to date on the activities and outputs of the monitoring program.	Two workshops over the life of the project Likely in Year 2 and Year 5	SARDI	Selected Area Working Group members Broader range of interested parties from the environmental watering group and community representatives

7.2 Reporting to CEWO

The timetable for reporting to CEWO is described in the table below.

Table 7.5. Summary of engagement, reporting and information transfer activities

What	Frequency	Timing / due date	Responsibility	Receiver	Description and high level requirements	Inputs
Monitoring and Evaluation Plan	One-off	Draft – 28 Feb 2014 Final – 17 Apr 2014	M&E Providers	CEWO	A plan for monitoring and evaluation in each Selected Area over the five-year period from 2014–15 to 2018–19.	
Monitoring work plan	Annual	August	M&E Providers	CEWO	An annual plan will be developed and provided to CEWO.	
Evaluation work plan	Annual	August	M&E Providers	CEWO	An annual plan will be developed and provided to CEWO.	
Area evaluation report	Annual	Draft – 30 Aug Final – 31 Oct First report – 2015 Final report – 2019	M&E Providers	CEWO	A cumulative evaluation of the outcomes of Commonwealth environmental water at each Selected Area, prepared in accordance with the M&E Plan. The report must be prepared in plain English with simple science and be suitable for publication on CEWO website.	M&E Plan Monitoring data for the Selected Area
Progress reports – 2013–14	Monthly	Nov 2013 to Jun 2014 (last business day of the month)	M&E Providers	CEWO	A written progress report, summarising tasks completed since the last report, tasks planned for the upcoming period, emerging issues etc.	Progress report template
Progress reports – 2014–15 onwards	Quarterly	Sep, Dec, Mar and Jun (last business day of month) for the duration of the LTIM Project	M&E Providers	CEWO	A written progress report, summarising tasks completed since the last report, tasks planned for the upcoming period, emerging issues etc.	Progress report template

What	Frequency	Timing / due date	Responsibility	Receiver	Description and high level requirements	Inputs
Monitoring data entry	Monthly Or as appropriate for indicators agreed by CEWO	Monthly (or appropriate frequency agreed by CEWO) for the duration of the LTIM Project	M&E Providers	Monitoring Data Management System	Processed monitoring data uploaded to the Monitoring Data Management System in accordance with data management protocols, as outlined in the M&E Plans.	Data management protocols
Information exchange	As appropriate to support delivery of environmental water		M&E Providers	Delivery partners	Information exchange on project activities (monitoring undertaken, observations, evaluation) and any information that is available to M&E Providers that would support the delivery of environmental water. This could be written and/or verbal. The Selected Area Working Group is an appropriate forum.	

7.3 Selected Area Working Group

7.3.1 Purpose

The Selected Area Working Group for the Lower Murray River will provide a forum for the exchange of information and intelligence that supports the implementation of the LTIM Project, through effective coordination of environmental watering and monitoring and evaluation.

7.3.2 Authority

The Selected Area Working Group will be organised, operated and Chaired by Dr Paul Dalby (M&E Provider), under the Terms of Reference approved by CEWO.

The Working Group has no executive powers, supervisory functions or decision-making authority in relation to the LTIM Project. It is an operational group tasked with a general support and advisory role.

7.3.3 Objectives

The Selected Area Working Group will facilitate:

- Effective coordination between environmental water delivery partners and other relevant monitoring and evaluation projects
- Communication to environmental water managers of any information that would improve environmental water management
- Exchange of information and intelligence relevant to improving the implementation of the LTIM Project and the efficacy of environmental watering activities, to support adaptive management on both a short-term (preliminary observations during watering events) and longer-term (evaluation outcomes) basis
- The identification, communication and management of any issues, risks or opportunities relevant to the LTIM Project.

7.3.4 Membership

The Selected Area Working Group includes organisations involved in environmental water planning and delivery, which are directly or indirectly responsible for the successful delivery of the LMR Selected Area LTIM Project.

The Working Group comprises the following members who have been nominated by the Project Leader and agreed to by CEWO:

Table 7.6. Membership of the Selected Area Working Group*

Name	Agency/position	Role
Qifeng Ye	**SARDI** – LMR Selected Area LTIM Project lead organisation	Working Group Chair Project Leader Executive Committee Chair (Stage 1)
Kane Aldridge	**University of Adelaide** – LMR Selected Area LTIM Project consortium partner	Working Group member Task Leader Executive Committee member (Stage1)
Rod Oliver	**CSIRO** – LMR Selected Area LTIM Project consortium partner	Working Group member Task Leader Executive Committee member (Stage 1)

Name	Agency/position	Role
Matt Gibbs	**DEWNR/University of Adelaide** – LMR Selected Area LTIM Project consortium partner	Working Group member Task Leader
Brenton Zampatti	**SARDI** – LMR Selected Area LTIM Project lead organisation	Working Group member Task Leader
Russell Shiel	**Wetland Research and Management** – LMR Selected Area LTIM Project consortium partner	Working Group member Task Leader
Michelle Bald	**DEWNR –** LMR Selected Area LTIM Project consortium partner (Stage 1)	Working Group member Executive Committee member (Stage 1)
Chris Wright	**DEWNR –** LMR Selected Area LTIM Project consortium partner during Stage 1	Working Group member Executive Committee member (Stage 1)
TBA	**EPA** – LMR Selected Area LTIM Project consortium partner during Stage1	Working Group member
CEWO Program Officer	**CEWO**	Working Group member
CEWO Delivery Team representative	**CEWO**	Working Group member
Susan Buckle	**MDBA**	Working Group member
Neville Garland	**MDBA**	Working Group member
Tracey Steggles	**DEWNR** – LMR Selected Area LTIM Project consortium partner during Stage 1	Working Group member
Tumi Bjornsson	**DEWNR** – LMR Selected Area LTIM Project consortium partner during Stage 1	Working Group member
Tony Herbert	**DEWNR** – LMR Selected Area LTIM Project consortium partner during Stage 1	Working Group member
Jarrod Eaton	**DEWNR** – LMR Selected Area LTIM Project consortium partner during Stage 1	Working Group member
Keith Rowling	**PIRSA Fisheries and Aquaculture**	Working Group member
Rebecca Turner	**DEWNR/SAMDB NRMB** – LMR Selected Area LTIM Project consortium partner during Stage 1	Working Group member Task Leader (Stage 1)
Nigel Rutherford	**SA Water**	Working Group member
Paul Dalby**	**In Fusion Consulting** – LMR Selected Area LTIM Project consortium partner during Stage 1	Working Group Chair (Stage 1) Project support (Stage 1)
Rhonda Butcher**	**Monash University**, LMR Selected Area LTIM Project M&E Adviser during Stage 1	LTIM Project M&E Adviser (Stage 1) Working Group member (Stage 1)
Sally Maxwell**	**DEWNR/CSIRO –** LMR Selected Area LTIM Project consortium partner	Task Leader (Stage 1)
Jason Nicol**	**SARDI** – LMR Selected Area LTIM Project lead organisation	Task Leader (Stage 1)

Note: *members may be refined during the implementation phase of the LTIM Project.

** members for Stage 1 M&E Plan development only.

7.3.5 *Terms of reference*

The Selected Area Working Group is responsible for providing strategic direction for the LTIM Project and exchanging information and intelligence to support project delivery and adaptive management. It will:

- Actively support and promote the LTIM Project within partner organisations
- Review key project documentation where appropriate, including evaluation reports
- Exchange operational intelligence relevant to the LTIM Project, including intelligence on upcoming watering or monitoring activities
- Exchange intelligence relevant to adaptive management of environmental water, including operational observations and monitoring and evaluation outcomes
- Consider stakeholder expectations of the LTIM Project where appropriate
- Exchange intelligence on any actual or perceived risks to the LTIM Project
- Communicate key messages of the LTIM Project to organisations involved in environmental water planning and delivery
- Document key discussion points and outcomes of Working Group meetings and distribute these to members in the form of minutes.

Meetings

Working Group meetings will be held at least twice during Stage 1 (2013–14) and quarterly or as required in Stage 2 (from 2014–15). Meetings will be held primarily at SARDI Aquatic Sciences, 2 Hamra Avenue, West Beach, South Australia.

Minutes and agendas

The M&E Provider will prepare and distribute meeting agendas and minutes. Agendas and minutes from the previous meeting will be distributed no later than five days prior to the meeting. Meeting minutes and action items will be distributed within two weeks of the meeting. Immediate actions may be circulated earlier.

Agenda items

Meeting papers will be distributed no later than five days prior to the meeting (where practical), and will include an agenda, minutes of the previous meeting, and any papers for consideration.

The standard agenda items for the Working Group are listed below. Members can submit additional items to be included on the agenda at the discretion of the Chair.

Table 7.7. Standard agenda items and responsibilities for the Working Group

Item	Responsibility
Review and accept minutes from last meeting	M&E Provider (Chair)
Update on action items from last meeting	Chair and members
Update on planned watering activities	Delivery partners, environmental water planning organisations
Update on planned monitoring activities	M&E Provider lead
Update on monitoring observations and evaluation outcomes to support adaptive management	M&E Provider lead
Update on community engagement	M&E Provider lead
Other business	All
Confirmation of next meeting	M&E Provider (Chair)

Grievances

Grievances identified within the Working Group will be mediated by the Chair. Where a grievance is deemed significant, a member or members of the Working Group may be removed from the Working Group, at the discretion of CEWO.

8 Project management

8.1 Project governance

The Project Leader, Dr Qifeng Ye, SARDI Aquatic Sciences, will lead the development and implementation of the M&E Plan, oversee the project and ensure project performance, coordination, reporting and communication. The Project Leader will be the contact for any communication between the project delivery team and CEWO Project Management Team area leader.

An Executive Committee was established for **Stage 1** including the following members:

- Qifeng Ye (SARDI), Chair
- Rod Oliver (CSIRO)
- Kane Aldridge (University of Adelaide)
- Michelle Bald (DEWNR)
- Chris Wright (DEWNR)

The role of the Executive Committee during Stage 1 was to agree on the allocation of resources, endorse project plans for the work teams, and resolve any conflicts or issues between the partners.

For Stage 2, the Project Leader will oversee and manage the project with support from **Task Leaders**:

- Kane Aldridge (University of Adelaide)
- Rod Oliver (CSIRO)
- Brenton Zampatti (SARDI)
- Matt Gibbs (University of Adelaide)
- Russell Shiel (Wetland Research and Management)

Task Leaders will be responsible for leading the delivery teams that will implement technical programs to monitor the agreed indicators.

Table 8.1. Project and task leaders and delivery team

Matter/activities	Indicators (category)	Task Leader	Delivery Team
Project leadership and management	N/A	Qifeng Ye, SARDI	Other Executive Committee members
Hydrology	Hydrology (River) (1) Hydrological regime (3)	Matt Gibbs, UoA	DEWNR representatives
River metabolism and ecosystem function	Stream metabolism (1)	Rod Oliver, CSIRO	Zygmunt Lorenz, CSIRO
Matter transport	Matter transport (3)	Kane Aldridge, UoA	Matt Hipsey, Univ. WA
Fish response	Fish (River) (1) Fish spawning and recruitment (3)	Brenton Zampatti, SARDI	Qifeng Ye, SARDI Juan Livore, SARDI Other SARDI researchers
Other fauna	Microinvertebrate diversity (3)	Russell Shiel, WRM	Lorwai Tan, WRM
Evaluation	N/A	Kane Aldridge, UoA	DEWNR representatives
Communication and	N/A	Qifeng Ye, SARDI	Rebecca Turner, SAMDB

Matter/activities	Indicators (category)	Task Leader	Delivery Team
Engagement			NRM/DEWNR

8.2 Risk assessment

Only the risks for which the delivery agent is partly or fully responsible have been assessed in this section. There may be other risks to this project that CEWO is solely responsible for managing. This Plan does not assess those risks.

Table 8.2 identifies risks to the project, including:

- Communication risks – risks to the project if communication is ineffective or inadequate
- Project risks – risks to the ability of the project team to undertake all of the required tasks to an acceptable standard within the timeframe and budget of the project
- Environmental risks – risks to the environment from carrying out monitoring tasks
- Health and safety risks – risks to the health and safety of the project team members as a result of their involvement in the project
- Political risks – risks of political issues being raised because of the project design, delivery or outcomes.

An assessment of the likelihood and consequence of these risks is made. A combination of these two assessments is used to make an overall assessment of risk to the project and its partners. A strategy for mitigation is proposed. The order of preference of how to mitigate the risks is:

1. Avoiding the risk by deciding not to start or continue with the activity that gives rise to the risk
2. Accepting or increasing the risk in order to pursue an opportunity
3. Removing the risk source
4. Changing the likelihood
5. Changing the consequences
6. Sharing the risk with another party or parties (including contracts and risk financing)
7. Retaining the risk by informed decision.

Table 8.2. Project risks, their level of significance, and a proposed mitigation strategy

Risk	Likelihood	Consequence	Level	Mitigation
Communication Risks				
Tight timeframes for consultation on the development of the M&E Plan. Stakeholders may not all feel that they have had the opportunity to be adequately involved. The project team may not be aware of all of the key issues.	High	High	High	Provide more than one opportunity for engagement Personally invite key stakeholders to contribute advice and review methodologies
Failure to engage key stakeholders. The project team is not aware of key issues and intelligence.	Low	Medium	Medium	Communicate widely Form the Selected Area Working Group
Failure to be clear about what people can influence, and to what degree. Stakeholders spend time trying to influence non-negotiable issues.	Medium	Medium	Medium	Continually reinforce the scope of the project Clear Terms for Reference for the Selected Area Working Group

Risk	Likelihood	Consequence	Level	Mitigation
Perception by stakeholders that project has not been successful because outcomes are not what they expected.	Medium	High	High	Clearly communicate the role, scope and expected outcomes of the project and how issues will be managed
Project Risks				
For Category 3 Hydrological regime Permission is not given to obtain validation data for the hydrodynamic models from the DEWNR, SA Water and Bureau of Meteorology.	Low	Low	Low	The task leader is in a joint position with DEWNR as the Principal Hydrologist. Permission to use validation data will be actively sought from relevant organisations prior to use. Additionally, velocity measurements are not essential; a modelled comparison between with and without Commonwealth environmental watering can still be provided. With validation data, there will be more confidence in the model outputs. Nevertheless the relative comparison is likely to be relevant either way. Some of the gauging has been done through other funded project e.g. weir pool raising project, with data suitable for validating model.
For Category 3 Matter transport modelling Permission is not given to obtain validation data for the Coorong, Lower Lakes and Murray River from the Environment Protection Authority, DEWNR and SA Water.	Very low	High	Low	EPA has agreed to provide in-kind support to this project through Dr Luke Mosely’s engagement in this project and provision of water quality data for validation. Also the Task leader is in a joint position with DEWNR as the Principal Ecologist and has established collaborative relationship with SA Water; the leader will actively seek permission from these organisations for data use.
For Category 3 Matter transport modelling Lack of funding for the monitoring data to be collected through South Australian Initiatives	Medium	High	Medium –High	If there is no monitoring being funded, adjustments to the budget could be made to collect a minimal amount of data to validate the model.

Risk	Likelihood	Consequence	Level	Mitigation
Unexpected delays to the project (e.g. due to weather).	High	Medium	High	Regular reporting mechanisms identified in Table 7.5
No environmental watering events occur in any one year.	Medium	Medium	Medium	Accept that monitoring results in any one year may not demonstrate an impact of environmental watering
Category 1 methods do not enable ecological effects of environmental watering to be adequately evaluated at the Selected Area scale.	Medium	High	High	The study approach is designed to enable this evaluation Category 3 indicators have been tested in LMR Selected Area Evaluate annual outcomes and adapt approach if required
Failure of individual Task Leaders or project participants to deliver on their requirements.	Medium	Medium	Medium	Sub-contracts include a clause linking payments to delivery of milestones Reporting outlined in Table 7.5 Review of project progress by the Executive Committee
Loss of key staff.	Low	High	Medium	Seek replacement from within the employing organisation. If a suitable individual cannot be found, seek an appropriate replacement from across the consortium partners, then externally
Environmental Risks				
Damage to environmental assets from field or laboratory work.	Low	High	Low	Seek environmental approvals for any field or laboratory work that may put environmental assets at risk
Health and Safety Risks				
Injury resulting from field or laboratory work.	Low	High	Medium	Staff are required to follow the health and safety rules and guidelines of their host organisation
Political Risks				
Evaluation does not adequately meet the objectives of the South Australian Government.	Low	High	TBD	Communication and reporting outlined in Table 7.4 and Table 7.5
Criticism of methodology by scientists not involved in project delivery.	Low	High	Medium	Refer criticisms to CEWO and LTIM Project M&E Adviser

Risk	Likelihood	Consequence	Level	Mitigation
Media criticism of the investment made into the LTIM Project (too low or too high).	Low	Medium	Medium	Refer criticisms to CEWO

8.3 Quality plan

This Quality Assurance Plan documents quality control and quality assurance procedures for activities at the Selected Area. The plan has been 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. Further information on QA/QC, data management, and health and safety procedures are provided for each indicator in their respective SOPs (Appendix B).

8.3.1 Equipment

Stream metabolism water quality samples and equipment maintenance

Quality control and quality assurance protocols are documented in the SOP for Category 1 Stream metabolism (Appendix B, pg 94). In terms of this method, the Quality Plan has been addressed by the descriptions of:

- Requirements for NATA accreditation for water quality analyses
- Holding times for water quality samples
- Calibration and maintenance of sensors and loggers
- Preservation and transport of water quality samples

Electrofishing boat for fish sampling

Fish sampling for category 1 and 3 indicators will be undertaken using electrofishing. SARDI Inland Waters and Catchment Ecology has two electrofishing boats*, Frank* and *Henri*. The primary difference between these is hull size (5.8 and 4.3 metres respectively) and the capacity of the electrofishing units (7.5 and 5.0 kW respectively). Both boats are operated and maintained in accordance with the *Australian Code of Electrofishing Practice 1997* and SARDI SOPs. Comprehensive details on operation, maintenance and risk management can be found in these documents, which can be supplied if required.

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

Monitoring teams will be led by experienced scientists who are skilled to appropriately perform sampling using standard, repeatable methods (gear, sample size, sample preparation and preservation). The SARDI Project Leader will ensure that Task Leaders develop suitable Quality Plans in consultation with the LTIM Project M&E Adviser to ensure the data and measurements taken in the LMR Selected Area are of high quality and appropriately scaled to be able to report against questions with suitable error estimates if required.

Relevant standards and guidelines will be considered, equipment records will be maintained, calibration directions provided with each instrument will be followed, and for each instrument the meter errors for each analyte will be documented and reported. Details about data collection will be developed in negotiation and agreement with the LTIM Project M&E Adviser. At the end of the first year, a plan documenting all indicators, metrics and analytes will be provided for all work in the LMR Selected Area, which demonstrates that quality sampling, analyses, reporting and data entry will be undertaken.

The South Australian consortium partners provide research and monitoring services as part of our core business. We all have established QA/QC processes for field sampling, laboratory analysis, experimental data collection, data entry and reporting. Specific QA/QC plans are provided for relevant activities in SOPs (Appendix B).

8.3.3 Data storage and management

Individual sub-contractors will be responsible for management of all primary (raw) data including governance, storage, backup, version control and custodianship.

- Hydrology data will be entered into Hydstra
- Water quality and stream metabolism data will be entered to various CSIRO database including excel and R-based data system
- Fish and microinvertebrate data will be entered into SARDI inland waters database (access)

A copy of data will be provided to the M&E Provider lead agency (SARDI) and held within SARDI corporate, standardised, authoritative data storage. Also, preliminary discussion has occurred to explore the potential for the Science Resource Centre in DEWNR for the storage and maintenance of all data.

In addition, data will be entered into the LTIM Monitoring Data Management System (MDMS). This will be done in the format which is specified in the data management section of the SOPs for each indicator (Appendix B).

8.3.4 Document management

Documents will be saved to identify the *[filename] [version number] [date in reverse].* For example, the second version of a report on a fish indicator prepared on 12 April 2015 will have a filename 'fish indicator report v2 150412'. Any minor comments on that file will have the initials of the author who made the changes added to the end of the filename, for example 'fish indicator report v2 150412 QY'.

Each document will have a document control monitor on the front page, as below. A document cannot be released until it is approved by the Project Leader.

Version	Date	Author	Approved by

8.3.5 Training

The team assembled to undertake this project are all highly experienced field operators, and it is not envisaged that they will require any training.

Should anyone require training, it will be at the instruction of the Project Leader. Under such circumstances, the Project Leader will require written confirmation from the trainer that the trainee has demonstrated competency in the required skills before that individual is permitted to undertake the relevant monitoring.

8.3.6 Auditing

CEWO has advised that they will be establishing whole-of-project audit procedures. The LMR Selected Area consortium has also identified the following self-auditing protocols.

Table 8.3. Self-auditing plan

Input/output	Audit procedure
Project partner sub-contracts	Payments made on delivery of milestones listed in the sub-contract, to be approved by the Project Leader
Technical reports and papers	Every technical report/paper and Annual Report will be independently reviewed
Data management protocols	Data quality will be audited by SARDI staff
Project risk assessment and mitigation plans	Mitigation of risks as per the risk management strategy will be audited quarterly by the Executive Committee
Health, safety and environmental risk assessment and mitigation plans	Each partner organisation of the consortium will sign off that they have audited the project for consistency with internal health and safety procedures
Communication and engagement plans	Delivery of communication and engagement plans will be audited quarterly by the Executive Committee

8.4 Health, safety and environment plan

The project consortium is unable to present a single health, safety and environment plan because staff within each organisation are required to follow their own internal rules and guidelines. Each partner organisation of the consortium will sign off that they have audited the project for consistency with internal health and safety procedures.

This section outlines how SARDI will manage work, safety and environment for this project.

Site Safety Management Plans (SSMP – these are confidential and not attached) have been implemented across PIRSA, including SARDI. They are a tool designed to assist PIRSA worksites to meet minimum Work Health Safety and Injury Management (WHS) legislative and PIRSAFE requirements.

Under these plans, activities are scheduled and responsibilities allocated to ensure that obligations are met. Completing the activities contained within the plan supports the site's compliance with WHS legislation and PIRSAFE policies and procedures. Evidence of completed activities is registered to meet compliance and audit requirements.

The SSMP provides the guidance and tools to meet the work health and safety requirements for the LTIM Project, along with PIRSA's other WHS policies and procedures.

8.4.1 Objective

To ensure that project risks are eliminated or mitigated through the identification of hazards, assessment of risk and the application of effective control measures.

8.4.2 Identification and control of risks

Risk management is conducted in accordance with PIRSAFE Risk Management Policies and Procedures. Risks are identified through the PIRSA WHS Risk Register (attached separately). This is covered under Activity 2.2 in the Site Safety Management Plan. A job task register is a document that compiles information relating to work tasks, the associated risks and controls.

The Project Leader will work with SARDI staff to identify and control workplace health and safety related risks, and develop a plan for controlling these risks.

Success measures for the plan will include:

- Compliance with WHS legislative and governance responsibilities
- A reduction in incidents, lost time and workers compensation claims
- Streamlined processes in WHS programs
- Consistency, integration and benchmarking of WHS programs across PIRSA
- Client satisfaction in WHS services and programs
- Positive cultural and behavioural changes and increased awareness
- A happier, healthier workforce, skilled with the tools of achieving a work–life balance
- Continuous improvement in WHS programs.

8.4.3 Risk register

The risk register is developed following the completion of the job task register. This is covered under Activity 2.7 in the Site Safety Management Plan. All residual risks that are high or extreme go on the risk register. A review of the job task register and risk register is undertaken annually.

8.4.4 Safe work procedures

SARDI conducts safe work practices in accordance with PIRSA WHS Contractor Management Procedures (attached separately). Further SOPs are developed for specific hazards. These SOPs are identified and developed through the job task register and risk register. This is covered under Activities 2.2, 2.7, 2.10, 2.20 and 2.21 in the Site Safety Management Plan.

Hazards are reported across PIRSA through the job task register and risk register, then analysed to identify trends and implement preventative measures. As a result, PIRSA has explicit SOPs relating to:

- Bushfire safety
- Driving
- Drug and Alcohol
- Energy Isolation
- Events
- Fatigue Management
- Field Work
- Hazard & Incident Reporting and Investigation
- Hazard Management
- Hazardous Manual Tasks
- Hazardous Substances Management
- Inclement Weather
- Injury Management
- Work Health and Safety Planning
- Plant and Equipment
- Risk management
- Site Safety Management Plans.

8.4.5 Procedures for site visits

SARDI conduct safe work practices for site visits and field trips in accordance with PIRSAFE Procedures. Site visit and field trip procedures are managed through our trip itinerary form (attached separately). This is covered under Activity 2.33 in the Site Safety Management Plan.

8.4.6 Fieldwork checklists

SARDI staff must complete a trip itinerary form for a field trip. A Designated Duty Officer is the land-based contact for field trip staff to ensure safety during field trips. Specific checklists have been developed for research and monitoring projects. Checklists will be developed for fieldwork relevant to monitoring indicators when the final list of indicators has been approved.

8.4.7 Legal and other requirements

- *Work Health and Safety Act 2012*
- *Work Health and Safety Regulations 2012*
- *Workers Rehabilitation and Compensation Act 1986*
- *Workers Rehabilitation and Compensation Regulations 2010*

8.4.8 Related documents

- PIRSAFE Procedures
- Site Safety Management Plan

8.4.9 WHS roles and responsibilities

The Chief Executive of PIRSA is required to identify, audit and demonstrate compliance with WHS legislation and the Workcover Performance Standards for Self-insurers through the PIRSAFE systems.

SARDI is required to integrate WHS within its business, performance and goals. SARDI assigns its own objectives, targets and key performance indicators to meet its business needs, in addition to PIRSA-wide objectives.

Site managers are appointed at each of SARDI's regional sites, who coordinate WHS site activities. PIRSA provides these site managers with standard practices, guidance and assistance, tools, systems and education.

In this particular project, the Project Leader from SARDI is responsible for ensuring that the objectives and goals of the WHS plan are met by SARDI staff. The Project Leader will require each consortium partner to sign a WHS Plan when they agree that it is consistent with their internal health and safety procedures.

The Project Leader will be responsible for implementing the agreed WHS Plan for the SARDI staff involved in the project. Where two organisations are involved in the same field trip, they will each have developed their own WHS Plan that meets their own internal WHS requirements.

8.4.10 Training and competency

Training and competency is managed in accordance with PIRSA WHS Training Procedures (attached separately). Training needs are identified through the Training Needs Analysis, which is a process that identifies, plans, implements and reviews WHS training programs specifically related to job tasks. This includes training on hazards, risks, controls and associated tasks, SOPs, licence requirements, and competency and certification requirements. This is covered under Activity 2.14 in the Site Safety Management Plan.

8.4.11 Contractor/sub-consultant management

The Project Leader will require each consortium partner to sign off that they have audited the project for consistency with internal health and safety procedures.

Contractors are managed in accordance with PIRSA WHS Contractor Management Procedures (attached separately).

Induction procedures for visitors and contractors are adhered to and documented in accordance with PIRSAFE Induction Procedures. This is covered under Activities 2.12 and 6.2 in the Site Safety Management Plan.

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Appendices

Appendix A – Budget spreadsheet for the proposed Monitoring and Evaluation Plan of the Lower Murray River Selected Area

[Provided in the version submitted to CEWO. Not included in external versions]

Appendix B – Standard Operating Procedures for the Lower Murray River Selected Area

Introduction

Standard Operating Procedures of Category 1 and 3 indicators are provided in this document for the Lower Murray River (LMR) Selected Area. Protocols for Category 1 indicators follow the LTIM Standard Protocols detailed in Hale *et al.* (2014) (Table B.1).

Table B.1. Category 1 and 3 indicators for the Lower Murray River (LMR) Selected Area.

Category	LMR Indicator	Comments re. LTIM Standard Protocol in Hale *et al.* (2014)
1	Stream metabolism	Follows the standard protocol for Stream metabolism
1	Fish (River)	Follows the standard protocol for Fish (River)
1	Hydrology (River)	Follows the standard protocol for Hydrology (River)
3	Fish spawning and recruitment (flow-cued spawners)	Larval fish sampling is a modified version of the standard protocol for Fish (larvae) to allow for comparison to SARDI long-term data set, but does not involve the use of light traps and has a slightly different sampling design.
3	Matter transport	
3	Hydrological regime	
3	Microinvertebrates	Sampling for riparian microcrustaceans follows the method developed for Category 2 indicator Microcrustaceans (Jenkin 2014), but the Haney trap is used in preference to the bucket method for potamoplankton sampling.

Category 1 Indicators

1 Stream metabolism

1.1 Evaluation questions

This monitoring protocol 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 contribute to patterns and rates of primary productivity?
- What did Commonwealth environmental water contribute to dissolved oxygen levels?

The process for evaluating these questions is illustrated in Figure B.1 with components covered by this protocol highlighted in blue.

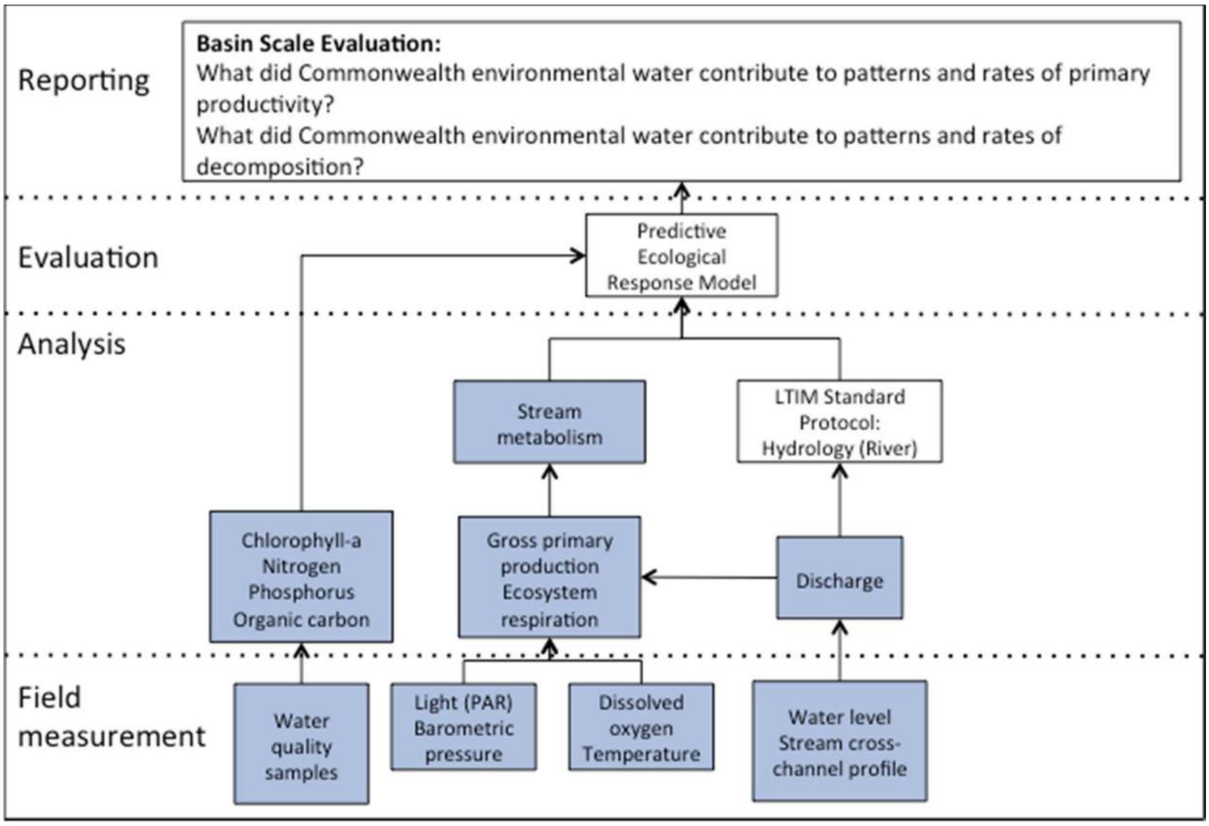

Figure B.1. Schematic of key elements of the LTIM Standard Protocol: Stream metabolism (taken from Hale *et al.* 2014).

1.2 Relevant ecosystem types

Rivers.

1.3 Relevant flow types

Fresh, bankfull, overbank.

1.4 Overview and context

Under the LTIM Project, stream metabolism is measured for two purposes:

1. To inform the Basin-scale quantitative evaluation of fish responses to Commonwealth environmental water (see Section 2 Fish (River)); and
2. To detect changes in primary productivity and decomposition in river in response to Commonwealth environmental water.

This protocol uses the replicate single station open water method and comprises:

- *In situ* logging of the dissolved oxygen concentration and temperature at ten minute intervals between September and February, which will provide data for estimating stream metabolism at the two sampling sites selected to represent the two geomorphological zones (*Gorge* and *Floodplain*) of the LMR Selected Area.

Covariates measures are:

- **Gauged water level related to cross-sectional area and flow velocity:** Measurements of water level and stream characteristics including water velocity, channel cross-sectional area and average depth of sampling sites. This information will be provided from established gauging stations in the LMR in conjunction with site measurements during sampling trips.
- **Water quality samples including chlorophyll concentrations:** Collection of discrete water quality samples for the analyses of chlorophyll-*a*, total nitrogen, NO_X, NH_4, total phosphorus, PO_4, and dissolved organic carbon will be collected routinely at intervals ≤6 weeks duration. During environmental flow events collection frequency will increase to assess the influence on water quality of the different flow phases, eg. increasing, maximum and decreasing flows.
- **Photosynthetically active radiation:** A terrestrial station logging photosynthetically active radiation (PAR) and barometric pressure at ten minute intervals to match the stream metabolism measurements will be established in a suitable nearby location.

This protocol is based on the single station open water stream metabolism method as detailed in Oliver and Merrick (2006), Oliver and Lorenz (2010) and Grace and Imberger (2006). Refer to Section 4.1.1 (pg 17) in the M&E Plan for background information, objectives and hypotheses, outputs and staff involvement for Stream metabolism.

1.5 Complementary monitoring and data

Hydrological data on stream discharge will be provided from the existing permanent stream gauging network associated with the weirs and highly managed flows of the LMR. Mean velocity will be determined from the discharge data using existing information held by the South Australian Department of Environment, Water and Natural Resources, supplemented with site measures of cross-sectional area and gauged water level measurements. Estimates of water depth will be calculated from discharge and cross-sectional area and used to convert volumetric rates of metabolism to areal rates for comparison across zones and Selected Areas.

1.6 Establishing sites

1.6.1 Overview

LTIM for Basin-scale evaluation has adopted a hierarchical approach to sample design (Hale *et al.* 2013). Briefly, the spatial hierarchy for stream metabolism is as follows:

- Selected Area (LMR)
  - Zone (*Gorge*)
    - Site

A 'zone' is a subset of a Selected Area that represents a spatially, geomorphological and/or hydrological distinct unit at a broad landscape scale. For example, separate river systems, sub-catchments or large groups of wetlands. A site is the unit of assessment nested within a zone and in this instance will be a section of river.

1.6.2 Sites

In the LMR Selected Area, two sites have been identified for measurements of stream metabolism. The first site is within the weir pool of Lock 5 downstream of Lock 6, and the second is downstream of Lock 1. These sites have been selected to represent the two major geomorphological zones of the LMR Selected Area, the *Floodplain* zone and the *Gorge* zone. These two zones respond differently to increases in flow, as the *Floodplain* has an open floodplain while the *Gorge* has a constrained floodplain. Because of these differences, hydrological characteristics such as connectivity differ markedly between them. The two zones have also been identified as important for fish monitoring.

Between September and February of each year a single water quality (WQ) station will be deployed within the water column at each of the two sites, downstream of Lock 6 and downstream of Lock 1, continuously recording dissolved oxygen and temperature at ten minute intervals. The stations for stream metabolism measurements will be located within each site as follows:

- Open water, mid stream, with sufficient depth that the sensors will not be exposed, nor touch the sediment
- Well mixed (non-stratified) water column to ensure measurements are representative of each site
- Constantly flowing reach
- No interference from tributaries, drains or significant groundwater inflows
- Safe to access
- Protected from vandalism to the extent possible
- Probes not located within macrophyte beds.

Measurements of light (PAR) and barometric pressure will be collected from nearby terrestrial locations which are planned to be within the fenced perimeter of the Lock stations (Lock 1 and Lock 5) where the staff will help maintain security. Light sensors will be located in an open area, not impacted by tree canopy or shading near to each of the two sites for careful matching with river metabolism measurements. A single barometric probe will be deployed at one of these stations as no significant differences in ambient conditions are expected across the region.

1.6.3 Timing

Stream metabolism measures are to be collected continuously between September and February as this is the period of active growth of organisms within the river and also the period when environmental flows to the LMR are likely. It is important to obtain one or two weeks of metabolism and water quality measurements prior to any flow event to provide a starting level for assessing changes associated with flow events. Stations will be serviced and calibrated at a frequency of no longer than 6 weekly intervals, but more frequent servicing will be required during environmental flow periods to ensure successful operation of probes during key times, and also to collect water quality samples. Increased servicing will be necessary during periods of high productivity due to increased likelihood of sensor fouling. Refer to Section 5 (pg 45) in the M&E Plan for a monthly monitoring schedule for stream metabolism.

1.7 Water quality samples

Water quality variables are important for interpreting the stream metabolism results and are an input to the ecological response model for Basin-scale evaluation. Water samples will be collected for: chlorophyll-*a*, total nitrogen (TN), total phosphorus (TP), nitrate–nitrite (NOx), ammonium (NH4), filterable reactive phosphorus (FRP) and dissolved organic carbon (DOC). In-situ spot measurements will be taken of pH, turbidity and electrical conductivity (EC) using a multi-probe water quality meter. As a minimum, water quality samples will be collected when sensors are deployed and at each time the station is serviced and calibrated (≤ 6 weekly intervals).

Filtering for dissolved nutrients (NOx, NH_4, FRP, DOC) and chlorophyll will take place on site and samples frozen for transport to the analytical laboratories. Sample analyses will be undertaken by the Australian Water Quality Centre (AWQC, NATA registered) and sampling protocols will meet NATA requirements (Scott Kraft, AWQC Customer Service Officer pers. comm.). All sample bottles will be supplied by AWQC and sample handling will be in accordance with preservation requirements as per the Australian Standard. AWQC will supply the syringes and 0.2 µm membrane filters used for filterable nutrient concentrations. Information on the methods including bottles, holding times and limits of detection are listed in Table B.2.

Table B.2. Information on the water quality analysis methods to be used by the AWQC. Reference method refers to American Public Health Association (APHA), International Standards Organisation (ISO) and the Standard Methods for Examination of Water and Wastewater (SM). Holding time is the length in hours that a sample can be stored using the reference method. Bottle = type of bottle for sample collection. LOR = limit of reporting.

Test Code	Reported Name	Matrix	Reference Method	Holding Time (hours)	Bottle	Units	LOR
AMMN_COL_5	Ammonia as N	FRESH-WATER	APHA 4500-NH3 G	672	PT120	mg/L	<0.005
CHLPHA95ET	Chlorophyll a & Phaeophytin a	WATER	ISO 10260 (1992)	24	BLKPT1	µg/L	<0.1
DOC_1	Dissolved Organic Carbon	WATER	SM5310C	336	PT350	mg/L	<0.3
FILTP_2	Phosphorus - Filterable Reactive as P	WATER	APHA 4500-P G	672	PT120	mg/L	<0.003
OXN_2	Nitrate + Nitrite as N	WATER	APHA 4500-NO3-I	672	PT120	mg/L	<0.003
TKNN_COL_1	TKN as N	WATER	APHA-N org A	672	PT120	mg/L	<0.05
P_TOT_2	Phosphorus - Total	WATER	APHA-N org A	672	PT120	mg/L	<0.005
TN_CALC_1	Nitrogen - Total	WATER	APHA-N org A	672	NONE	mg/L	<0.06

1.7.1 Equipment

- Sample containers and appropriate preservatives (sourced from AWQC NATA laboratory)
- 0.2 µm filters and suitable filtering device (e.g. syringe filter) for dissolved nutrients and carbon (sourced from AWQC NATA laboratory)
- 47 mm glass fibre (GFC) filters and suitable filtering device for chlorophyll-a
- Water quality meter(s) with pH, turbidity and electrical conductivity probes
- Deionised water for sample blanks
- Integrated sampling tube and collecting bucket
- Eskies and ice for sample preservation and storage
- Datasheets and/or field computer
- Chain of custody sheets.

1.7.2 Protocol

1. Integrated samples are collected mid stream and *in-situ* measurements made at the same location mid depth.
2. Samples are collected upstream and away from the side of the boat.
3. Avoid surface films, but if present, a description should be entered onto the field sheet.
4. Filtering for dissolved nutrients (NOx, NH_4, FRP, DOC) and chlorophyll-a takes place on site as samples are collected.
5. Samples are stored on ice for transport to field base and then frozen for transport to laboratory.

1.8 In-situ logging

Stream metabolism measures for temperature, dissolved oxygen, light (PAR) and barometric pressure are to be continuously logged at ten minute intervals during the deployment period. To ensure reliable measurements the loggers require regular downloading of data to minimise loss, and also regular maintenance, cleaning and battery replacement. Ten trips are planned between deployment of the *in-situ* logging stations in September and their retrieval in February (although retrieval could be extended if environmental flows were to be delivered later in the season). This ensures that the deployed probes are checked, cleaned and calibrated on average at 3-weekly intervals and that water quality measurements are representative of changing conditions; and that there is capacity to respond to environmental watering events. This does not mean that the probes will be checked every 3 weeks as they may be checked more frequently at critical times during the rise, fall and duration of an event when fouling may increase the need for cleaning and when detailed metabolism and water quality measurements are critical. This is possible because most field trips are shared with sampling for the larval fish monitoring component of Category 3 Fish spawning and recruitment (see Section 4), which occurs fortnightly between October and January. To accommodate increased field trip frequencies during flow events, probe maintenance may need to be extended in the absence of environmental watering to the maximum 6 week period set in the standard method (Hale *et al.* 2014). This flexible protocol will aid reliable data capture during critical stages of events so that changes associated with environmental watering can be identified.

1.8.1 Equipment

- Dissolved oxygen logger consisting of a multi-parameter water quality probe with integrated optical (fluorescence) dissolved oxygen probe and water temperature
- PAR sensor and loggers measuring µmol photons/m^2/s (µEs/m^2/s)
- Barometric pressure sensor and logger

- Tool kit and spare parts for the multi-parameter probe; including spare batteries and spare probes
- Probe calibration log
- Field sheets
- Laptop and data cables for connecting to probes / logger
- Air bubbler with battery (e.g. one suitable for a large fish tank) and a large bucket (e.g. 20 L), for probe calibration.

1.8.2 Protocol

1. Prior to deployment in the field, and on each occasion in the field the probe(s) will be calibrated according to the manufacturer's instructions and results of calibration entered into a calibration log.
2. Before leaving the office/laboratory for deployment and on each occasion in the field the following should be checked for all electronic measurement equipment:
   - Batteries are charged and properly inserted
   - Previous data downloaded and memory cleared
   - Cable and cable connections checked
   - Obvious/minor faults on sensors including growth or dirt on the probes or tubing checked
   - All equipment listed above is in functional order.

1.8.3 Field method – water column measures

1. Record the following on the field sheet:
   - River name and ANAE Stream id
   - Date and time
   - GPS coordinates (latitude and longitude; GDA94)
   - Name(s) of survey team.
2. Record site characteristics:
   - Substrate type
   - Width of channel
   - Presence of any geomorphic features
   - Percent canopy cover
   - Land use immediate adjacent to site.
3. Collect water quality samples and spot measures according to instructions above.
4. Calibrate dissolved oxygen sensor on site:
   - Calibrate according to manufacturer's instructions for both oxygen free water (e.g. 1% sodium sulfite Na_2SO_3 solution) and 100% saturation (air saturated water). On-site calibration of 100% saturation is achieved by placing the probe in a bucket of stream water which itself is sitting in the stream to ensure thermal control. Air is bubbled through the water in the bucket for at least 45–60 minutes. This should result in a stable reading from the probe. It is important that the probe is not in the direct line of air bubbles.
5. Set the dissolved oxygen, temperature, PAR and barometric pressure loggers to record at ten minute intervals. Synchronise loggers so as to obtain corresponding readings.
6. Select an appropriate place for the deployment of sensors and loggers noting:
   - Dissolved oxygen and temperature sensors must be placed in open water, mid stream and at a depth that will not expose sensors for the entire deployment period. Sensors

should not be placed in eddies, backwaters or where flow is influenced by structures.
- PAR sensor should be deployed above the water surface (and remain so for entire deployment) as described above.
- Sensors will be deployed on suitable existing structures, this is proposed to be a DEWNR equipment raft downstream of Lock 6, and a permanent channel pole marker downstream of Lock 1.

7. Deploy loggers.
8. Leave loggers deployed for between three and six weeks.
9. Perform servicing, cleaning and calibration of loggers at each repeat visit.
10. Repeat water quality samples and spot measures at each repeat visit.
11. Repeat 100% saturation value check (water saturated air) and note the value of any drift.
12. Record any relevant information, such as changes in site characteristics since deployment.
13. Upload data onto laptop following manufacturer's instructions.
14. Calibrate all sensors and loggers and perform routine maintenance / cleaning as necessary.

1.9 Data analysis and evaluation

This method adopts the approach of determining gross primary production (GPP), ecosystem respiration (ER) and re-aeration rate (K_{O2}) from a series of diel dissolved oxygen curves. Curve fitting models estimating these parameters require data for dissolved oxygen in mg O_2/L, temperature, PAR and barometric pressure (in atmospheres) at ten minute intervals. The salinity can be approximated as 0 unless the electrical conductivity is above 500 µS/cm in which case salinity = 6 x 10^{-4} x EC (Based on conversion factor of 1 µS/cm = 0.6 mg/L TDS). Analyses provide estimates of GPP and ER in mg O_2 /L/Day with uncertainties for each and goodness of fit parameters. These parameters are converted to areal measurements by multiplying by the average reach depth.

Evaluation of this data will be based on two approaches:

- A comparison of changes in dissolved oxygen concentrations and stream metabolism in response to environmental water events, approximating a before and after or time series assessment.
- An approach described in the LTIM Project evaluation plan as *counterfactual*, where a comparison is made between observed conditions and the conditions that would have occurred in the absence of environmental water (Gawne *et al.* 2014). In this approach the unperturbed conditions are modelled from established relationships between stream metabolism and environmental conditions derived over time from the LTIM Project data collection, or in this case also from previous studies (Oliver and Merrick 2006, Oliver and Lorenz 2010).

1.10 Data management

All data provided for this indicator will conform to the data structure defined in the LTIM Data Standard (Brooks and Wealands 2014). The data standard provides a means of collating consistent data that can be managed within the LTIM Monitoring Data Management System (MDMS).

The spatial unit for which data is reported for this indicator is known as an 'assessment unit'. The assessment unit for this indicator is: the site (river section).

Each row of data provided for this indicator will identify the assessment unit, the temporal extent of the data and a number of additional variables (as guided by this standard method). The exact data structure for this indicator is maintained and communicated in the LTIM Data Standard and will be enforced by the MDMS when data is submitted.

Logger data

Variable	Description	Type	Req	Range
assessmentUnitId	The approximate point along the stream at which the measures were collectively taken	string	Y	
dateStart	Start date/time (inclusive) that these measures were observed	dateTime	Y	
dateEnd	End date/time (exclusive) that these measures were observed	dateTime	Y	
dissolvedOxygen	Measure of dissolved oxygen in milligrams per litre	number	N	[0,16]
temperature	Measure of water temperature in degrees Celsius	number	N	[0,+]

Discrete data

Variable	Description	Type	Req	Range
assessmentUnitId	The approximate point along the stream at which the measures were collectively taken	string	Y	
dateStart	Start date (inclusive) that these measures were observed	dateTime	Y	
dateEnd	End date (exclusive) that these measures were observed	dateTime	Y	
discharge	Measure of water discharge in megalitres per day	number	N	[0,+]
ecosystemRespiration Volumetric	mg / L / day	number	N	[0,+]
grossPrimaryProductivity Volumetric	mg / L / day	number	N	[0,+]
photosyntheticallyActiveRadia tion	µEs/m^2/s	number	N	[0,+]
velocity	Mean water velocity in metres per second	number	N	[0,+]
chlorophyllA	Measure of chlorophyll-a in micrograms per litre	number	N	[0,+] < LoR
totalNitrogen	Measure of total nitrogen in milligrams per litre	number	N	[0,+] < LoR
nitrateNitrite	Measure of nitrate/nitrite in milligrams per litre	number	N	[0,+] < LoR
ammonium	Measure of ammonia in milligrams per litre	number	N	[0,+] < LoR
totalPhosphorus	Measure of total phosphorus in milligrams per litre	number	N	[0,+] < LoR
filterableReactivePhosphorus	Measure of filterable reactive phosphorus in milligrams per litre	number	N	[0,+] < LoR
dissolvedOrganicCarbon	Measure of dissolved organic carbon in milligrams per litre	number	N	[0,+] < LoR

1.11 Quality Assurance/Quality Control

Quality control and quality assurance protocols have been addressed by the descriptions of:

- Requirements for NATA accreditation for water quality analyses
  - Water quality samples will be collected following the described protocol using methods detailed by the Australian Water Quality Centre, a NATA registered laboratory that will undertake the sample analyses. Water quality samples will be collected in duplicate and analysed along with field blanks. Holding times for water quality samples will follow AWQC and NATA requirements (see Table B.2).
- Preservation and transport of water quality samples
  - Samples will be filtered in the field and kept on ice until transported to the analytical laboratory within two days either by the collection staff or by courier. Chlorophyll samples will be filtered in the field and the filter stored frozen until analyses within four days.
- Calibration and maintenance of sensors and loggers
  - Sites for stream metabolism measurements will be located within the two zones of the LMR Selected Area that are proposed for fish assessments. At one site within each zone, stream metabolism will be measured continuously over the period September to February. Due to the risk of vandalism and the preference for regular cleaning and maintenance to ensure reliable data sets, field trips will be made at least every four weeks to service and calibrate the water quality logger and to collect associated water quality samples.
- Handling of datasheets
  - Written field data will be recorded in waterproof field books using pencil, scanned on return to the laboratory to ensure safe copies, and data written to a file that meets the LTIM Project data standard.

1.12 Health and safety

As with all programs that include field based methods, a Health Safety and Environment Plan (HSEP) has been developed as a part of the MEP for the LMR Selected Area.

1.13 References

Brooks, S. and Wealands, S.R. (2014). Commonwealth Environmental Water Office Long Term Intervention Monitoring Project: Data Standard. Report prepared for the Commonwealth Environmental Water Office by The Murray–Darling Freshwater Research Centre. MDFRC Publication 29.3/2013.

Gawne, B., Brooks, S., Butcher, R., Cottingham, P., Everingham, P. and Hale, J. (2013). Long Term Intervention Monitoring Project River Monitoring and Evaluation Requirements Lower Murray for Commonwealth environmental water. Final Report prepared for the Commonwealth Environmental Water Office by The Murray–Darling Freshwater Research Centre, MDFRC Publication 01.2/2013.

Grace, M. and Imberger, S. (2006). Stream Metabolism: Performing and Interpreting Measurements, Monash University.

Hale, J., Stoffels, R., Butcher, R., Shackleton, M., Brooks, S. and Gawne, B. (2014). Commonwealth Environmental Water Office Long Term Intervention Monitoring Project – Standard Methods. Final Report prepared for the Commonwealth Environmental Water Office by The Murray–Darling Freshwater Research Centre, MDFRC Publication 29.2/2014.

Oliver, R. and Lorenz, Z. (2010). Flow and metabolic activity in the channel of the Murray River. In: Ecosystem Response Modelling in the Murray–Darling Basin (Eds. Saintilan, N. and Overton, I.). CSIRO Publishing, Melbourne, pp. 265–278.

Oliver, R. L., and Merrick, C. J. (2006). Partitioning of river metabolism identifies phytoplankton as a major contributor in the regulated Murray River (Australia). *Freshwater Biology* **51**: 1131–1148.

Field data sheet(s)

Example: Stream metabolism data collection sheet

Streamid:		River name:		Date:	
Observers:			Deployment / retrieval		
Stream characteristics:					
Stream width (m):					
Substrate type:					
Geomorphic features:					
Canopy cover (%)					
Adjacent land use:					
Notes:					

Water quality samples (check if collected)

Chlorophyll-a		Total P		FRP	
Total N		NOx		NH4	
DOC					

In-situ logging

DO calibration (% saturation):			
Oxygen free water		100% saturation	
Logging commence / finish time:			
DO / Temperature sensor depth:			
Notes:			

2 Fish (River)

2.1 Evaluation questions

This monitoring protocol addresses the following Basin-scale evaluation questions:

Short-term (one year) questions:

- What did Commonwealth environmental water contribute to native fish community resilience?
- What did Commonwealth environmental water contribute to native fish survival?

Long-term (five-year) questions:

- What did Commonwealth environmental water contribute to native fish populations?
- What did Commonwealth environmental water contribute to native fish diversity?

The process for evaluating these questions is illustrated in Figure B.2, with components covered by this protocol highlighted in blue.

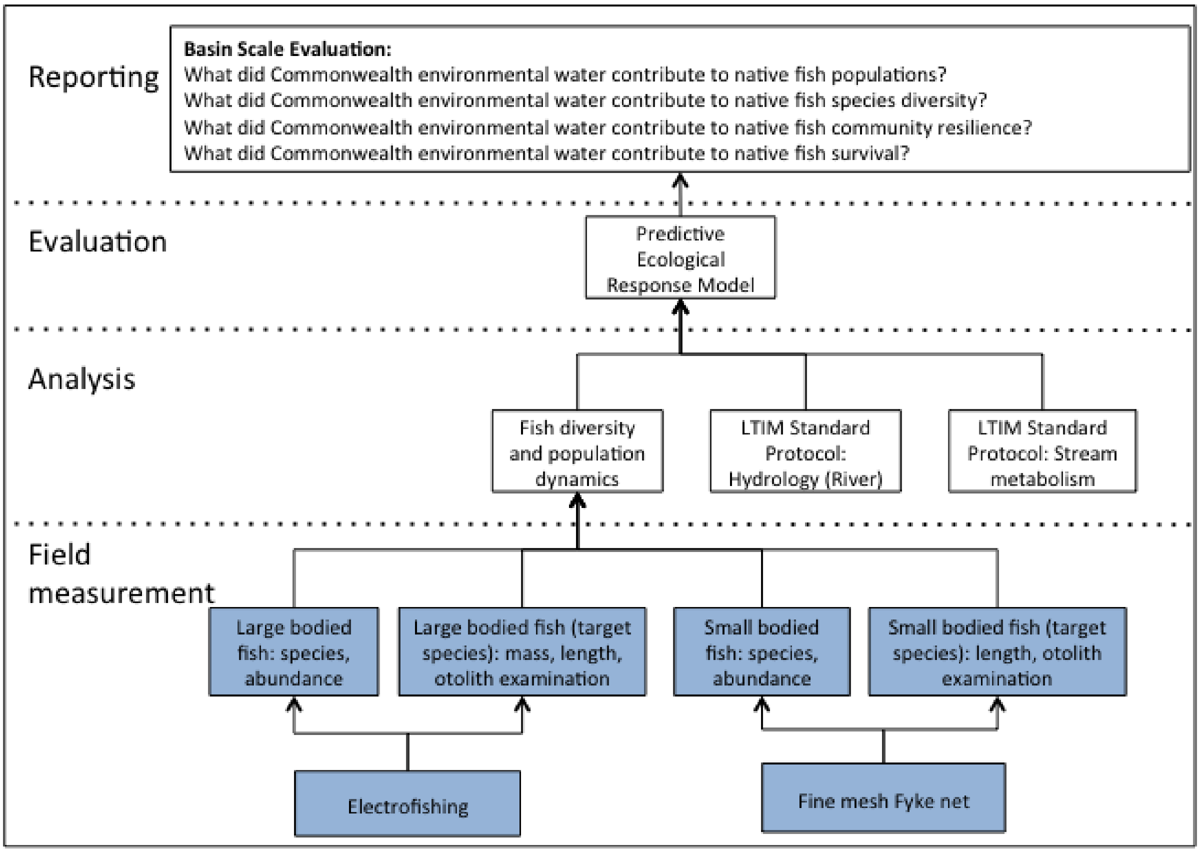

Figure B.2. Schematic of key elements in LTIM Standard Protocol: Fish (River) (taken from Hale *et al.* 2014).

2.2 Relevant ecosystem types

Rivers.

2.3 Relevant flow types

These methods describe annual monitoring conducted during March–May of each year independent of specific watering events. The methods are therefore relevant to all flow types – baseflow, fresh, bankfull and overbank.

2.4 Overview and context

These standard methods describe monitoring required for the Basin Scale evaluation of the response of river fish to Commonwealth environmental water. Refer to Section 4.1.1 (pg 22) in the M&E Plan for background information, objectives, outputs and staff involvement for fish (river). The methods describe the sampling design and protocol for small- and large-bodied fishes in river channels for the LTIM project.

This protocol describes sampling once each year during autumn to measure:

- Catch-per-unit-effort (CPUE) of each fish species for:
    - Electrofishing
    - Small-meshed fyke nets.
- Population structure data for target species:
    - Length
    - Weight
    - Approximate age structure (from otolith examination).

Covariates may include:

- Dissolved oxygen
- Salinity/electrical conductivity
- Discharge/flow
- Water temperature
- Turbidity
- Relative water level.

2.5 Establishing sites

2.5.1 Equipment

- Boat
- GPS

2.5.2 Protocol

LTIM for Basin-scale evaluation has adopted a hierarchical approach to sample design (see Figure B.2 and Hale *et al.* 2014). The spatial hierarchy for Fish (River) monitoring is as follows:

- Selected Area (LMR)
    - Zone (*Gorge*)
        - Site.

Zone placement within Selected Areas

The LMR Selected Area is comprised of two distinct geomorphological units, namely the *Gorge* and the *Floodplain*. The *Gorge* zone has been selected as a subset of a Selected Area that represents a spatially, geomorphological and/or hydrological distinct unit at a broad landscape scale.

The selected zone complies with most of the characteristics listed below.

The zone selected for basin-scale data should have the following characteristics:

- The zone should be situated on a single river channel within a Selected Area, and the zone should contain channel habitat that is generally representative of the Selected Area as a whole.
- Within the channel of this zone there should ideally be a flow gauging station measuring height and discharge (otherwise a manual gauging station must be established (see Section 3: Hydrology (River).
- If possible, the zone should contain relatively high abundances of the target species (Section 2.6), to maximise potential to obtain powerful age- or stage-structure data.
- This zone must be among the zones of a Selected Area most likely to receive Commonwealth environmental water, towards some significant change in river hydrology during that Commonwealth environmental water delivery event.
- The zone must contain channel habitat that can be readily accessed—either by boat or car—for sampling using the full suite of active and passive gears detailed below.

Site placement within zones

A 'site' is defined as follows:

- An **800 m reach of channel within a zone** (Figure B.2).
- Site location for channel sampling should be fixed throughout the LTIM program.
- Each site should be accessible and be representative of the zone.
- Ideally, each site will coincide with a pre-existing discharge and river height gauging station.
- Each site should not be within 1 km of a significant tributary and/or distributary.

Sites will be located between Lock 1 and 3 in the LMR Selected Area with consideration of the specifications listed below.

The below specifications for site number and distribution apply to all areas.

- **Ten channel sites** should be located within the zone targeted for Basin-scale monitoring/analysis.
- All ten sites for Basin-scale data should be located on a single channel.
- These sites should be distributed randomly throughout the zone selected for Basin-scale data collection, such that the samples collected are representative of that zone. However, they should not be spread over a distance farther than 100 km.

Sample placement within sites

A sampling grid will be established within each site to ensure individual samples can be randomly sampled from that site, and are therefore representative of that site as a whole. Sampling should be *random with respect to the environment* to avoid temporal and spatial biases:

- Focusing sampling on particular habitat types that are easiest to sample (e.g. slackwaters) may bias our 'whole-site' sample towards particular fish assemblages associated with those habitats. Further, if Commonwealth environmental water flows are affecting fish community structure by altering the availability of non-target habitat types (e.g. those habitats poorly represented within a Selected Area at the inception of the long-term program), then *a priori* focus on particular habitat types yields very low power to detect such temporal changes.
- A stratified–random design may seem like a solution to the above problem. By 'stratified–random' we mean a sampling design whereby individual samples are taken randomly not

from the site as a whole, but within each key habitat at a site. This design requires *a priori* specification of what the key habitats of the river channel are, which may be difficult given one of the objectives of this program is to search for common responses to flow across seven Selected Areas throughout the Basin, each of which may have unique habitat composition. Perhaps more importantly, a stratified–random design does not fix the problem mentioned above; Commonwealth environmental water creating/restoring important habitat types, which may not have been targeted from the beginning.

We propose that a totally random sampling design is most appropriate for detecting flow-induced temporal trends within zones and Selected Areas, and spatiotemporal trends among zones and Selected Areas. Each 800m site is subdivided by fixed transects spaced 50 m apart. Points of intersection between the transects and the river bank define the sampling grid (Figure B.2).

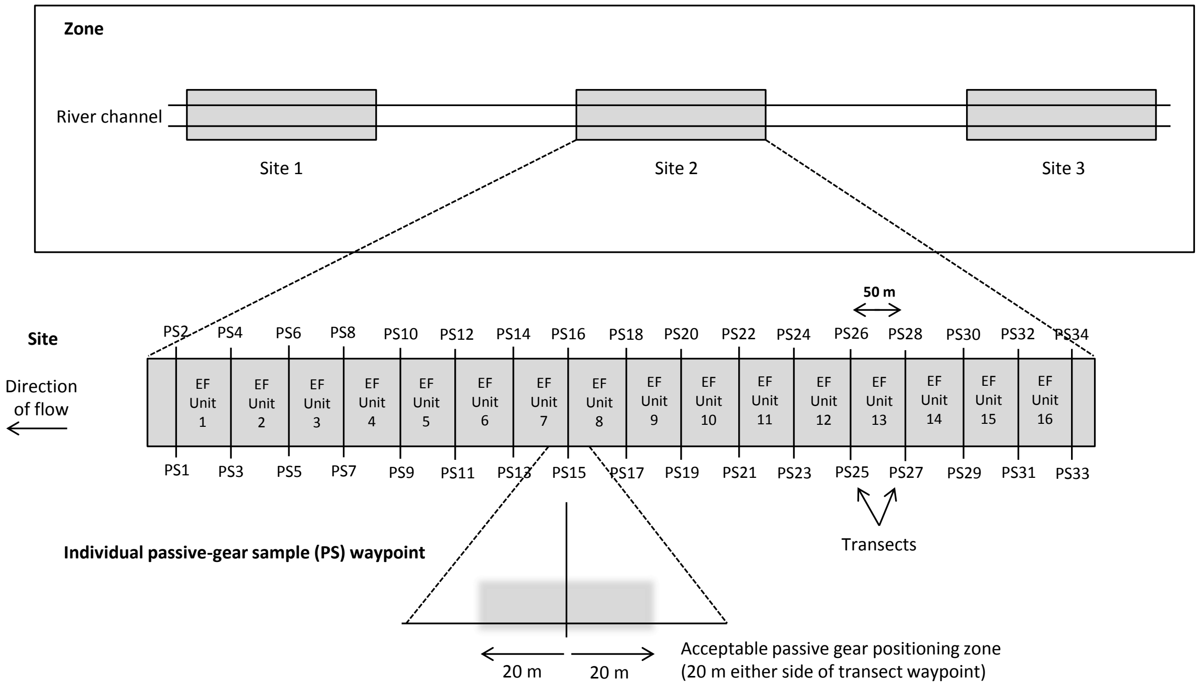

Figure B.3. Diagram of hierarchical sample design illustrating zones, sites and sample locations (taken from Hale *et al.* 2014).

The sample design specified in Figure B.3 defines two key sampling locations: electrofishing (EF) units (16 in total), and passive-gear sample (PS) waypoints (34 in total). Use of these EF units and PS waypoints will be explained in Section 2.7 below.

To establish the PS grid, PS waypoints will be saved in a GPS, so that the GPS can be used to locate each PS waypoint over the monitoring period.

2.6 Representative species from life-history guilds

2.6.1 Overview

Fishes belonging to different life history guilds may respond in different ways to managed and natural flows. Towards a more complete knowledge of fish population response to flows, monitoring will target representatives of the three primary life history guilds: equilibrium, periodic and opportunistic. CEWO/Adviser request additional data collected from these target species.

2.6.2 Protocol

Within each Selected Area CEWO/Adviser request providers identify six target species, two from each guild. Within each guild, one of the two species will be fixed, and common to all Selected Areas (as much as practicable), while the identity of the other species will be flexible across Selected Areas.

Across all Selected Areas the equilibrium life history species targeted for detailed data collection will be Murray cod. The second equilibrium species in the LMR will be freshwater catfish.

Across all Selected Areas the periodic life-history species targeted will be golden perch. The second and only other known periodic species in the LMR will be silver perch.

Across all Selected Areas the opportunistic life-history species targeted will be carp gudgeon, *Hypseleotris* spp. The second opportunistic species in the LMR will be Murray rainbowfish.

2.7 Sampling protocol

2.7.1 Equipment

- Boat electrofisher, including nets, storage and processing equipment
- Ethics and fisheries permits from relevant institutions
- GPS
- GPS coordinates of site structure (PS waypoints and EF units; Figure B.3)
- PS waypoints determined using random number generator (sample locations within sites)
- 12 fine-mesh fyke nets (10 for use; 2 spare) per site
- Anchoring devices for fyke nets (stakes, chains, etc.)
- Large (1000 mm) and small (300 mm) measuring boards
- Scales, either quality hanging scales with bag or bench scales with bucket/tray for fish
- Water quality multimeter
- Data sheets.

2.7.2 Protocol

Timing of sampling

The channel sites of each Selected Area will be sampled once each autumn (March–May inclusive). Refer to Section 5 (pg 45) in the M&E Plan for a monthly monitoring schedule for Fish (River).

Large-bodied species

Sampling

Large-bodied species will be sampled using boat electrofishing.

Sustainable Rivers Audit (SRA) electrofishing protocol will be a subset of what is described here, so that data collected as part of the CEWO LTIM Project can be compared and contrasted with SRA large-bodied fish data. Small-bodied species will not be collected for processing using electrofishing, but collect all stages (including juveniles) of large-bodied species for processing.

Herein, 'small-bodied' species are those belonging to the following families:

- Galaxiidae
- Retropinnidae
- Atherinidae
- Melanotaeniidae

- Ambassidae
- Nannopercidae
- Eleotridae
- Gobiidae
- Poecilidae.

All other fish families of the Basin are considered 'large-bodied'.

The entire 800 m site will be electrofished. Within each electrofishing unit of a site (EF unit Figure B.3) two 'shots' of 90 s 'on-time' should be carried out. This results in a total of 2880 s (48 min on-time) for each site. No more than 180 s of shocking should be allocated to each EF unit, such that electrofishing effort is spread out across the entire site, thus giving a more random sample with respect to the (site's) environment. Note that, *within* EF units the location of shots is left to the discretion of the service provider.

Processing - electrofishing

For every individual belonging to a target large-bodied species, the following will be obtained or implemented:

1. Identified to species.
2. Total (TL; round or square caudal fin species) OR fork (FL; fork-tailed species) lengths, in millimetres (mm).
3. Mass in grams (g) (use scales that have been recently calibrated).

If > 20 individuals are obtained within a 90 s shot, the above information on a random sub-sample of 20 individuals will be recorded . The random sub-sample will be the first 20 individuals sampled during a 90 s shot.

Non-target species will be identified and enumerated. All species will be returned to the water.

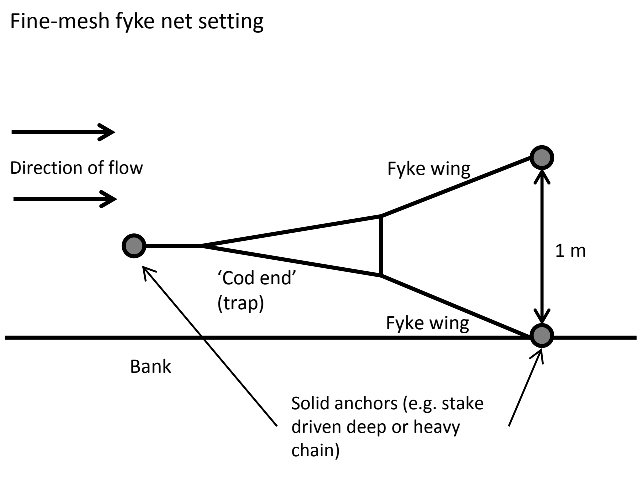

Figure B.4. Diagram indicating the positioning of fine-mesh fyke nets in river channels, relative to the bank and direction of water flow. Cod-end should face upstream so as to not collect debris and act as a water velocity 'parachute' (taken from Hale *et al.* 2014).

Small-bodied species

Sampling

Small-bodied species will be sampled using a passive technique only; fine-mesh fyke nets. The fine-mesh fyke nets (2 mm mesh) should be double wing (Figure B.4) (each wing: 2.5 m × 1.2 m), with a first supporting hoop covered by a plastic grid (5 cm x 5 cm) to keep large aquatic vertebrates out of the trap.

A random number generator will be used to randomly select a subset of 10 PS waypoints (Figure B.3) from the total of 34. As noted in Figure B.3, a waypoint encompasses a total of 40 m of bank (20 m either side of specific waypoint), so providers should endeavour to find the point on the bank as close to the exact waypoint as possible. If it is impossible (in the strict sense, not just inconvenient) to set a fyke net at a certain waypoint (current is too fast; bank is far too steep; water too deep; too many emergent macrophytes to be an effective fish sample), then an adjacent, unoccupied waypoint will be used.

Fine-mesh fyke nets will be set in the afternoon and retrieved the following morning. Set and retrieval times will be recorded for each individual net.

Fine-mesh fyke nets will be set with the cod end facing the current, so that water velocity is deflected around the net and wings (Figure B.4). For the net to be effective both wings and the cod end will be anchored to the bottom. So that sampling effort is held constant across nets, the wings will have an aperture of 1 m (Figure B.4).

Processing

The following measurements will be made for non-target, small-bodied species:

1. Identify (to species) and enumerate all individuals. Random sub-samples may be used if nets capture too many fish for complete processing, as long as proportion of total sample sub-sample represents is recorded.

Further measurements are required for those small-bodied species targeted as part of the opportunistic guild (see Section 2.6):

2. Obtain total (TL; round or square caudal fin species) OR fork (FL; fork-tailed species) lengths, in millimetres (mm), of up to the first 10 individuals from both target species, from each net. Ensure ten are randomly selected from the overall sample. This may be achieved, for example, by using an aquarium net to 'blindly' sub-sample from a bucket until 10 individuals have been measured.

Covariates

Water quality parameters will be measured at each site during all sampling times. Dissolved oxygen (ppm), electrical conductivity (µS), water temperature (°C) and turbidity (NTU) will be measured using a water quality multimeter. Discharge data (ML day^{-1}) and relative water level (m AHD, relative to the Australian Height Datum) from the closest gauging station will be obtained from the DEWNR Surface Water Archive (www.waterconnect.sa.gov.au).

Otolith collection and analysis

Otoliths will be collected from target species (Section 2.6) populations for the following purposes:

1. Estimation of von Bertalanffy (vB) growth parameters, such that we have a vB model for each target species, for each area. These models will be used to coarsely approximate the age distribution (in years) of target species, based on their lengths, within each of the monitoring

years. Age distributions will subsequently be used to coarsely approximate survivorships, hence year-class strength, in the absence of capture-mark-recapture data. Furthermore, otoliths may be used to back-calculate temporal variance in growth rates, in response to changes in flow.

2. For periodic and equilibrium targets, determine the relationship between age and length of (approximate, or what one assumes to be) 0+ and 1+ individuals within each year, to reduce uncertainty of age prescription during early life history.
3. For opportunistic species, determine the age composition (in years) of the populations within each area.

The otolith collection and reading protocol is dependent on which life-history guild the species belongs to:

Opportunistic species

During each annual census (Years 1 to 4), retain a minimum of 6 individuals of each of the two species (carp gudgeon and Murray rainbowfish) from each of the 10 sites, giving a minimum of 60 pairs of otoliths for each opportunistic species, each year, per area. The 6 individuals collected within each site will, as much as practicable, span the entire length range observed at that site, for that species.

Periodic and Equilibrium species

Two comprehensive otolith samples from equilibrium and periodic target species over the course of the five-year program; one at the beginning of the program (Year 1) and one in Year 4 (following autumn censuses). Accordingly, we will use these data to obtain two vB growth curves for each of the four target species of an area: one at the beginning of the program and one toward the end of the program. The vB curves from Year 1 will give the modelling team some idea of how variable length–age relationships are between areas, and this will, in turn, improve their ability to progress population models as annual census data arrives. The vB curves from Year 4 will improve our area-specific vB curves, while also enabling service providers to explore the possibility of back-calculating growth rates in response to flow events over the five-year period.

Where possible, otoliths from at least 50 individuals of each target species will be collected. Samples for estimating the parameters for vB curves will not be random with respect to the structure of the population. Samples containing representatives across the full range of lengths within the population (ideally), and approximately equal numbers of individuals within each length-class will be collected.

2.8 Data analysis and evaluation

2.8.1 Relative abundance estimation

Abundances will be recorded as ‘catch-per-unit-effort’ (CPUE). Data will be structured in spreadsheets by individual ‘samples’, which are individual net hauls, or abundances within discrete electrofishing shots (see Section 2.7). Units will depend on sampling method—electrofishing versus fyke netting. Electrofishing CPUE will have units number of individuals per unit on-time for each shot. Fyke netting CPUE units will be number of individuals per net per hour.

2.8.2 Population structure data for target species

Additional data is required for target species:

- Total length or fork length (mm), depending on species (see Section 2.7).
- Mass (gm).

- Length–age data:
    - Year 1 and Year 4 data sets for the four species belonging to the Periodic and Equilibrium guilds;
    - Annual data sets for the opportunistic species;
    - Raw data required, not just vB parameter estimates.
    - Yearly ages of fish (0+, 1+,…x+), will be tagged by their species identity, place and date of capture, total or fork length (mm), and mass (g).

2.8.3 Community data

No data analysis or evaluation will be undertaken for the Selected Area. For the analyses of Basin-scale community response to Commonwealth environmental water to be carried out by the M&E Advisors CPUE data at the level of the site (species by site matricies) corresponding to each sampling method will be provided:

1. Electrofishing (large-bodied species; target + non-target).
2. Fine-mesh fyke nets (small-bodied species; target + non-target).

2.8.4 Data management

All data provided for this indicator will conform to the data structure defined in the LTIM Data Standard (Brooks and Wealands 2014). The spatial unit for which data is reported for this indicator is known as an ‘assessment unit’. The assessment unit for this indicator is: the site (river section).

Each row of data provided for this indicator will identify the assessment unit, the temporal extent of the data and a number of additional variables (as guided by this standard method). The exact data structure for this indicator is maintained and communicated in the LTIM Data Standard and will be enforced by the MDMS when data is submitted.

Variable	Description	Type	Req	Range
assessmentUnitId	The site, which may be a length of stream of an area of wetland(s) that meets the criteria defined in the standard method	string	Y	
dateStart	Start date (inclusive) that these measures were observed	dateTime	Y	
dateEnd	End date (exclusive) that these measures were observed	dateTime	Y	
sampleNumber	Arbitrary name/number that identifies the net, trap or electrofishing unit within the assessment unit	string	Y	
speciesName	Latin name for species of fish	string	Y	LookupList
totalLength	Fork length (in mm), where necessary	number (1 decimal)	N	[0,+]
forkLength	Fork length (in mm), where necessary	number (1 decimal)	N	[0,+]
weight	Mass (in grams)	number (2	N	[0,+]

		decimals)		
sampleType	Sampling equipment used	category	N	CourseFyke FineFyke
ageAdult	Age determined by examination of otolith (years)	integer	N	[0,+]
FykeCatch	Mean of catch per unit effort	number (8 decimals)	N	
electroCatch	Mean of catch per unit effort	number (8 decimals)	N	

2.9 Quality Assurance/Quality Control

Quality control and quality assurance protocols are documented in the Quality Plan developed as part of the Monitoring and Evaluation Plan for all Selected Areas. QA/QC activities specific to this protocol include:

- Electrofishers will be experienced operators of units. They will be supervised by Senior Operators on-site, and have obtained their electrofishing certificates through a reputable course.
- Monitoring and Evaluation Providers will have relevant boat licenses.
- All sampling will be conducted under an exemption of section 115 of the *Fisheries Management Act 2007*.
- All personnel involved in field work will be professionally trained and have a Senior Operator supervising on-ground work.

2.10 Health, safety and environment plan

Health and safety standards and methods in the field will follow SARDI Aquatic Sciences Standard Operating Procedures.

2.11 References

Brooks, S. and Wealands, S.R. (2014). Commonwealth Environmental Water Office Long Term Intervention Monitoring Project: Data Standard. Report prepared for the Commonwealth Environmental Water Office by The Murray–Darling Freshwater Research Centre. MDFRC Publication 29.3/2013.

Hale, J., Stoffels, R., Butcher, R., Shackleton, M., Brooks, S. and Gawne, B. (2014). Commonwealth Environmental Water Office Long Term Intervention Monitoring Project – Standard Methods. Final Report prepared for the Commonwealth Environmental Water Office by The Murray–Darling Freshwater Research Centre. Murray–Darling Freshwater Research Centre, MDFRC Publication 29.2/2014.

Field data sheet(s)

Example: LTIM Monitoring – Electrofishing data sheet

Date: ______________________________ **Selected Area:** ______________________________

Zone: ______________________________ **Site:** ______________________________

EF Unit	Shot	Species	TL (mm)	SL (mm)	FL (mm)	Weight (g)	Recapture (0,1)	Tag #

Example: LTIM Monitoring – Fine-mesh fyke field data

Date: ______________________ **Selected Area:** ______________

Zone: ______________________ **Site:** ______________

Fyke 1 of 10 PS waypoint: ______________

Time set: ______________________ Time retrieved: ______________

Abundances:

Species	Sub-sample (proportion)	Count

Standard lengths of two target small-bodied species (refer to LTIM protocol)

Species	Standard lengths (mm) of first (random) 20 individuals
Hypseleotris	

Fyke 2 of 10 PS waypoint: ______________

Time set: ______________________ Time retrieved: ______________

Abundances:

Species	Sub-sample (proportion)	Count

Standard lengths of two target small-bodied species (refer to LTIM protocol)

Species	Standard lengths (mm) of first (random) 20 individuals
Hypseleotris	

3 Hydrology (river)

3.1 Evaluation questions

This protocol does not directly address specific evaluation questions but is important, providing fundamental information for analysis and evaluation of monitoring outcomes against hydrological conditions and environmental watering for all indicators. It indirectly addresses the following Basin scale evaluation questions:

Short-term (one year) questions:

- What did Commonwealth environmental water contribute to native fish reproduction?
- What did Commonwealth environmental water contribute to native larval fish growth and survival?

Long-term (five-year) questions:

- What did Commonwealth environmental water contribute to hydrological connectivity?
- What did Commonwealth environmental water contribute to native fish species diversity?
- What did Commonwealth environmental water contribute to fish community resilience?

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 contribute to patterns and rates of primary productivity?
- What did Commonwealth environmental water contribute to temperature regimes?
- What did Commonwealth environmental water contribute to pH levels?
- What did Commonwealth environmental water contribute to turbidity regimes?
- What did Commonwealth environmental water contribute to salinity regimes?
- What did Commonwealth environmental water contribute to dissolved oxygen levels?

The process for evaluating these questions is illustrated below in Figure B.5.

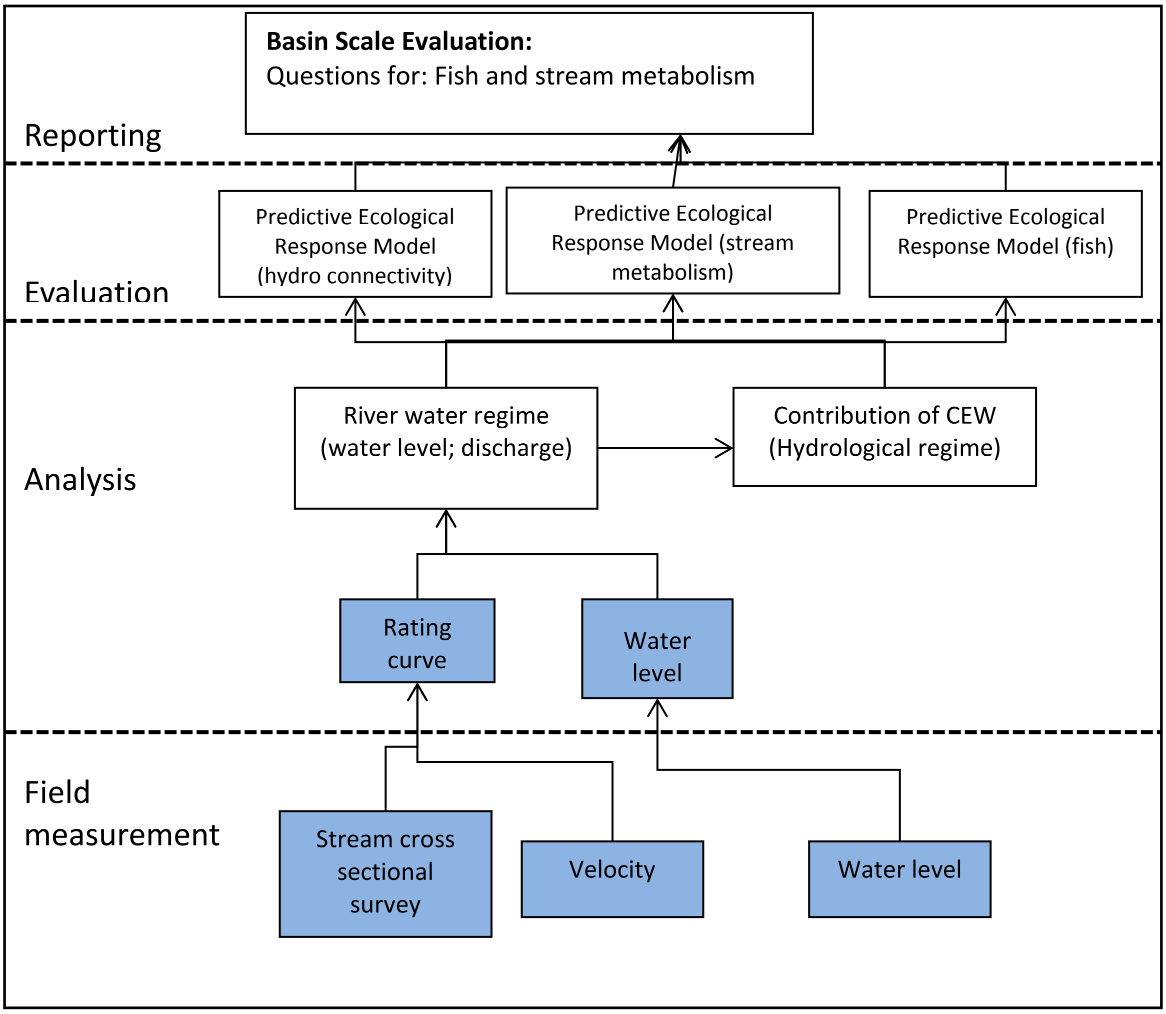

Figure B.5. Schematic of key elements of the LTIM Standard Protocol: Hydrology (River), which has been adapted from the schematic of Hydrology (River) in Hale *et al.* (2014).

3.2 Relevant ecosystem types

Rivers.

3.3 Relevant flow types

Baseflow, freshes, and bankfull.

3.4 Overview and context

Hydrology (River) is an event based monitoring protocol designed to capture aspects of a rivers water regime that influence behaviour and condition of native fish, stream metabolism, and water quality. In particular, this protocol aims to quantify the effect of Commonwealth environmental water on aspects of river hydrology that are most important for native fish, stream metabolism, and water quality. This protocol is based on a combination of field measures and hydrological modelling and comprises:

- Cross sectional survey
- Velocity measurements and development of a rating curve
- Daily Mean ‘Stage’ Height.

Refer to Section 4.1.3 (pg 25) in the M&E Plan for background information, objectives, outputs and staff involvement for Hydrology (River).

3.5 Complementary monitoring and data

For the LMR Selected Area, the river hydrology monitoring is available from local gauging stations. These records are considered appropriate as they are just upstream and within the zone and if no tributaries exist between the site and the gauging station. It should be noted there are some anabranches around some of the stations that are within the zone, but the necessary upstream flow gauge is considered accurate.

3.6 Monitoring locations and timing

3.6.1 Locations

The discharge upstream of the LMR Selected Area is recorded at the Flow to South Australia (A4261001) station. This record is calculated based on two stations, Murray River D/S Rufus River (AW426200) and the flow through the Lindsay–Mullaroo Anabranch (AW414211), with allowances made for losses and extractions in this anabranch. This station is considered high quality, and used for multiple reporting purposes. Within the LMR Selected Area, discharge over each weir is calculated based on the upstream water level, downstream water level, and a rating curve relationship to calculate discharge. The relationship was derived using multiple velocity cross sections downstream of each weir. Based on current data availability discharge records available in the area are outlined in Table B.3.

Table B.3. Station data available

Station Number	Station Name
A4261001	Flow to SA
A4260513	Lock 5 DS
A4260663*	Lyrup PS
A4260515	Lock 4 DS
A4260517	Lock 3 DS
A4260528*	Overland Corner
A4260619	Lock 2 DS
A4261110*	DS Morgan
A4260903	Lock 1 DS

* Flow data only valid for certain flow ranges

3.6.2 Timing

Water level and calculated discharge data at the stations outlined in Table B.3 is collected on a daily, or sub-daily basis. Data is readily available in hydstra databases, and can be exported at any time.

3.7 Monitoring protocol

3.7.1 Equipment

Monitoring data in Table B.3 is collected using infrastructure in place, typically stilling wells or mounted pressure transducers for water level, and the conversion to flow using existing relationships.

3.7.2 Protocol

Monitoring data collected by complementary monitoring programs (Table B.3) will continue to adopt current best practice protocols, as monitored and maintained by the DEWNR Resource Monitoring Unit based at Berri, as well as SA Water at each Lock.

3.8 Data analysis and evaluation

No reporting or analysis is included in this indicator. However the data collected is important, providing fundamental information for analysis and evaluation of monitoring outcomes against hydrological conditions and environmental watering for all indicators.

3.9 Data management

All raw data will be stored on databases of the intellectual property owners, and made available as necessary.

3.10 Quality Assurance/Quality Control

All organisations providing the data (DEWNR and SA Water) have appropriately trained staff and procedures for obtaining and managing data to a suitable standard. Quality Control is undertaken regularly as telemetered data is archived in a Hydstra database.

3.11 Health, safety and environment plan

The agencies collecting the data (DEWNR and SAWater) follow a HSEP. As the data is not collected as part of the LTIM Project, the HSEP is not reproduced here.

3.12 References

Hale, J., Stoffels, R., Butcher, R., Shackleton, M., Brooks, S. and Gawne, B. (2014). Commonwealth Environmental Water Office Long Term Intervention Monitoring Project – Standard Methods. Final Report prepared for the Commonwealth Environmental Water Office by The Murray–Darling Freshwater Research Centre. Murray–Darling Freshwater Research Centre, MDFRC Publication 29.2/2014.

Category 3 Indicators

4 Fish spawning and recruitment (flow-cued spawners)

4.1 Evaluation questions

This monitoring protocol addresses the following local and regional scale evaluation questions:

Short-term (one year) questions:

- What did Commonwealth environmental water contribute to native fish reproduction?
- What did Commonwealth environmental water contribute to native larval fish growth and survival?

Long-term (five-year) questions:

- What did Commonwealth environmental water contribute to native fish populations?
- What did Commonwealth environmental water contribute to fish population/community resilience?
- What did Commonwealth environmental water contribute to native fish survival?

The process for evaluating these questions is illustrated below in Figure B.6.

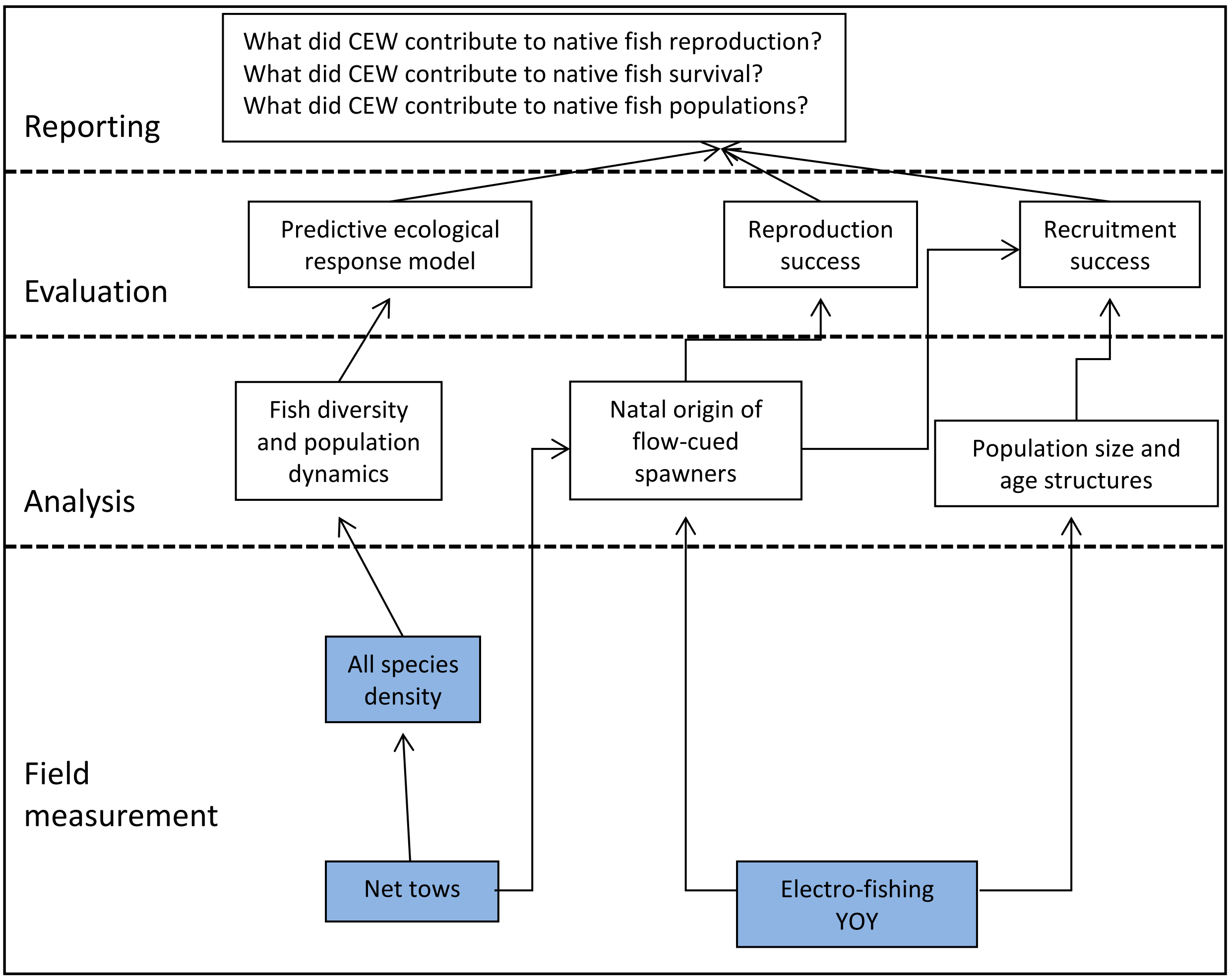

Figure B.6. Schematic of key elements of the LTIM Standard Protocol: Fish spawning and recruitment (flow-cued spawners).

4.2 Relevant ecosystem types

Rivers.

4.3 Relevant flow types

These methods describe monitoring to be conducted annually during the period October to April, independent of specific watering events. The methods are therefore relevant to all flow types (baseflow, freshes, bankfull and overbank).

4.4 Overview and context

This Category 3 method will be used in place of the Category 2 Fish (larvae) method because it takes a more holistic approach to identifying causal links between environmental water delivery and fish spawning and recruitment in the LMR Selected Area. Refer to Section 4.2.1 (pg 30) in the M&E Plan for background information, objectives and hypotheses, outputs and staff involvement for Fish spawning and recruitment.

Sampling for larval fish will be conducted in the main channel of the LMR using net tows to estimate larval fish abundances. Spawn date and location of larvae and YOY golden perch will be determined by analysing otolith microstructure and chemistry (strontium isotope ratios).

Covariates include:

- Dissolved oxygen
- Salinity/electrical conductivity
- Discharge/flow
- Water temperature
- Turbidity
- Relative water level.

4.5 Complementary monitoring and data

Sampling for the larval component of this indicator will be conducted at two locations for which SARDI has long-term (2005–2013) data from previous projects, including some that were funded by CEWO.

For otolith microstructure and chemistry analyses, juvenile golden perch will be obtained through Category 1 Fish (River) sampling and complementary electrofishing conducted by SARDI.

4.6 Monitoring locations and timing

4.6.1 Locations

Sampling for eggs and early life-stage golden perch and silver perch will be conducted at two locations in the main channel of the LMR, approximately 5 kilometres below Lock 1 (*Gorge* zone) and 5 kilometres below Lock 6 (*Floodplain* zone) in accordance to SARDI's long-term data set. At each location three sites will be established. Three larval tows will be conducted at one of the sites (consistent with long-term data set) and one tow will be conducted at each of the two remaining sites.

Juvenile golden perch will be collected through Category 1 Fish (River) sampling in the *Gorge* zone and by complementary electrofishing at a minimum of six sites in the *Floodplain* zone of the LMR Selected Area.

4.6.2 *Timing*

At each site larval fish sampling will occur on a fortnightly basis from October to January (total of 8 trips) from 2014–15 to 2017–18 seasons***.*** Juvenile golden perch will be sampled in March/April of each year from 2015–2018. Refer to Section 5 (pg 45) in the M&E Plan for a monthly monitoring schedule for Fish spawning and recruitment.

4.7 Monitoring protocol

4.7.1 *Collection of larval fish*

Larval fish sampling will be conducted using paired bongo nets towed behind a boat. Samples will be fixed in ethanol and preserved for analysis in the lab. Volume of water through the net will be estimated with a flow-meter attached to the front of the net. Larval fish sorting, species identification and counting for all species will be conducted in the laboratory.

Equipment

- Paired bongo net (500 µm mesh; square-framed 0.5 x 0.5 m and 3 m long)
- Ethanol
- 32µm mesh seive
- Sample containers
- Squeeze bottle (for sample rinsing)
- Flow meter
- Water quality multimeter
- Field sheets.

Protocol

1. Bongo net to be towed behind boat for 15 minute tows.
2. Nets are towed in zig-zag using a 20 m rope, in the river main channel in areas with a depth greater than 1 m. The volume of water filtered through each net is determined using a flow meter (General Oceanics), fitted in the centre of the mouth openings.
3. Plankton tows are conducted using a pair of square-framed, 0.5 x 0.5 m, 3 m long bongo nets of 500 µm mesh. Nets are equipped with a 60 cm pneumatic float in the centre of the frame, so the frame sat five cm below the water surface.
4. Once the tow is completed, samples from each net are rinsed into containers with and preserved in 95% ethanol.
5. Water quality parameters (dissolved oxygen, electrical conductivity, water temperature and turbidity) are recorded at each site.
6. Samples are transported to a laboratory for sorting under magnification lamps.
7. Where possible, all larvae are identified to species level, using published descriptions (Lake 1967, Puckridge and Walker 1990, Neira *et al.* 1998, Serafini and Humphries 2004), with the exception of carp gudgeons (*Hypseleotris* spp.), For carp gudgeons the genus will be treated as a species complex due to close phylogenetic relationships and very similar morphologies (Bertozzi *et al.* 2000, Serafini and Humphries 2004).

4.7.2 *Collection of juvenile golden perch*

Juvenile (including young-of-year) golden perch will be sampled by boat electrofishing in the littoral zones of main channel and anabranch habitats of the LMR using a boat mounted 7.5kVA Smith-Root electrofishing unit through sampling for Category 1 Fish (River) and other complementary projects.

4.7.3 *Spatio-temporal origin*

Spawn date and location of larval and YOY golden perch will be determined by analysing otolith microstructure and chemistry (strontium isotope ratios). Fish natal origin will be determined by comparing strontium ratios in fish otolith cores with a spatio-temporal isoscape of water strontium ratios collected from a broad spatial range of water sources in the southern connected MDB during the golden perch spawning season (October to February). Water strontium isotope ratios are influenced by zonal geomorphology and may differ significantly between catchments in the MDB. Strontium is readily taken up by an otolith, so the strontium isotope ratios in a fish's otolith core will reflect those of the waters in which the fish was spawned and developed.

Fish will be aged following the methods of Zampatti and Leigh (2013), and Sr isotope analysis for otolith and water will be conducted following Woodhead *et al*. (2005), McDonald *et al*. 2008 and Crook *et al*. (2013).

4.7.4 *Covariates*

Water quality parameters will be measured at each site during all sampling times. Dissolved oxygen (ppm), electrical conductivity (µS), water temperature (°C) and turbidity (NTU) will be measured using a water quality multimeter. Discharge data (ML day^{-1}) and relative water level (m AHD, relative to the Australian Height Datum) from the closest gauging station will be obtained from the DEWNR Surface Water Archive (www.waterconnect.sa.gov.au).

4.8 Data analysis and evaluation

Larval fish abundances will be expressed as number of individuals per cubic meter of water filtered. Permutational analysis of variance will be used to test whether abundance of golden perch and silver perch larvae differed among sampling events, zones and years. To model relationships between abundance of flow-cued spawners and one or more water quality (WQ) predictor variables (see covariates in Section 4.4), as described by the Bray–Curtis resemblance matrix, we will use the DistLM (distance-based linear models) routine and the model-building criteria of forward R^2. Ordination of fitted values for the DistLM will be achieved through distance-based redundancy analysis (dbRDA), with vector overlays to show individual WQ parameters that were important in driving variation along dbRDA axes.

Data at the level of the site (species by site abundance matrices) expressed as the mean CPUE (for each species) for the site will be provided as per Category 2 Fish (Larvae) (Brooks and Wealands 2014).

To determine spatio-temporal variation in water $^{87}Sr/^{86}Sr$ over the spring/summer, water samples will be collected fortnightly–monthly from X sites across the study region. Otolith microstructure and geochemistry will be used to retrospectively determine the spatio-temporal provenance (i.e. birth time and place) of golden perch larvae and juveniles from the lower Murray (Gorge and Floodplain zones) and relate this to hydrology and water temperature at the time and place of spawning. These data will be integrated to develop an understanding of golden perch life history and response to flow, particularly Commonwealth environmental water dependent upon CEWO/MDBA quantifying the source and daily volumes of environmental water). Collection and ageing of otoliths from a representative subsample of the golden perch population in the lower Murray will enable determination of age structures and successful recruitment of strong cohorts and association with hydrology.

4.9 Data management

All data provided for this indicator will conform to the data structure defined in the LTIM Data Standard (Brooks and Wealands 2014). The spatial unit for which data is reported for this indicator is known as an 'assessment unit'. The assessment unit for this indicator is: the site (river section).

Each row of data provided for this indicator will identify the assessment unit, the temporal extent of the data and a number of additional variables (as guided by this standard method). The exact data structure for this indicator is maintained and communicated in the LTIM Data Standard and will be enforced by the MDMS when data is submitted.

Variable	Description	Type	Req	Range	Example
assessmentUnitId	a single reach of the Lower Murray River in either the *Gorge* or *Floodplain* zone represented by either a name or polygon within which observations are made	String	Y		LK1S1
dateStart	Start date (inclusive) that these measures were observed	dateTime	Y		15/05/2014 11:35
dateEnd	End date (exclusive) that these measures were observed	dateTime	Y		16/05/2014 2:35
speciesName	Latin name for species of fish	String	Y		*Macquaria ambigua*
trawlNetCatch	Abundance of species as number of individuals per cubic meter of water filtered	Number (8 decimals)	Y	[0,+]	5.00358601 ind/m^3
dissolvedOxygen	Measure of dissolved oxygen in milligrams per litre	Number (2 decimals)	N	[0,16]	3.42 mg/L
turbidity	Measure of turbidity in Nephelometric Turbidity Units (NTUs)	Number (0 decimals)	N	[0,+]	150 NTU
electricalConductivity	Measure of salinity in micro Siemens per centimetre	Number (2 decimals)	N	[0,+]	200 µS/cm
pH	Measure of pH in standard units	Number (2 decimals)	N	[0,14]	7.89
waterTemperature	Measure of water temperature in degrees celcius	Number (2 decimals)	N	[0,+]	22.6 °C

4.10 Quality Assurance/Quality Control

Quality control and quality assurance protocols are documented in the Quality plan developed as part of the Monitoring and Evaluation Plan for all Selected Areas. QA/QC activities specific to this protocol include:

- It is the sole responsibility of the provider to have specific fisheries and ethics permits with them while sampling.

4.11 Health, safety and environment plan

Standard procedures for work health and safety developed for all field work for PIRSA and some specific to SARDI Aquatics sciences will be followed in accordance to the activity being undertaken.

4.12 References

Bertozzi, T., Adams, M. and Walker, K.F. (2000). Species boundaries in carp gudgeons (Eleotrididae : *Hypseleotris*) from the River Murray, South Australian: Evidence for multiple species and extensive hybridization. *Marine and Freshwater Research* **51**: 805–815.

Brooks, S. and Wealands, S.R. (2014). Commonwealth Environmental Water Office Long Term Intervention Monitoring Project: Data Standard. Report prepared for the Commonwealth Environmental Water Office by The Murray–Darling Freshwater Research Centre. MDFRC Publication 29.3/2013 Revised Jan 2014.

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Serafini, L.G. and Humphries, P. (2004). Preliminary guide to the identification of larvae of fish, with a bibliography of their studies, from the Murray–Darling Basin. Cooperative Research Centre for Freshwater Ecology, Murray–Darling Freshwater Research Centre, Albury and Monash University, Clayton. Identification and Ecology Guide No. 48.

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Zampatti, B.P. and Leigh, S.J. (2013). Within-channel flows promote spawning and recruitment of golden perch, *Macquaria ambigua ambigua* (Richardson, 1845) (Percichthyidae) – implications for environmental flow management in the River Murray, Australia. *Marine and Freshwater Research* **64**: 618–630.

Field data sheet example:

Example: Fish spawning and recruitment – larval fish sampling data collection sheet

Location: **Date:** **Field staff:**

Plankton Tows, furthest downstream first (approx 15 mins at 2000rpm on taco)
WQ+Zooplankton grabs taken prior to commencing larval tows (3 reps*2 grabs, surface midwater)

Day plankton tows:

Start time	**Duration mins.**	**Net.**	**Site b 9km downstream**	**Flowmeter Start:**	**Flowmeter Finish:**
		Port	1		
		Starboard	1		
WQ	**DO**	**Turb**	**Cond**	**pH**	**Temp**
Surface					

Start time	**Duration mins.**	**Net.**	**Site a 7km downstream**	**Flowmeter Start:**	**Flowmeter Finish:**
		Port	1		
		Starboard	1		
WQ	**DO**	**Turb**	**Cond**	**pH**	**Temp**
Surface					

Start time	**Duration mins.**	**Net.**	**Normal site Rep no.**	**Flowmeter Start:**	**Flowmeter Finish:**
		Port	1		
		Starboard	1		
		Port	2		
		Starboard	2		
		Port	3		
		Starboard	3		

WQ	**DO**	**Turb**	**Cond**	**pH**	**Temp**
Surface					
Middle					
Bottom					

Night Plankton Tows:

Start time	**Duration mins.**	**Net.**	**Rep. no.**	**Flowmeter Start:**	**Flowmeter Finish:**
		Port	1		
		Starboard	1		
		Port	2		
		Starboard	2		
		Port	3		
		Starboard	3		

Night Water Quality:

	DO	**Turb**	**Cond**	**pH**	**Temp**
Surface					
Middle					
Bottom					

5 Matter transport

5.1 Evaluation questions

This monitoring protocol addresses the following Basin and Selected Area scale evaluation questions:

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

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

Additional short-term (one year) and long-term (five-year) Selected Area questions:

- What did Commonwealth environmental water contribute to nutrient and carbon cycling?
- What did Commonwealth environmental water contribute to sediment transport?
- What did Commonwealth environmental water contribute to ecosystem function?
- What did Commonwealth environmental water contribute to water quality?

The process for evaluating these questions is illustrated in Figure B.7, with components covered by this protocol highlighted in blue.

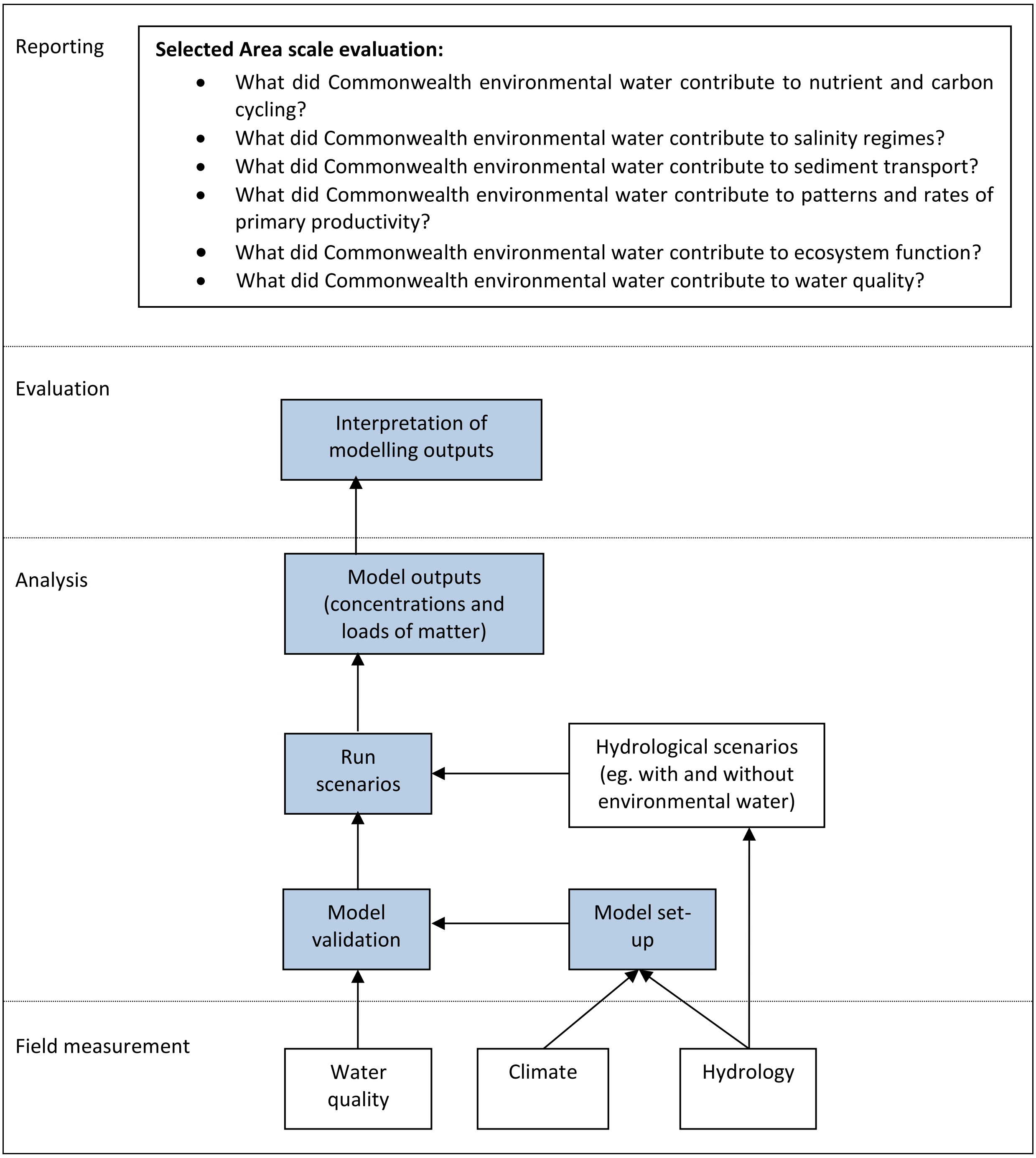

Figure B.7. Schematic of key elements of the LTIM Protocol: Matter transport.

5.2 Relevant ecosystem types

All – rivers, wetlands and floodplains.

5.3 Relevant flow types

All – baseflow, fresh, bankfull and overbank.

5.4 Overview and context

This component will use a 3D hydrodynamic–biogeochemical model to evaluate the response of concentrations and transport of dissolved and particulate matter (salt, nutrients and orhganic matter) to environmental water provisions in the Lower Murray River, Lower Lakes and Coorong (see 4.2.2, pg. 34 for more details). This model has been developed and used extensively in the region (Aldridge *et al.* 2013, Hipsey and Busch 2012a, Hipsey and Busch 2012b). Two interlinked modelling platforms that represent the area between Lock 1 and the Southern Ocean will be used. One model is for the LMR Selected Area below Lock 1, and another is for Coorong, Lower Lakes and Murray Mouth, with the former used as an input to the latter. Although outside of the LMR Selected Area, incorporation of Coorong, Lower Lakes and Murray Mouth increases the capacity of the LTIM Project to demonstrate outcomes within other areas and allows an assessment of exports to the Southern Ocean. No data will be collected through the LTIM program, but validation of the models will rely solely on complementary monitoring data. Refer to Section 4.2.2 (pg 34) in the M&E Plan for background information, objectives and hypotheses, outputs and staff involvement for Matter transport.

5.5 Complementary monitoring and data

Validation data for the Coorong, Lower Lakes and Murray River will be sought from the Environment Protection Authority, Department for Environment, Water and Natural Resources and SA Water. Permission to use this data will be sought from these organisations prior to use (see Table 8.2). If permission is not given, adjustments to the budget would be needed to validate the model. Additional climatic and hydrological input data will be sourced from the Bureau of Meteorology (climate), MDBA (inflow) and Flinders Ports (Southern Ocean water level).

5.6 Monitoring sites and timing

5.6.1 Sites

The modelling of matter transport will conducted for the area between Lock 1 and the Southern Ocean in the *Gorge* zone of the Lower Murray River and the Lower Lakes and Coorong. As all monitoring data will be collected by complementary monitoring programs and the exact sites of these monitoring programs have not been finalised, it is impossible to provide final locations of sampling sites. However, a list of likely sites is provided below (Table B.4), based on sampling sites used in previous years.

Table B.4. Likely sampling sites for model validation. Exact sites will depend on data availability.

Waterbody	Site name	X	Y	Zone
LMR Selected Area	Blanchetown (Lock 1)	373768.9	6195837	UTM 54S
	Wellington	353152.5	6086654	UTM 54S
Lower Lakes	Lake Albert Middle	346724.2	6056213	UTM 54S
	Lake Alexandrina Opening	348468.4	6080369	UTM 54S
	Lake Alexandrina Middle	331761.4	6077836	UTM 54S
	Point McLeay	324379.4	6068672	UTM 54S
Coorong	Goolwa Barrage	302100.7	6066302	UTM 54S
	Murray Mouth	308001.3	6063098	UTM 54S
	Ewe Island	315228.9	6062110	UTM 54S

Waterbody	Site name	X	Y	Zone
	Mark Point	325761.5	6054914	UTM 54S
	Parnka Point	355250.6	6025735	UTM 54S

5.6.2 Timing

All monitoring data for validation will be collected by complementary monitoring programs and so the exact timing of sample collection cannot be determined for the next five years of the LTIM Project. However, it is anticipated that sampling will vary between weekly (Murray River) and quarterly (Coorong and Lower Lakes).

5.7 Monitoring protocol

5.7.1 Equipment

All monitoring data will be collected by complementary monitoring programs and so the exact equipment to be used cannot be defined in the M&E Plan.. However, broadly, the equipment will likely include:

- water samplers
- water quality probes
- various laboratory apparatuses.

5.7.2 Protocol

As all monitoring data will be collected by complementary monitoring programs and the exact protocol to be used has not been finalised, it is impossible to provide a description of the protocol that will be used. Broadly, it is anticipated that:

1. Measurements of water temperature, electrical conductivity, dissolved oxygen, pH and turbidity will be taken at 0.5 metre intervals through the water column.
2. Integrated-depth water samples will be collected and sent to the Australian Water Quality Centre, a NATA accredited laboratory for analysis.
3. Samples will be analysed for filterable reactive phosphorus, total phosphorus, nitrate, ammonium, total Kjeldahl nitrogen, dissolved silica, and chlorophyll *a* concentrations, using standard techniques (Aldridge *et al.* 2013).

5.8 Data analysis and evaluation

The model will run scenarios to assess the response of concentrations and transport of dissolved and particulate matter, making a direct comparison of outcomes with and without Commonwealth environmental water provisions. It is not possible to replicate the scenarios and so no statistical analyses are possible and validation of the model outputs is essential. The model incorporates a large number of complicated biogeochemical processes, for which there is often no data available, and at a relatively fine spatial scale. The detailed nature of the model means that it is only validated for a given set of climatic conditions, so it is essential that validation is conducted routinely. Information collected from field and laboratory work through existing monitoring programs will be used to validate the model. This data, and permission to use it, will be sought from the Environment Protection Authority, Department for Environment, Water and Natural Resources and SA Water. Additional climatic and hydrological input data will be sourced from the Bureau of Meteorology (climate), MDBA/CEWO (inflow) and Flinders Ports (Southern Ocean water level). The model validation will involve comparing observed and modelled concentrations of the various parameters for each flow scenario. In an iterative process, any issues identified will be corrected to minimise uncertainty with modelling outputs. The validation process is essential to allow for an adequate assessment of the contributions of Commonwealth environmental water provisions to matter transport in the LMR Selected Area.

Following validation, the model will be run for defined (flow) scenarios to assess the response of concentrations and transport of dissolved and particulate matter. The comparison of modelled concentrations of the various parameters for each flow scenario (with and without Commonwealth environmental water) will provide the basis for the evaluation and reporting. The difference between the scenarios can be attributed to Commonwealth environmental water, although uncertainty in model outputs will be appropriately acknowledged. The model outputs will be presented as changes in concentrations and cumulative loads (at Lock 1, Wellington, Barrages and Murray Mouth) throughout the watering year. This will be reported on annually, with reports building on knowledge and results gained from previous watering years, including from CEWO short-term intervention monitoring.

5.9 Data management

All core data (output) is described below, although the model requires additional data inputs (see previous description). As part of the quality assurance and quality control, observed data will be compared to the ranges described below. Although all raw data will be stored on databases of the intellectual property owners, compiled data will also be stored and managed by the project team. Modelling outputs will be uploaded to CEWO databases as required.

Variable	Description	Data type	Required	Range
Water temperature	A measure of water temperature	Continuous	Yes	10–30°C
Electrical conductivity	A measure of salinity	Continuous	Yes	200–200000 µS/cm
Dissolved oxygen	A measure of dissolved oxygen	Continuous	Yes	3–12 mg/L
pH	A measure of acidity/basicity	Continuous	Yes	6–9 pH units,
Turbidity	A measure of water clarity	Continuous	Yes	0–300 NTU
Filterable reactive phosphorus	A measure of dissolved inorganic phosphorus	Continuous	Yes	0–0.3 mg/L
Total phosphorus	A measure of total phosphorus	Continuous	Yes	0–1 mg/L
Nitrate	A form of dissolved nitrogen	Continuous	Yes	0–0.3 mg/L
Ammonium	A form of dissolved nitrogen	Continuous	Yes	0–0.3 mg/L
Total Kjeldahl nitrogen	A measure of organic nitrogen plus ammonium	Continuous	Yes	0–3 mg/L
Dissolved silica	A measure of inorganic silica	Continuous	Yes	0–10 mg/L

Variable	Description	Data type	Required	Range
Chlorophyll *a*	A measure of algal biomass	Continuous	Yes	0–200 µg/L

5.10 Quality Assurance/Quality Control

As all monitoring data will be collected by complementary monitoring programs the exact quality assurance and control measures cannot be provided here. However, all organisations providing the data (SA Water, EPA and SA Water) have appropriately trained staff and procedures for obtaining and managing data to a suitable standard. In any case, the project team includes personnel highly experienced with handling and interpreting the type of data (parameters and locations) that will be considered within this study. As such, the project team will ensure that all data obtained from complementary monitoring programs are interrogated for potential errors. Any potential errors will be investigated and if necessary removed. Quality of modelling outputs will be assessed through validation against observed data. Through this process, any potential errors will be identified and fixed the models will be rerun until the outputs are of a suitable scientific output.

5.11 Health, safety and environment plan

Given the nature of this project (office-based), risks to health, safety and environment are considered to be low and can be managed through everyday workplace policies and guidelines. Health, safety and environment policies of all partner organisations will be adhered to by staff as required by their organisations. All organisations involved within this project will have individual policies and guidelines for health, safety and environment. However, an outline of how policies and guidlelines are managed within the lead organisation of this component of the project (The University of Adelaide) is outlined below.

The University of Adelaide is committed to maintaining the highest possible standard of health, safety and well-being for all employees and students (and others) while they are at work at the University. The University recognises the importance of integrating the continuous improvement of health and safety into all organisational activities, ranking this equal with all other operational considerations.

The University's Health, Safety and Wellbeing Team provide support to the University community on all safety, injury management and wellbeing issues. Services include:

- Management of the University Occupational Health & Safety Management System (OHSMS) and consultative framework
- Support in developing, implementing and reviewing of OH&S Policies, Procedures and Instructions
- Development of the Corporate OH&S Action Plan to ensure continuous improvement in OH&S
- Injury Management (workers compensation, rehabilitation, employee assistance program)
- Investigation of major incidents and implementation of improved hazard control measures
- Coordination of staff wellbeing initiatives and programs
- Management of the University OH&S Audit program.

5.12 References

Aldridge, K.T., Busch, B.D. and Hipsey, M.R. (2013). An assessment of the contribution of environmental water provisions to salt and nutrient dynamics in the lower Murray, November 2011–July 2012. Prepared for the Commonwealth Environmental Water Office, Department of Sustainability, Environment, Water, Populations and Communities, Canberra.

Hipsey, M.R. and Busch, B.D. (2012a). Lower Murray River dissolved oxygen modelling. University of Western Australia, Perth.

Hipsey, M.R. and Busch, B.D. (2012b). Lower lakes water quality recovery dynamics. University of Western Australia, Perth.

6 Hydrological regime

6.1 Evaluation questions

This monitoring protocol addresses the following LMR Selected Area evaluation questions:

Short-term question:

- What did Commonwealth environmental water contribute to help increase hydraulic diversity within weir pools?
- What did Commonwealth environmental water contribute to temperature regimes?

Long-term question:

- What did Commonwealth environmental water contribute to hydrological connectivity?
- What did Commonwealth environmental water contribute to temperature regimes?

The process for evaluating these questions is illustrated below in Figure B.8.

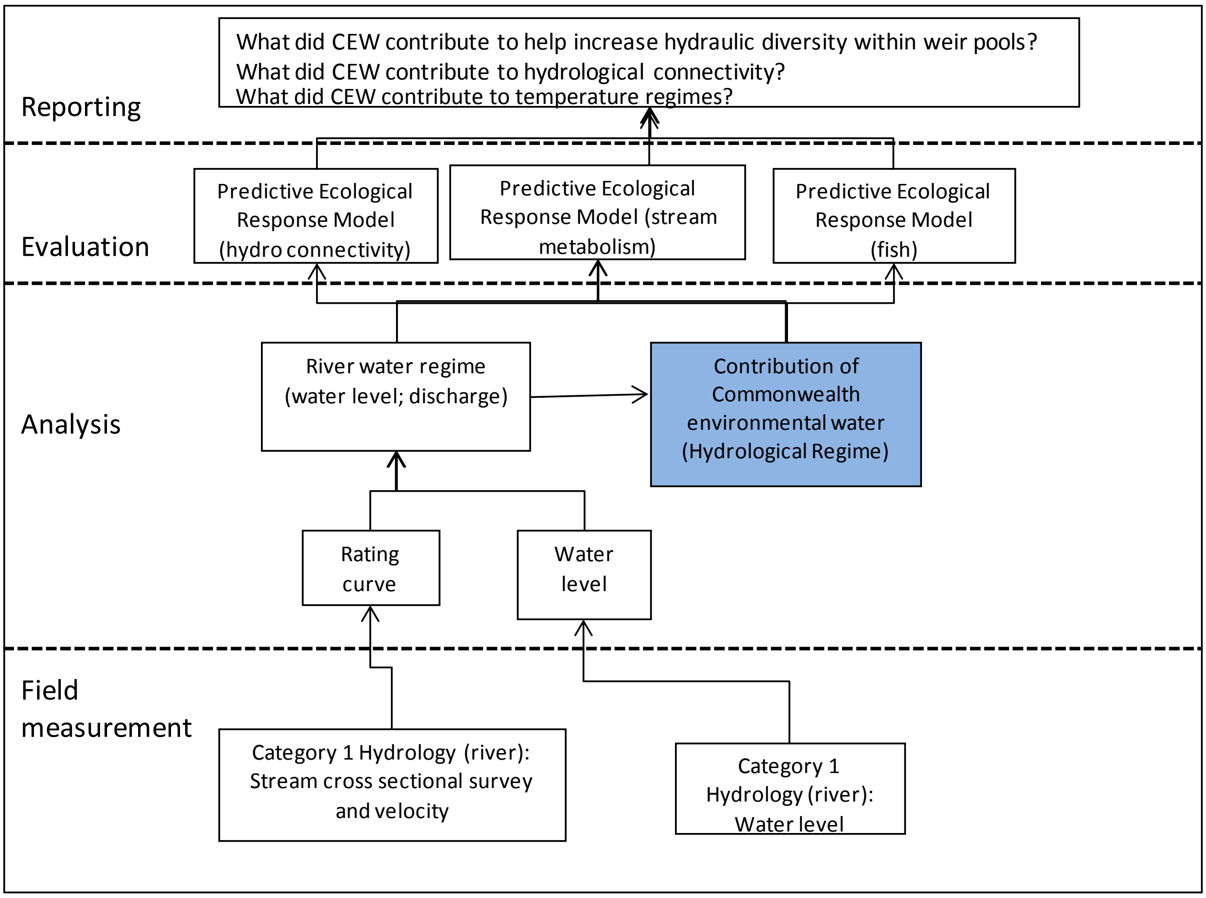

Figure B.8. Schematic of key elements of the LTIM Standard Protocol: Hydrological regime (adapted from the Hydrology (River) schematic in Hale *et al.* 2014).

6.2 Relevant ecosystem types

All – rivers, wetlands and floodplains.

6.3 Relevant flow types

All – baseflow, freshes, bankfull and overbank.

6.4 Overview and context

This component will use three 1D–2D coupled hydrodynamic models that have been developed and used extensively in the region (e.g. Macky and Bloss 2012, McCullough 2013, Wallace 2014). The models represent the majority of the LMR Selected Area: Lock 5 to Lock 4 including the Pike River anabranch, Lock 4 to Lock 3 including the Katarapko River anabranch, and the main river channel from Lock 3 to Mannum. Some opportunistic velocity data is expected to be collected over the length of the LTIM program to further validate the model outputs of interest. The majority of the validation data will rely on complementary monitoring data, such as river levels and discharge. Data from this indicator supports the evaluation for all other indicators. Refer to Section 4.2.3 (pg 38) in the M&E Plan for background information, objectives and hypotheses, outputs and staff involvement for Hydrological regime.

6.5 Complementary monitoring and data

Validation data for the hydrodynamic models will be sought from the Department for Environment, Water and Natural Resources, SA Water and Bureau of Meteorology. Variables required include discharge, water level, extractions, rainfall and Morton's Lake evaporation. Permission to use this data will be obtained from these organisations prior to use (Table 8.2). If permission is not given, adjustments to the budget would be needed to validate the model.

6.6 Monitoring locations and timing

6.6.1 Locations

Velocity monitoring will be undertaken opportunistically in the LMR Selected Area, based on ongoing assessment of model performance (where there is more data of value) and the types of Commonwealth environmental watering events expected over the program. Based on current data availability, monitoring data collected by complementary monitoring programs is provided in Table B.5.

Table B.5. Station data available for model validation.

Variable	Station Number	Station Name
WL[1]	A4260512	Lock 5 US
WL,Q[1]	A4260513	Lock 5 DS
WL,Q*	A4260663	Lyrup PS
WL	A4260537	Berri Irrigation PS
WL[1]	A4260514	Lock 4 US
WL,Q[1]	A4260515	Lock 4 DS
WL	A4261065	Solara PS
WL	A4260550	Loxton Irrigation PS
WL[1]	A4260516	Lock 3 US
WL,Q	A4260517	Lock 3 DS
WL,Q*[1]	A4260528	Overland Corner

Variable	Station Number	Station Name
WL	A4260518	Lock 2 US
WL,Q	A4260619	Lock 2 DS
WL,Q*	A4261110	DS Morgan
WL	A4260902	Lock 1 US
WL,Q	A4260903	Lock 1 DS
WL	A4261164	Swan Reach
WL	A4261163	Walker Flat
WL[1]	A4261161	Mannum

* Flow data only valid for certain flow ranges

[1] Data used as an input to the models, hence cannot be used for validation

6.6.2 Timing

All monitoring data in Table B.5 will be collected on a daily, or sub-daily basis. Velocity monitoring will be undertaken opportunistically depending on model validation outcomes and Commonwealth environmental water events expected. It is expected that cross sections of velocity will be recorded at one or two locations the main river channel in most years over the program. Refer to Section 5 (pg 45) in the M&E Plan for a monthly monitoring schedule for Hydrological regime.

6.7 Monitoring protocol

6.7.1 Equipment

Monitoring data in Table B.5 is collected using infrastructure in place, typically moored buoy or structure mounted pressure transducers for water level, and the conversion to flow using existing relationships. Velocity cross sections will be monitored using boat based ADCP instruments.

6.7.2 Protocol

Monitoring data collected by complementary monitoring programs (Table B.5) will continue to adopt current best practice protocols, as monitored and maintained by the DEWNR Resource Monitoring Unit based at Berri, as well as SA Water at each Lock. Velocity monitoring will also be undertaken by the DEWNR Resource Monitoring Unit, again using best practice methods and is considered of high quality, and high spatial resolution, for the purposes of model validation.

6.8 Data analysis and evaluation

The models will run scenarios to assess hydrologic variables with and without the contribution of environmental water, to make a direct comparison of outcomes with and without Commonwealth environmental water provisions. It is not possible to replicate the scenarios, so no statistical analyses are possible and validation of the model outputs is essential. Data collected (outlined in Section 6.6) will be used to validate the model for the event that occurred, with Commonwealth environmental water provisions. This will involve comparing observed and modelled flows, water levels and velocities. In an iterative process, any issues identified will be corrected to minimise uncertainty with modelling outputs. The validation process is essential to allow for an adequate assessment of the contributions of Commonwealth environmental water provisions to hydrology in the LMR Selected Area.

This comparison of modelled outputs for each flow scenario (with and without Commonwealth environmental water) will provide the basis for the evaluation and reporting. The difference between the scenarios can be attributed to Commonwealth environmental water, although uncertainty in model outputs will be appropriately acknowledged. This will be reported on annually, with reports building on knowledge and results gained from previous watering years, including CEWO short-term intervention monitoring where it makes sense to do so.

6.9 Data management

All core output data is described below, although the model requires additional data inputs (see previous description). As part of the quality assurance and quality control, observed data will be compared to the ranges described below. Although all raw data will be stored on databases of the intellectual property owners, compiled data will also be stored and managed by the project team. Modelling outputs will be uploaded to CEWO databases as required.

Variable	Description	Type	Req	Range	Example
site	Number of sampling station where water variables are measured	String	Y		A4260512
samplingTime	The date/time that water variables are measured	Date Time	Y		12-April-16 12:10
discharge	Water discharge in megalitres per day	Number (0 decimals)	Y	[0,+]	12,042 ML/d
waterLevel	Water level in metres	Number (1 decimal)	Y	[0,+]	10.1 m
velocity	Water velocity in metres per second	Number (2 decimals)	Y	[0,+]	0.86 m/s

6.10 Quality Assurance/Quality Control

All organisations providing the data (DEWNR, BoM and SA Water) have appropriately trained staff and procedures for obtaining and managing data to a suitable standard. Quality Control is undertaken regularly as telemetered data is archived in a Hydstra data base. Furthermore, the project team will ensure that all data obtained from complementary monitoring programs are interrogated for potential errors. Any potential errors will be investigated and if necessary removed. Quality of modelling outputs will be assessed through validation against observed data. Through this process, any potential errors will be identified and fixed the models will be rerun until the outputs are of a suitable scientific output.

6.11 Health, safety and environment plan

Given the nature of this project (office-based), risks to health, safety and environment are considered to be low and can be managed through everyday workplace policies and guidelines. Health, safety and environment policies of all partner organisations will be adhered to by staff as required by their organisations. All organisations involved within this project will have individual policies and guidelines for health, safety and environment. However, an outline of how policies and guidlelines are managed within the lead organisation of this component of the project (The University of Adelaide) is outlined below.

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- Injury Management (workers compensation, rehabilitation, employee assistance program)
- Investigation of major incidents and implementation of improved hazard control measures
- Coordination of staff wellbeing initiatives and programs
- Management of the University OH&S Audit program.

6.12 References

Hale, J., Stoffels, R., Butcher, R., Shackleton, M., Brooks, S. and Gawne, B. (2014). Commonwealth Environmental Water Office Long Term Intervention Monitoring Project – Standard Methods. Final Report prepared for the Commonwealth Environmental Water Office by The Murray–Darling Freshwater Research Centre. Murray–Darling Freshwater Research Centre, MDFRC Publication 29.2/2014.

McCullough, D. (2013). Riverine Recovery – Pike Floodplain Hydraulic Modelling 2012–13. Technical Note, Riverine Recovery Project, Department of Environment, Water and Natural Resources, Government of South Australia.

Macky, G. and Bloss, C. (2012). Riverine Recovery – Weir Pool Hydraulic Modelling. Technical Note, Riverine Recovery Project, Department of Environment, Water and Natural Resources, Government of South Australia.

Wallace, T.A. (2014). River Murray Channel Environmental Water Requirements Hydrodynamic modelling results and conceptual models. Report to the Goyder Institute, Project E.1.9. *In Press*.

7 Microinvertebrates

7.1 Evaluation questions

This monitoring protocol addresses the following local and regional scale evaluation questions:

Short-term (one year) Basin and Selected Area questions:

- What did Commonwealth environmental water contribute to microinvertebrate diversity?

Additional short-term (one year) Selected Area questions:

- What did Commonwealth environmental water contribute via upstream connectivity to microinvertebrate communities of the LMR Selected Area?
- What did Commonwealth environmental water contribute to the timing of microinvertebrate productivity and presence of key species in relation to diet of golden perch larvae?

Additional long-term (five-year) Selected Area questions:

- What did Commonwealth environmental water contribute to microinvertebrate productivity?
- What did Commonwealth environmental water contribute to microinvertebrate community composition?
- What did Commonwealth environmental water contribute to resilience of microinvertebrate egg banks? (comparing year 1 to 5)

The process for evaluating these questions is illustrated in Figure B.9, with components covered by this protocol highlighted in blue.

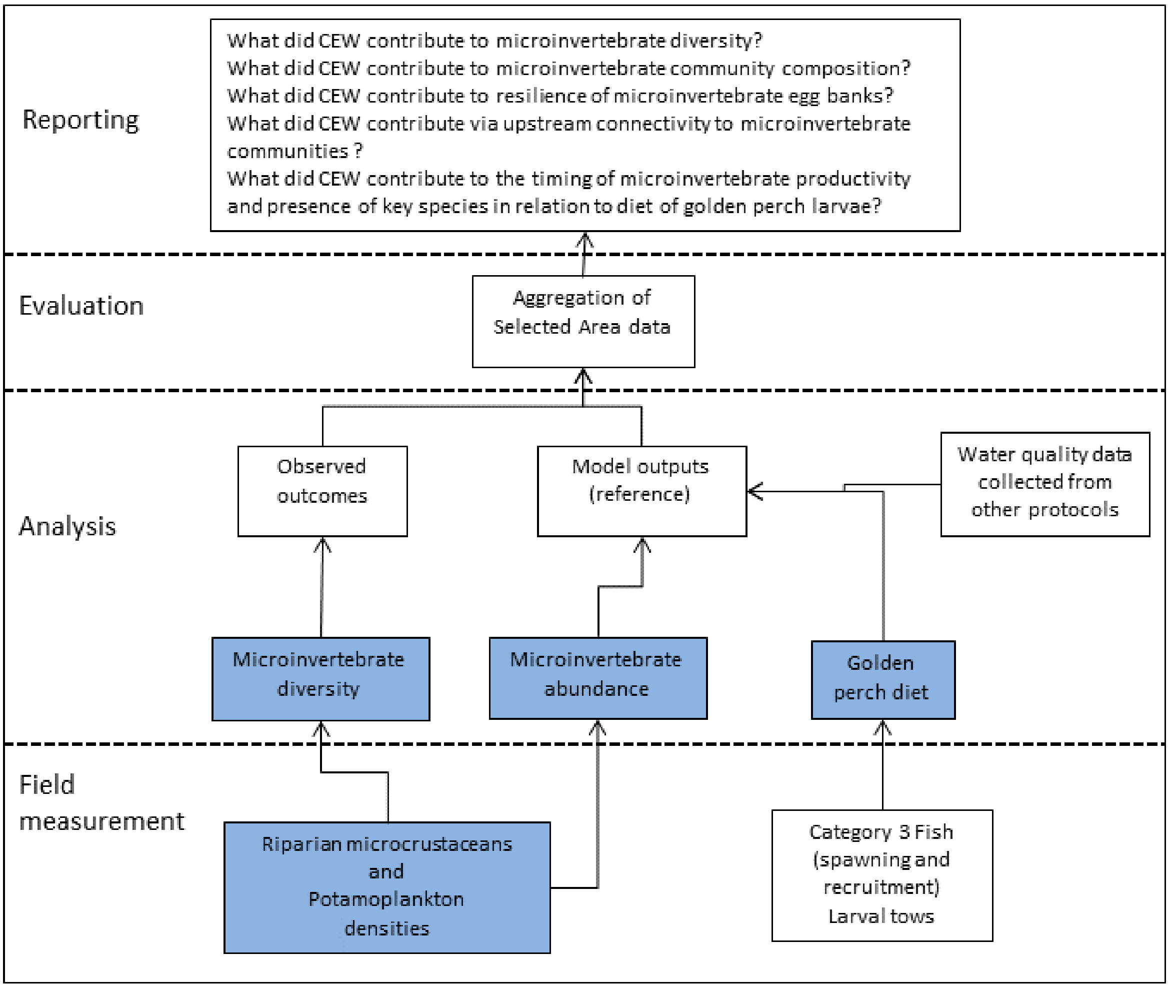

Figure B.9. Schematic of key elements of the LTIM Standard Protocol: Microinvertebrates.

7.2 Relevant ecosystem types

Rivers.

7.3 Relevant flow types

These methods describe annual monitoring conducted during the period October to January of each year independent of specific watering events. The methods are therefore relevant to all flow types (baseflow, freshes, bankfull and overbank).

7.4 Overview and context

These standard methods describe monitoring required for the Basin Scale evaluation of microinvertebrate productivity and community composition in response to Commonwealth environmental water. The methods describe the sampling design and protocol for microcrustaceans in riparian margin sediments of the Lower Murray, and for main stream potamoplankton at two (nearby) LMR sites as relevant to the LTIM project. Refer to Section 4.2.4 (pg 40) in the M&E Plan for background information, objectives and hypotheses, outputs and staff involvement for Microinvertebrates.

Sampling will be from October through to late January each year to match the timing of larval fish sampling (see Section 4 for Category 3 Fish spawning and recruitment). Pelagic habitats will be sampled with a 4-l Haney trap (quantitative, 3 bulked trap volumes) and a 37 µm-mesh plankton tow (qualitative). The trap provides a site-specific density, but the small volume underestimates zooplankton diversity. The net tow samples a greater volume, and thereby provides a more representative diversity estimate.

Covariates include:

- Dissolved oxygen
- Salinity/electrical conductivity
- Discharge/flow
- Water temperature
- Turbidity
- Relative water level.

7.5 Complementary monitoring and data

For the diet component of this indicator, golden perch larvae will be obtained from the larval fish sampling for Category 3 Fish spawning and recruitment (see Section 4.7.1).

7.6 Monitoring locations and timing

7.6.1 Locations

Sampling for microinvertebrates will be conducted at two locations in the main channel of the LMR, approximately 5 kilometres below Lock 1 (*Gorge* zone) and 5 kilometres below Lock 6 (*Floodplain* zone). Microinvertebrate monitoring will take place at 3 sites within each location. Riparian microcrustacean sampling for comparison with upstream microcrustacean assemblages will occur as near to the potamoplankton sampling sites as is feasible.

7.6.2 Timing

At each site sampling will occur on a fortnightly basis from October to January (total of 8 trips) from 2014–15 to 2017–18 seasons. Refer to Section 5 (pg 45) in the M&E Plan for a monthly monitoring schedule for Microinvertebrates.

7.7 Monitoring protocol

7.7.1 Collection of riparian microcrustaceans

A similar benthic corer as specified by the Jenkins (2014) method will be used for riparian microcrustacean samples in the Lock 1 and Lock 6 reaches of the LMR Selected Area. Benthic corers should be modified slightly from King (2004), the details of which can be found in (Morris 2008). The benthic cores within each site will be collected at the same time as larval fish sampling (see Section 4 for Category 3 Fish spawning and recruitment). Collection times will be recorded. Benthic samples will be collected with a corer. Five cores will be collected from haphazard locations within each site with replicates spaced at least 20 m apart. The retained sample will be washed into a sample jar and stored in ethanol.

Equipment

- Benthic corers (50 mm diameter x 120 mm long, 250 mL volume)
- Rubber trowel
- 4L buckets

- 37 µm sieve
- Sample containers/jars
- Ethanol (90% w/v)
- Field sheets.

Protocol

1. The corer is placed onto the sediment surface, the top is then sealed with a plastic cap and the sediment and overlaying water extracted with the aid of a hardened rubber trowel.
2. The contents of the corer will be emptied into a 4 litre bucket and allowed to settle for at least one hour.
3. Once settled, the supernatant will be poured through a 37 µm sieve to retain microcrustaceans and rotifers.
4. The retained sample will be washed into a sample jar and stored in ethanol (90% w/v).
5. Five cores will be collected from haphazard locations within each site with replicates spaced at least 20 m apart.

7.7.2 Collection of potamoplankton

Composite trap (Haney trap) samples and a pelagic net tow will also be collected at each site in association with larval fish sampling. Three consecutive Haney trap samples will be taken, filtered through the standard plankton net, which is then flushed using a squeeze bottle into the terminal 200 ml PET collecting bottle to provide a 12-litre filtrate of potamoplankton, which is then topped up with 90% ethanol. The accompanying net tow will be 3 hauls of a 5-metre line plankton net, the catch decanted through the net to reduce the filtrate volume to approximately 30–40 ml in the PET bottle, then topped up with 90% ethanol.

[Note: the transparent Haney trap is used in preference to the Jenkins bucket method in the Lower Murray River. Faster plankters, such as copepods, are known to avoid more visible sampling gear, hence are undersampled by bucket).

A 37 µm-mesh Frey net (with 4 mm stainless mesh over the net aperture) will be used on the first field trip in October to determine if marginal emergent vegetation, where present, supports a diverse microinvertebrate assemblage. Analysis of Frey net samples may require modification of the riparian sampling method should this assemblage prove to be more diverse, and/or more accessible to juvenile fish, than is the benthic corer-derived assemblage.

Equipment

- 4-litre butterfly door Perspex Haney trap
- 37 µm-mesh Frey net (with 4 mm stainless mesh over the net aperture)
- Standard plankton net
- Squeeze bottle
- 200 mL PET collecting bottle
- 90% ethanol
- Field sheets.

Protocol

1. Three consecutive Haney trap samples will be taken.
2. Samples will be filtered through the standard plankton net.
3. Samples will be then flushed using a squeeze bottle into the terminal 200 ml PET collecting bottle to provide a 12-litre filtrate of potamoplankton, which is then topped up with 90% ethanol.

4. Three hauls of a 5-metre line plankton net will be taken.
5. Samples then will be decanted through the net to reduce the filtrate volume to approximately 30–40 ml in the PET bottle, then topped up with 90% ethanol.

7.7.3 Covariates

Water quality parameters will be measured during larval fish sampling for Category 3 Fish spawning and recruitment (Section 4.7.4). Discharge data (ML day^{-1}) and relative water level (m AHD, relative to the Australian Height Datum) from the closest gauging station will be obtained from the DEWNR Surface Water Archive (www.waterconnect.sa.gov.au).

7.7.4 Processing

Entire samples will be preserved individually in 90% ethanol and returned to the laboratory for microinvertebrate identification and enumeration. Quantitative samples will be subsampled (3 x 1 ml Sedgewick-Rafter cell counts to provide an SD and SE of the subsampling method), microinvertebrates identified to species, and counts expressed as density l^{-1}. For the net tows, the settled volume will be decanted into a 125 mm square gridded Greiner tray, the first 200–300 individual microinvertebrates encountered identified to species, and the counts recorded as proportional composition. The remainder of the tray will be scanned for missed taxa, which will be recorded as 'present'. For the benthic samples, the settled volumes will be examined in gridded Greiner trays and the microinvertebrates identified to species level. The length (and width) of the first 30 specimens or each taxon will be measured to provide a comparison with upstream benthic samples taken by the same method.

Egg bank information will be derived from resting egg/ephippia production identified during the course of identification of microinvertebrates where breeding condition is routinely noted. These are the source populations of egg banks. Propagule density/diversity information also will be collected during analysis of the surficial floc/sediments collected in the Jenkins-method riparian microcrustacean sampling.

7.7.5 Larval golden perch diet

Golden perch larvae collected as part of the Category 3 Fish spawning and recruitment (Section 4.7.1), will be processed for diet content. The gut from larvae representing a broad size range will be removed and stored in ethanol (90% w/v). The microinvertebrates found in the content will be identified, counted and measured (when possible) to establish abundance of species per individual larvae.

7.8 Data analysis and evaluation

Microinvertebrate taxa by site will be provided on an Excel matrix. Benthic cores and pelagic samples will be treated separately. Community data presentation will be allied with larval fish sampling following discussion with the relevant SARDI researchers.

Microinvertebrate abundances will be expressed as number of individuals per litre. Permutational analysis of variance will be used to test whether abundances of microinvertebrates differed among sampling events, zones and years, with emphasis on pre- and post-Commonwealth environmental water delivery assemblages. To model relationships between abundance of microinvertebrates and one or more water quality (WQ) predictor variables, as described by the Bray–Curtis resemblance matrix, we will use the DistLM (distance-based linear models) routine and the model-building criteria of forward R2 Ordination of fitted values for the DistLM will be achieved through distance-based redundancy analysis (dbRDA), with vector overlays to show individual WQ parameters that were important in driving variation along dbRDA axes.

Gut content data (prey species abundance) will be compared to ambient microinvertebrate community data to identify potential selectivity in the feeding of golden perch larvae. To assess the effect of Commonwealth environmental water on the diet of golden perch larvae, dietary items will be compared between pre- and post-Commonwealth environmental water delivery phases.

7.9 Data management

All data provided for this indicator will conform to the data structure defined in the LTIM Data Standard (Brooks and Wealands 2014). The data standard provides a means of collating consistent data that can be managed within the LTIM Monitoring Data Management System (MDMS).

The spatial unit for which data is reported for this indicator is known as an 'assessment unit'. The assessment unit for this indicator is: the site (river section).

Each row of data provided for this indicator will identify the assessment unit, the temporal extent of the data and a number of additional variables (as guided by this standard method). The exact data structure for this indicator is maintained and communicated in the LTIM Data Standard and will be enforced by the MDMS when data is submitted.

Variable	Description	Type	Req	Range	Example
assessmentUnitId	A single reach of the Lower River Murray in either the *Gorge* or *Floodplain* zone represented by either a name or polygon within which observations are made	String	Y		LK1S1
dateStart	Start date (inclusive) that these measures were observed	dateTime	Y		15/05/2014 11:35
dateEnd	End date (exclusive) that these measures were observed	dateTime	Y		16/05/2014 2:35
sampleType	Net tow or trap volume	Number (0 decimals)	Y		4000 mLs
speciesName	Latin name for species of microinvertebrate	String	Y		*Brachionus novaezealandiae*
trawlNetCatch	Number of taxa per sample	Number (0 decimals)	Y	[0,+]	20
haneyTrapCatch	Number of individuals per litre	Number (0 decimals)	Y	[0,+]	3,000 ind. L^{-1}
benthicCatch	Number of individuals (microinvertebrates or their propagules) per litre	Number (0 decimals)	Y	[0,+]	3,000 ind. L^{-1}
preyAbundance	Number of prey items in gut contents of golden perch larvae	Number (0 decimals)	Y	[0,+]	3

7.10 Quality Assurance/Quality Control

Quality control and quality assurance protocols are documented in the Quality plan developed as part of the Monitoring and Evaluation Plan for all Selected Areas. Field sampling for microinvertebrates will be undertaken in conjunction with Category 3 Fish spawning and recruitment. Refer to those QA/QC protocols described in Section 4.10 of Appendix B (Pg 117).

7.11 Health and safety

Standard procedures for work health and safety developed for all field work for PIRSA and some specific to SARDI Aquatics sciences will be followed in accordance to the activity being undertaken.

7.12 References

Brooks, S. and Wealands, S.R. (2014). Commonwealth Environmental Water Office Long Term Intervention Monitoring Project: Data Standard. Report prepared for the Commonwealth Environmental Water Office by The Murray–Darling Freshwater Research Centre. MDFRC Publication 29.3/2013.

Jenkins, K. (2014). Microcrustaceans SOP (Background document provided by Kim Jenkins and CEWO for this project).

King A.J. (2004). Density and distribution of potential prey for larval fish in the main channel of a floodplain river: Pelagic versus epibenthic meiofauna. *River Research and Applications*. **20**: 883–897

Morris, P. M. 2008. Microinvertebrate community response to changing water regimes in the Macquarie Marshes, NSW, Australia. PhD thesis. University of New England, Armidale, NSW, Australia.

Appendix C – Objectives, evaluation questions, hypotheses and outcomes for each component of the project.

DEWNR Level 3 objectives and evaluation questions and CEWO outcomes and evaluation questions were sources from existing literature. Where evaluation questions were not associated with DEWNR objectives they were developed through the M&E Plan. Existing DEWNR evaluation questions were modified to acknowledge the Commonwealth environmental water (CEW) contribution.

DEWNR Level 1 Lower Murray objectives	DEWNR Level 2 Lower Murray objectives	DEWNR Level 3 Lower Murray objectives*	Indicators for LTIM Project	DEWNR Selected Area 1-year evaluation questions	1-year hypothesis	CEWO Basin-scale 1-year evaluation questions[#]	DEWNR Selected Area 5-year evaluation questions	5-year hypothesis	CEWO Basin-scale 5-year evaluation questions[#]	CEWO 1-year expected outcomes[#]	CEWO 5-year expected outcomes[#]	CEWO Basin Outcomes[#]	Basin Plan Objectives[#]
Fish	Restore resilient populations of flow dependant specialists	Restore resilient populations of Golden and Silver perch (flow-dependent specialists)	Category 1: Fish (River)			What did CEW contribute to native fish community resilience? What did CEW contribute to native fish survival?			What did CEW contribute to native fish populations? What did CEW contribute to native fish diversity?	Condition	Larval and juvenile recruitment	Resilience	Resilience
			Category 3: Flow-cued spawners	What did CEW contribute to the reproduction of flow-cued spawning species (Golden perch) (as observed through relative abundance of larvae and YOY)	Increased flow will enhance spawning, larval survival and ultimately recruitment of flow-cued spawning species	What did CEW contribute to native fish reproduction?; what did CEW contribute to native larval fish growth and survival?	a) What did CEW contribute to the abundance of flow-cued spawning species (Golden perch) (as measured by CPUE, increase ≥30% over a 5 year period); b) what did CEW contribute to the population age structure for Golden perch (as measured by evidence of a large recruitment every 2 years in 5 – as demonstrated by separate cohorts each representing >30% of the population)	Increased flow will enhance recruitment of flow-cued spawning species leading to healthy population age structures and increased abundances thus more resilient populations	What did CEW contribute to native fish populations?; what did CEW contribute to fish population/community resilience? what did CEW contribute to native fish survival?	Condition	Larval and juvenile recruitment	Resilience	Resilience
Other fauna	Improve microinvertebrate diversity	None currently available	Category 3: Microinvertebrate diversity	What did CEW contribute to microinvertebrate abundance and diversity?	CEW will contribute to increased microinvertebrate abundance and diversty	What did CEW contribute to microinvertebrate diversity?	What did CEW contribute to microinvertebrate diversity?	Increased environmental watering will result in increased diversity and changes in community composition to reflect improved flows.	None identified		Species diversity	Ecosystem diversity	Biodiversity

DEWNR Level 1 Lower Murray objectives	DEWNR Level 2 Lower Murray objectives	DEWNR Level 3 Lower Murray objectives*	Indicators for LTIM Project	DEWNR Selected Area 1-year evaluation questions	1-year hypothesis	CEWO Basin-scale 1-year evaluation questions[#]	DEWNR Selected Area 5-year evaluation questions	5-year hypothesis	CEWO Basin-scale 5-year evaluation questions[#]	CEWO 1-year expected outcomes[#]	CEWO 5-year expected outcomes[#]	CEWO Basin Outcomes[#]	Basin Plan Objectives[#]
Habitat	Maintain water quality	Maintain water quality within ranges that support aquatic biota and normal biogeochemical processes	Category 1: Stream metabolism; Category 3: Dissolved and particulate matter	What did CEW contribute to dissolved oxygen (being maintained above 50% saturation (4 mg O2L)) throughout the water column at all times) What did CEW contribute to the maintenance of water quality suitable for aquatic ecosystems?	Untimely or excessive organic carbon loads to the river, either from internal or external sources, will reduce oxygen concentrations below levels that support aquatic biota leading to organism death or displacement, and shift biogeochemical cycles to more anoxic pathways causing enhanced sediment nutrient release CEW provisions will contribute to the maintenance of water quality suitable for aquatic ecosystems	What did CEW contribute to dissolved oxygen levels What did CEW contribute to salinity regimes?	What did CEW contribute to dissolved oxygen (being maintained above 50% saturation (4 mg O2L)) throughout water column at all times What did CEW contribute to the maintenance of water quality suitable for aquatic ecosystems?	Successive environmental water provisions will enhance aquatic productivity but minimise excessive organic carbon loads to the river by reducing floodplain stores, and maintaining oxygen concentrations at levels that support aquatic biota CEW provisions will contribute to the maintenance of water quality suitable for aquatic ecosystems	What did CEW contribute to dissolved oxygen (being maintained above 50% saturation (4 mg O2L)) throughout water column at all times What did CEW contribute to salinity regimes?	Salinity/ dissolved oxygen/ pH/ dissolved organic carbon	CEW helped maintain water quality within ranges that support aquatic biota and normal biogeochemical processes	Chemical water quality	Water quality
		Maintain a diurnally mixed water column to ensure diverse phytoplankton communities, and avoid negative water quality outcomes	Category 3: Dissolved and particulate matter; Category 3: Hydrological regime	What did CEW contribute to the maintenance of a diurnally mixed water column?	CEW provisions will contribute to the maintenance of a diurnally mixed water column	What did CEW contribute to temperature regimes?	What did CEW contribute to the maintenance of a diurnally mixed water column?	CEW provisions will contribute to the maintenance of a diurnally mixed water column	What did CEW contribute to temperature regimes?	Algal blooms		Process	Ecosystem function
Function	Transport of inorganic and organic material	Ensure adequate flushing of salt from the Murray River System into the Southern Ocean	Category 3: Dissolved and particulate matter	What did CEW contribute to help increase the transport of salt from the Murray River to the Southern Ocean?	CEW provisions will increase the transport of salt from the Murray River to the Southern Ocean	What did CEW contribute to salinity regimes?	What did CEW contribute to help increase the transport of salt from the Murray River to the Southern Ocean?	CEW provisions will increase the transport of salt from the Murray River to the Southern Ocean	What did CEW contribute to salinity regimes?	Salinity/ dissolved oxygen/ pH/ dissolved organic carbon		Chemical water quality	Ecosystem function

DEWNR Level 1 Lower Murray objectives	DEWNR Level 2 Lower Murray objectives	DEWNR Level 3 Lower Murray objectives*	Indicators for LTIM Project	DEWNR Selected Area 1-year evaluation questions	1-year hypothesis	CEWO Basin-scale 1-year evaluation questions#	DEWNR Selected Area 5-year evaluation questions	5-year hypothesis	CEWO Basin-scale 5-year evaluation questions#	CEWO 1-year expected outcomes#	CEWO 5-year expected outcomes#	CEWO Basin Outcomes#	Basin Plan Objectives#
Function	Transport of inorganic and organic material	Provide diverse hydraulic conditions within the river channel including the full range of velocity classes from very slow to fast in the lower third of weir pools, such that habitat and processes for the dispersal of organic and inorganic material between reaches are maintained	Category 1: Stream metabolism; Category 3: Hydrological regime	What did CEW contribute to habitat (incorporating the full range of velocity classes present in the lower third of weir pools, particularly in the period spanning Sep–Mar)	CEW will help sustain diverse hydraulic conditions in weir pools, such that habitat and processes for the dispersal of organic and inorganic material between reaches are maintained, reducing over-accumulations of organic matter, avoiding low oxygen concentrations, and sustaining foodweb structure by moderating organic carbon supplies.	What did CEW contribute to patterns and rates of decomposition; to dissolved oxygen levels; and to patterns and rates of primary productivity	What did successive CEW contribute to habitat by incorporating the full range of velocity classes present in weir pools, particularly in the period Sep–Mar to reduce over-accumulations of organic matter in river reaches, avoid low oxygen concentrations, and sustain suitable foodweb structure	CEW will help sustain successive seasons of diverse hydraulic conditions in weir pools, such that habitat and processes for the dispersal of organic and inorganic material between reaches are maintained, reducing over-accumulations of organic matter, avoiding low oxygen concentrations, and sustaining foodweb structure by moderating organic carbon supplies	What did successive CEW contribute to patterns and rates of decomposition; to dissolved oxygen levels ; and to patterns and rates of primary productivity	Primary productivity		Process	Ecosystem function
			Category 3: Hydrological regime	What did CEW contribute to help increase hydraulic diversity within weir pools? What did CEW contribute to habitat (incorporating the full range of velocity classes present in the lower third of weir pools, particularly in the period spanning Sep–Mar)	CEW provisions will increase hydraulic diversity within the weir pools	What did CEW contribute to help increase hydraulic diversity within weir pools?	What did CEW contribute to help increase hydraulic diversity within weir pools?	CEW provisions will increase hydraulic diversity within the weir pools	What did CEW contribute to hydrological connectivity?	Hydrological connectivity		Process	Ecosystem function
		Maintain habitats and provide processes for the dispersal of organic and inorganic material and organisms between river channel and wetlands	Category 1: Stream metabolism; Category 3: Hydrological regime	What did CEW contribute to lateral connectivity (being provided to wetlands during >90% of inundation events)	If temporary wetlands are inundated and export organic carbon to the river then there will be: increased heterotrophy in the river channel as shown by decreased photosynthesis compared to respiration; a reduction in the proportions of autotrophic to	What did CEW contribute to patterns and rates of decomposition; what did CEW contribute to patterns and rates of primary productivity	What did CEW contribute to regular inundation of lower and higher elevation temporary wetlands over the 5 year period, and did this lead to bird and fish breeding events, and persistent export of organic matter to the river (influencing microbial communities)	If temporary wetlands are inundated and export organic carbon to the river regularly over an extended period then there should be: a persistent increased heterotrophy in the river channel as shown by decreased photosynthesis compared to respiration; a	What did CEW contribute to patterns and rates of decomposition; what did CEW contribute to patterns and rates of primary productivity; what did CEW contribute to hydrological connectivity	Primary productivity		Connectivity	Ecosystem function

DEWNR Level 1 Lower Murray objectives	DEWNR Level 2 Lower Murray objectives	DEWNR Level 3 Lower Murray objectives*	Indicators for LTIM Project	DEWNR Selected Area 1-year evaluation questions	1-year hypothesis	CEWO Basin-scale 1-year evaluation questions[#]	DEWNR Selected Area 5-year evaluation questions	5-year hypothesis	CEWO Basin-scale 5-year evaluation questions[#]	CEWO 1-year expected outcomes[#]	CEWO 5-year expected outcomes[#]	CEWO Basin Outcomes[#]	Basin Plan Objectives[#]
					heterotrophic organisms and a shift in the trophic structure of heterotrophic microorganisms to decomposers and detritivores			persistent change in the proportions of autotrophic to heterotrophic organisms and a persistent shift in the trophic structure of heterotrophic microorganisms to decomposers and detritivores					
			Category 3: Dissolved and particulate matter; Category 3: Hydrological regime	What did CEW contribute to help increase the area/duration of wetland inundation and transport of inorganic and organic material?	CEW provisions will increase the area/duration of wetland inundation and transport of inorganic and organic material	what did CEW contribute to patterns and rates of primary productivity?	What did CEW contribute to help increase the area/duration of wetland inundation and transport of inorganic and organic material?	CEW provisions will increase the area/duration of wetland inundation and transport of inorganic and organic material	what did CEW contribute to patterns and rates of primary productivity?	Nutrient and carbon cycling		Connectivity	Ecosystem function
Function	Transport of inorganic and organic material	Provide processes for the mobilisation of carbon and nutrients from the floodplain to the river in order to reduce the reliance of in-stream foodwebs on autochthonous productivity	Category 1: Stream metabolism	What did CEW contribute to open water productivity measurements during Sep–Mar (as indicated by a temporary shift from near zero or autotrophic dominance (positive Net Daily Metabolism) towards heterotrophic conditions (negative Net Daily Metabolism)	CEW increases connectivity and the export of carbon and nutrient to the river increasing heterotrophy with decreased photosynthesis compared to respiration; a reduction in the proportions of autotrophic to heterotrophic organisms and a shift in the trophic structure of heterotrophic microorganisms to decomposers and detritivores	What did CEW contribute to patterns and rates of primary productivity?	a) What did successive CEW contribute to open water productivity measurements (as indicated by a persistent shift from near zero or autotrophic dominance (positive Net Daily Metabolism) towards heterotrophic conditions (negative Net Daily Metabolism)); b) what did CEW contribute to a persistent reduction in the proportions of autotrophic to heterotrophic organisms; c) what did CEW contribute to a persistent shift in the trophic structure of heterotrophic microorganisms to decomposers and detritivores	CEW successively increases connectivity and the export of carbon and nutrient to the river with persistent increased heterotrophy shown by decreased photosynthesis compared to respiration; persistent reduction in the proportions of autotrophic to heterotrophic organisms; and a persistent shift in the trophic structure of heterotrophic microorganisms to decomposers and detritivores	What did CEW contribute to patterns and rates of primary productivity?	CEW enhanced the mobilisation of carbon and nutrients from the floodplain reducing the reliance of in-stream foodwebs on autochthonous productivity	CEW enhanced the successive mobilisation of carbon and nutrients from the floodplain reducing the reliance of in-stream foodwebs on autochthonous productivity and increasing the energy supply to aquatic biota	Connectivity	Ecosystem function

***Sourced and/or adapted from Bloss *et al*. (2012); Gibbs *et al*. (2012); and Wallace (2014). [#]Sourced from Gawne *et al*. (2013a).

Acronyms

ANAE	Interim Australian National Aquatic Ecosystem
ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
AS/NZS ISO	Australian/New Zealand Standard International Organisation for Standardisation
CED	Causal effect diagram
CEW	Commonwealth Environmental Water
CEWH	Commonwealth Environmental Water Holder
CEWO	Commonwealth Environmental Water Office
CLLMM	Coorong Lower Lakes and Murray Mouth
CPUE	Catch Per Unit Effort
CR	Community Respiration
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DO	Dissolved Oxygen
DEWNR	Department of Environment, Water and Natural Resources
EPA	Environment Protection Authority
EPBC Act	Environment, Protection and Biodiversity Conservation Act
EWR	Environmental Water Requirement
GPS	Global Positioning System
IAP2	International Association of Public Participation
LMR	Lower Murray River
LMRIA	Lower Murray Reclaimed Irrigation Area
LTIM	Long Term Intervention Monitoring
MDB	Murray–Darling Basin
MDBA	Murray–Darling Basin Authority
MDBC	Murray–Darling Basin Commission
MDBNRMS	Murray–Darling Basin Natural Resources Management Strategy
MDFRC	Murray–Darling Freshwater Research Centre
M&E	Monitoring and Evaluation
MERI	Monitoring, Evaluation, Reporting and Improvement
NATA	National Association of Testing Authorities
NRM	Natural Resources Management

NRMB	Natural Resources Management Board
PAR	Photosynthetically Active Radiation
PIRSA	Primary Industries and Regions South Australia
QA/QC	Quality assurance/quality control
RRP	Riverine Recovery Project
SAMDB	South Australian Murray–Darling Basin
SARDI	South Australian Research and Development Institute
SOP	Standard Operating Procedures
SSMP	Site Safety Management Plans
TLM	The Living Murray
UoA	University of Adelaide
WHS	Work Health Safety and Injury Management
WQ	Water Quality
YOY	Young-of-the-year (with reference to newly recruited 0+ year old fish)