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COMMONWEALTH ENVIRONMENTAL WATER OFFICE LACHLAN SELECTED AREA MONITORING, EVALUATION AND RESEARCH PLAN (2019-2022)






Revision 1: March 2020

Commonwealth Environmental Water Office

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Front cover photos: Images from the Lachlan River system by the Lachlan LTIM field team

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ACRONYMS AND ABBREVIATIONS

ACCEPTED ACRONYM	STANDARD TERM (CAPITALISATION AS SPECIFIED)
ANAE	Australian National Aquatic Ecosystem
C&E	Communication and Engagement
CEWH	Commonwealth Environmental Water Holder
CEWO	Commonwealth Environmental Water Office
CPD	Collaborative Pairs *Program*
CPUE	Catch per unit effort
DOIW	NSW Department of Industry- Water
ER	Ecosystem respiration
EWAG	Environmental Water Advisory Group
EWKR	Environmental Water Knowledge and Research
GPP	Gross Primary Production
GS	General Security
HCVAE	High Conservation Value Aquatic Ecosystems
HS	High Security
IMEF	Integrated Monitoring of Environmental Flows
LAP	Land Access Protocol
LRWG	Lachlan Riverine Working Group
LTIM Project	Long Term Intervention Monitoring Project
M&E	Monitoring and Evaluation
MDBA	Murray-Darling Basin Authority
MDMS	Monitoring Data Management System
MER Program	Monitoring, Evaluation and Research Program
NoW	NSW Office of Water
NPP	Net primary production
NPWS	NSW National Parks and Wildlife Service
NSW DPI	NSW Department of Primary Industries
PM	Project Management
QA/QC	quality assurance / quality control
SMWS	Safe Method Work Statement
SOP	Standard Operating Procedure
SRA	Sustainable Rivers Audit
TAGs	Technical Advisory Groups
WHS	Workplace Health and Safety
WRP	Water Resource Plan

ACKNOWLEDGMENTS

The project team as well as the Commonwealth Environmental Water Office (CEWO) respectfully acknowledge the traditional owners of the land on which this work is conducted, their Elders past and present, their Nations of the Murray-Darling Basin, and their cultural, social, environmental, spiritual and economic connection to their lands and waters. The Lachlan River flows through the lands of the Nari Nari, Ngiyampaa, Waradjuri and Yita Yita Nations, and we acknowledge these people as the traditional owners of the land on which this publication is focused.

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1 INTRODUCTION

The Commonwealth Environmental Water Holder (CEWH) is responsible under the *Water Act 2007* (Cth) for managing Commonwealth environmental water holdings. These holdings amount to more than 2,700 gigalitres (as at July 2019) of water entitlements across the Murray-Darling Basin. The holdings must be managed to protect or restore the environmental assets of the Murray-Darling Basin, and other areas where the Commonwealth holds water, to give effect to relevant international agreements. The Basin Plan (Commonwealth of Australia 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 environmental objectives of the Basin Plan.

Monitoring and evaluation are critical for supporting effective and efficient use of Commonwealth environmental water. Monitoring and evaluation also provides important information to ensure the CEWH meet their reporting obligations. Between 2014 and 2019, the Commonwealth Environmental Water Office (CEWO) has undertaken monitoring and evaluation of the ecological outcomes of environmental watering through the Long Term Intervention Monitoring Project (LTIM Project, https://www.environment.gov.au/water/cewo/monitoring/ltim-project). At the same time, the CEWO has undertaken research which seeks to improve the science available to support environmental water management in the Murray-Darling Basin through the Murray-Darling Basin Environmental Water Knowledge and Research Project (EWKR Project https://www.environment.gov.au/water/cewo/monitoring/ewkr).

The Monitoring, Evaluation and Research Program (MER Program https://www.environment.gov.au/water/cewo/monitoring/mer-program) will build on the work of the LTIM and EWKR Projects to undertake monitoring, evaluation and research activities within seven Selected Areas and at the Basin-scale between 2019 and 2022. These activities will enable the CEWO to continue to:

1. Demonstrate outcomes from Commonwealth environmental water;
2. Inform environmental water management;
3. Fulfil legislative reporting obligations; and
4. Build on our knowledge of the contribution of environmental water to the aquatic health of the Murray-Darling Basin.

Funding for the Lachlan MER Program has been assigned to four activity streams:

1. Core monitoring and evaluation: this is the continuation of the LTIM monitoring and evaluation activities in the river system;
2. Contingency monitoring and evaluation: these are monitoring and evaluation activities that are implemented 'on demand' in response to specific events or watering actions in the river system;
3. Communication and engagement: this includes a portfolio of activities that will be conducted over the 3 years of the MER Program to continue the strong engagement program established under the LTIM Project; and
4. Research: this is a set of activities that will address key knowledge gaps for the river system to better inform environmental water management in the Lachlan River system, and more broadly.

This Monitoring, Evaluation and Research Plan (MER Plan) details the monitoring, evaluation and research activities that will be implemented under the MER Program for the Lachlan Selected Area from 2019 – 2022. This MER Plan includes a description of:

- the Lachlan River catchment and Selected Area (Section 2);
- Commonwealth environmental water in the Lachlan Selected Area (Section 3);
- monitoring and research priorities (Section 4);
- monitoring and evaluation approaches for each indicator and priority research questions (Section 5 and Standard Operating Procedures in Appendix A);
- integrated research, a proposed research portfolio and a research plan (Section 6 and Appendix D);
- a monitoring schedule (Section 7);
- a communication and engagement plan (Section 8 and Appendix E);
- A project management plan, (Sections 9, 10 and 11 and the Health and Safety Appendix C).

A budget for the implementation of the M & E Plan is submitted as a separate document.

2 LACHLAN SELECTED AREA DESCRIPTION

The headwaters of the Lachlan River are located on the Breadalbane Plain in New South Wales (NSW) between Yass and Goulburn. The river flows west for approximately 1,400 km and in most years it terminates at Great Cumbung Swamp. In years of high flows, water from the Lachlan River can pass through the swamp to the Murrumbidgee River.

The area of the Lachlan River system identified as the focus for the MER Program is referred to as the 'Selected Area'. Under the LTIM Project, the Lachlan Selected Area was located at the western end of the Lachlan River from the outlet of Lake Brewster to the terminal Great Cumbung Swamp. Under the MER Program, the Selected Area has been expanded to incorporate the reach between Forbes and Lake Brewster. Thus, the Lachlan Selected Area includes the Lachlan River system from Forbes to the Great Cumbung Swamp (Figure 2-1). It encompasses associated anabranches, flood runners and billabongs, including terminal wetlands such as Merrowie Creek, Lachlan Swamp and Booligal Wetlands, but excluding Middle Creek and Willandra Creek.

The river system is complex, with a diversity of in-channel and floodplain features that provide a variety of habitats for the species in the region. Flows and water levels are naturally variable and unpredictable providing temporally complex habitats. A wide range of aquatic habitats such as pools, backwaters and billabongs, in-stream woody habitat and aquatic plants are provided by the Lachlan River and its floodplains (Gawne et al. 2013a). The Lachlan River catchment supports many flora and fauna listed as vulnerable or endangered under federal or NSW state legislation. The Great Cumbung Swamp, at the terminus of the Lachlan River, is one of the most important waterbird breeding areas in eastern Australia and supports one of the largest remaining stands of river red gums in NSW.

Of the 470,000 hectares of wetlands in the Lachlan region, 95% occur in the Selected Area including numerous nationally and regionally significant wetlands such as the Great Cumbung Swamp, Lachlan Swamp and Booligal Wetlands. These wetlands contain important ecological, cultural and social values, and are particularly valuable as waterbird and migratory bird habitats (Environment Australia 2001).

Like many rivers of the Murray Darling basin, flow regulation in the Lachlan river catchment has had a significant effect on the average annual flow as well as inter-annual and seasonal variability (Driver et al. 2004a). This is believed to have been a key driver in a deterioration of the freshwater ecosystems within the catchment and the Lower Lachlan river system has previously been assessed as being in poor ecosystem health on the basis of an extremely poor native fish community, highly modified flow regimes (hydrology), and a physical form and vegetation community that is in poor to moderate condition (MDBA 2012). The Millennium Drought (2001-2009) resulted in large areas of river red gums becoming stressed, and a further decline in the condition of wetland vegetation. Some recovery of the wetlands and rivers has been observed since 2010, attributed to natural flow events and environmental watering actions. In 2016, the Booligal wetlands supported the largest and most successful breeding colony of straw-necked ibis in the Murray Darling Basin since 1984.

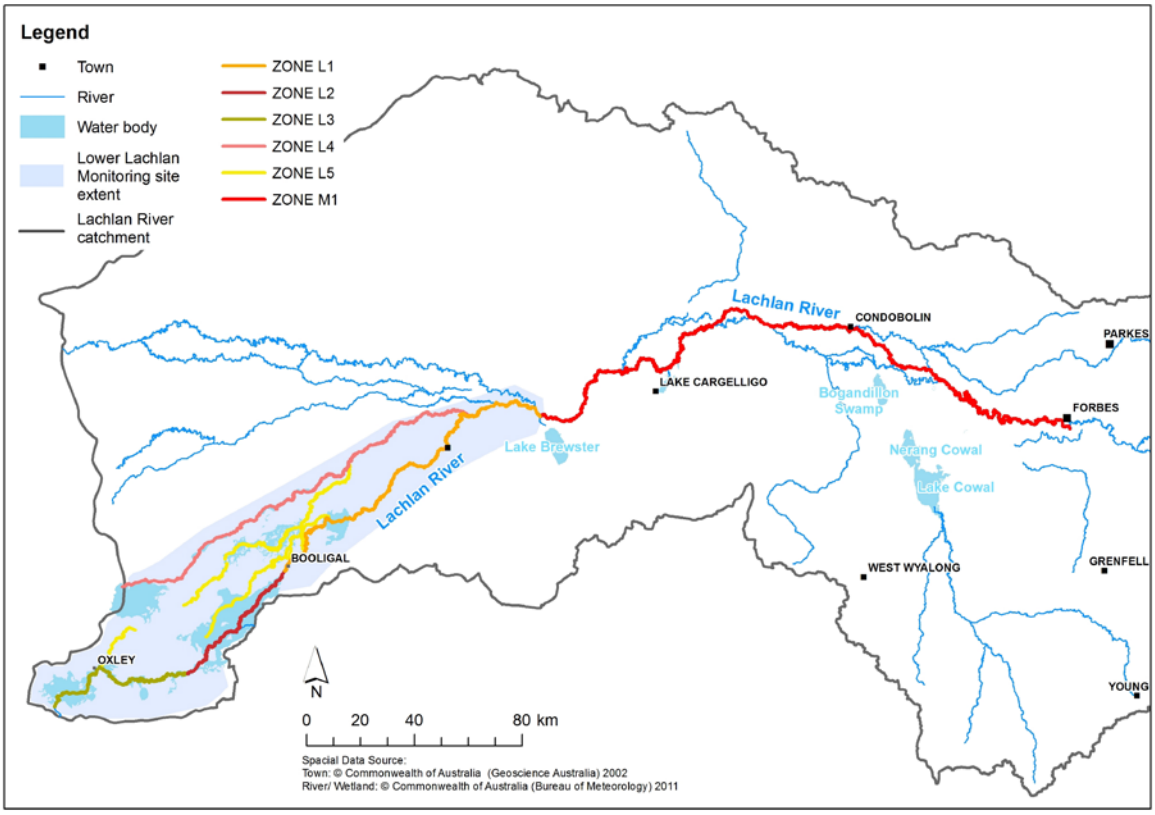

Figure 2-1. The Lachlan Selected Area showing the monitoring zones. The grey shaded area shows the core monitoring zones and area of focus for the LTIM lower Lachlan river system Selected Area.

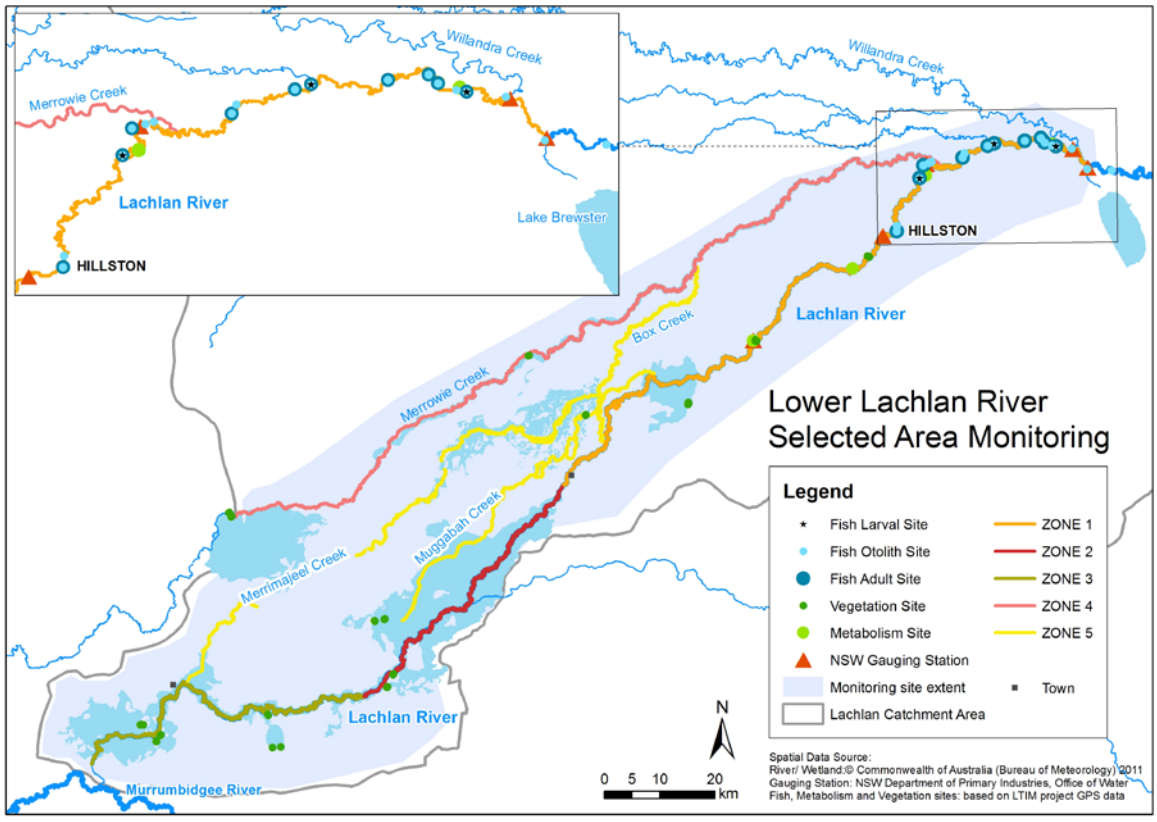

Figure 2-2. The Lower Lachlan river system showing the monitoring sites for the LTIM Project.

2.1 HYDROLOGICAL CHARACTER

Natural stream flow in the Lachlan River system is highly variable (Kemp 2004) and similar in character to many western flowing NSW rivers. There are strong east-west climate, geomorphic and stream flow gradients in the catchment. The majority of the flow is derived from the upper catchment and the river reaches maximum capacity (3,197 ML/day) at Forbes (Green et al. 2011). Downstream of Forbes streamflow reduces as the stream gradient and rainfall declines and the river becomes a complex of distributary channels. Further below the junction of the Lachlan River and Willandra Creek, the river is characterised by distributary channels, anabranches and distributaries, many of which do not return to the main branch of the river, resulting in further declines in main channel streamflow. At the upstream end of the Cumbung Swamp, mean daily flows are less than 20% of those at Forbes (Green et al. 2011).

The mean annual flow decreases from a maximum at Forbes of 988 GL/yr to 257 GL/yr at Booligal. Flows in the river display distinct periods of wet and dry conditions (Figure 2-3 and Figure 2-4). The Millennium Drought (2000 – 2009) was one of the longest sustained periods of below average flow since records began in the early 1900s. The 1950s were a particularly wet period in the catchment, with three of the highest annual flows occurring in 1956, 1950 and 1952 (Figure 2-4).

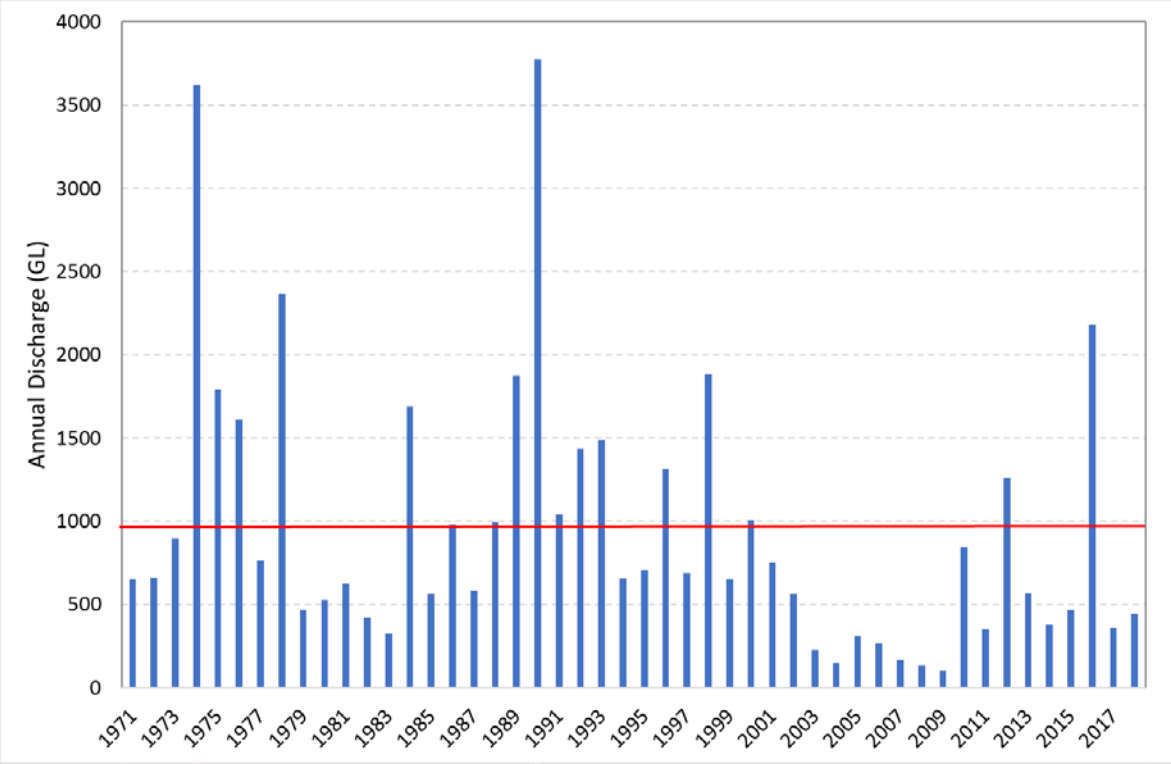

Figure 2-3. Annual flow at Forbes (NSW Gauging Station 412004). The red line shows the long term mean annual flow (988 GL/yr). Data from NSW Waterinfo.

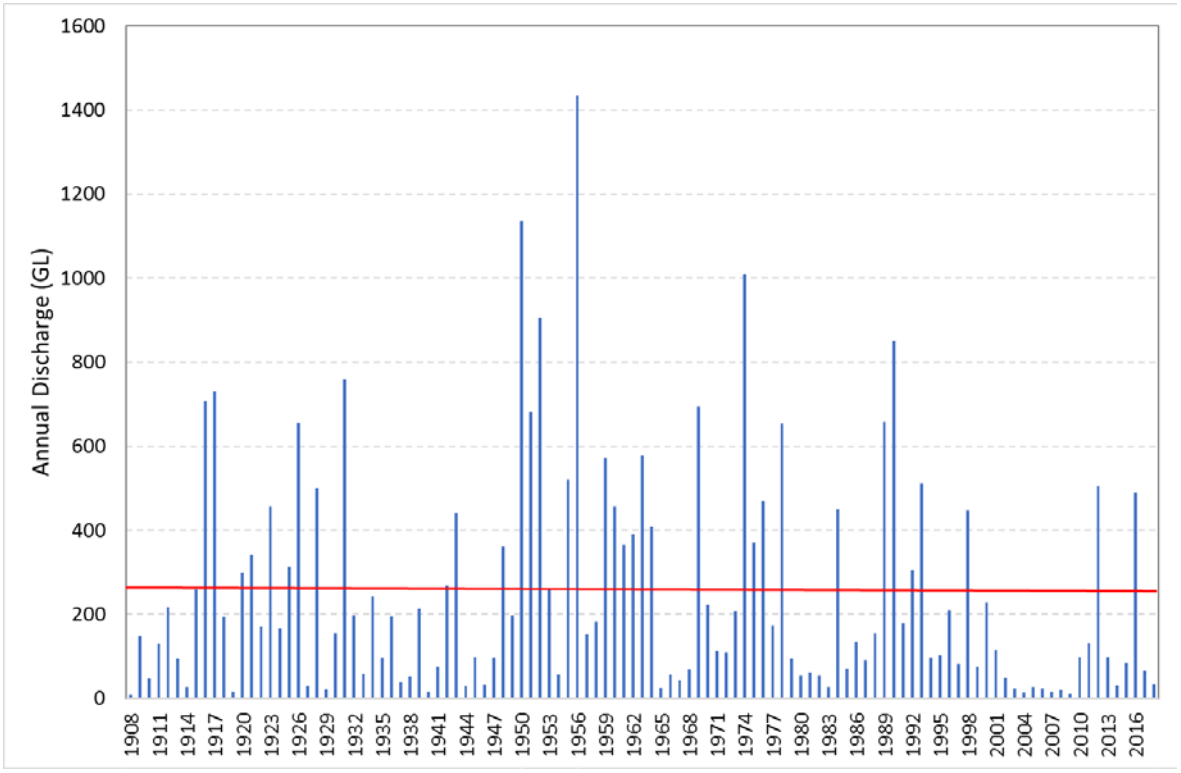

Figure 2-4. Annual flow at Booligal (NSW Gauging Station 412005). The red line shows the long term mean annual flow (257 GL/yr). Data from NSW Waterinfo.

River regulation and irrigation activities have intensified across the Lachlan River Catchment since the construction of Wyangala dam in 1935 (Kingsford 2000). There are 10 large dams and 323 weirs within the Lachlan River Catchment (Armstrong et al. 2009), including Carcoar Dam, Lake Cargelligo and Lake Brewster. The flows released from these dams and weirs support irrigation along almost the entire length of the catchment. Regulation and flow extraction of the Lachlan River has altered the behaviour and distribution of floodwaters (Driver et al. 2004b, Driver et al. 2010, Higgisson et al. 2019b).

2.2 MONITORING AND EVALUATION ZONES

In 2014, our team developed the LTIM Monitoring and Evaluation Plan (M & E Plan, Dyer et al. 2014) in line with the CEWO's Monitoring and Evaluation Requirements (Gawne et al. 2013a) and the LTIM Logic and Rationale Document (Gawne et al. 2013b). The M & E Plan described the approach to evaluation and included descriptions of monitoring indicators, sampling methods, timing and locations (Dyer et al. 2014). The LTIM Project adopted a hierarchical approach to the spatial elements of sampling design (Gawne et al. 2013) that involved Zones and Sites nested within the Selected Area and this approach is continued within the MER Program. Zones are a subset of the Selected Area that represent a spatially, geomorphological and/or hydrological distinct unit at a broad landscape scale. A site is the unit of assessment nested within a zone. The Lachlan Selected Area can be partitioned into spatially, geomorphologically and hydrologically distinct river channel zones at a broad landscape scale (Table 1, Figure 2-1).

In establishing the monitoring and evaluation program for the MER Program, the lower Lachlan river system is the core area in which monitoring and evaluation will occur. This ensures continuity of the monitoring data set and approach to evaluating the use of Commonwealth environmental water. The zones within the lower Lachlan from the LTIM Project are retained but the zone numbers are appended with an L to denote zones within the lower Lachlan river system (Table 1 and Figure 2-1).

Under the MER Program, contingency monitoring and evaluation may occur across the entire Selected Area, including the mid Lachlan. Zones appended with an M are new zones within the mid Lachlan river system (Table 1 and Figure 2-1).

Table 1. Zones for the Lachlan Selected Area.
To maintain continuity of the data set and approach, the original number of zones for the LTIM Project are retained, but appended with an L to denote zones within the lower Lachlan river system. Zones appended with an M are new zones within the mid Lachlan river system.

ZONE	LOCATION	CHARACTER
Zone M1	Lachlan River channel between Forbes and Brewster Weir	This zone contains populations of target species of fish, including freshwater catfish and is likely to regularly receive Commonwealth environmental water.
Zone L1	Lachlan River channel between Brewster Weir and Booligal	This zone contains relatively high abundances of the required target species of fish (with potentially limited numbers of freshwater catfish). Situated in the upper reaches of the Selected Area, this zone also is likely to regularly receive Commonwealth environmental water.
Zone L2	Lachlan River channel between Booligal and Corrong	Located downstream of Booligal Weir and similar to Zone 1 in geomorphology. This zone differs hydrologically because of water diversion and extraction above Booligal Weir.
Zone L3	Lachlan River channel between Corrong and its terminus in the Great Cumbung Swamp	This zone starts at the point at which the mid-Lachlan wetland system re-enters (drains into) the main Lachlan channel, providing an increase in riverine productivity, stimulating food webs. The fish assemblages are currently dominated by alien species.
Zone L4	Merrowie Creek	A distributary creek that receives intermittent regulated stock and domestic flows as well as targeted environmental flows at Tarwong Lake and Cuba Dam. No data exist on the fish assemblage present within Merrowie Creek.
Zone L5	Torringanny, Box, Merrimajeel and Muggabah Creek system	The largely ephemeral, effluent streams of the Merrimajeel and Muggabah system north of the Lachlan main channel and Merrowie creek. This complex system is fundamentally different to main channel zones acting more like linear wetlands that are likely to only retain water for limited periods during and following environmental flow deliveries.

3 COMMONWEALTH ENVIRONMENTAL WATERING

Environmental water has been allocated to the Lachlan River since 1992 (from NSW) and the river system has received Commonwealth environmental water since 2010. Currently, environmental water for the Lachlan River comprises both Commonwealth government holdings of water entitlements (Commonwealth environmental water) and NSW government-held licensed environmental water (NSW environmental water holdings) as well as planned water under the Lachlan Regulated Water Sharing Plan (https://legislation.nsw.gov.au/#/view/regulation/2016/365/full). Commonwealth water holdings have been consistent since 2014-15 and at February 2019, the Commonwealth government held a total of 87 856 ML in entitlement (Table 2).

Table 2. Environmental water holdings in the Lachlan River Valley as at 1 July 2017.

	WATER HOLDINGS (ML) BY ENTITLEMENT TYPE		
WATER HOLDER	HIGH SECURITY	GENERAL SECURITY	**TOTAL**
CEWH	933	86 923	**87 856**
NSW	1,795	36 569	**38 364**
TOTAL	**2,728**	**123 492**	**126 220**

3.1 WATERING OPTIONS AND EXPECTED OUTCOMES

Commonwealth environmental water has been delivered in the Lachlan catchment since 2010 and more than 205 GL of Commonwealth environmental water has been delivered to date to achieve a wide range of outcomes. Watering actions are defined within an annual planning cycle and draw on MDBA's long term environmental objectives, as well as antecedent watering conditions, seasonal, operational and local management considerations. Where possible, the CEWO have sought to achieve multiple benefits from watering events to maximise the outcomes. Within the main channel environmental flows have sought outcomes ranging from hydrological connectivity and variability, improvements in dissolved oxygen concentrations, providing cues for native fish spawning and providing refuge habitat. A number of significant wetlands have also received environmental flows including Booligal swamp, Lake Tarwong and the Great Cumbung Swamp. These wetland flows have sought to support waterbird breeding, vegetation condition and fish dispersal outcomes.

Commonwealth environmental water in the Lachlan Selected Area can be delivered alone but is more typically delivered in concert with NSW environmental water and operational flows (managed by Water NSW).

Environmental water can be delivered as:

- Discrete events: delivered from storages and/or regulated using infrastructure to target sites.
- Augmented events: with water used to modify (enhance or extend) a natural flow event at target sites.
- "Piggy-backed" events: where water is 'piggy-backed' on water delivered for stock and domestic or irrigation purposes.

Annual plans for managing Commonwealth environmental water in the Lachlan catchment are prepared as portfolio management plans (see https://www.environment.gov.au/water/cewo/catchment/lachlan/). At the time of preparing this MER Plan (mid 2019), catchment conditions and weather patterns suggest very dry conditions. Allocations are low and access to carryover volumes of water are likely to be reduced to ensure that critical needs are met. Environmental water planning is currently focussed on supporting key assets (such as the central reed beds of the Cumbung Swamp) and providing refugia in the landscape (by providing water to key wetland assets and managing in-stream water quality). Watering actions are likely to be small in 2019-20 as drought conditions persist, and unless inflows increase dramatically, there will be further decline in the availability of environmental water in subsequent years. Under these circumstances, watering actions are likely to be constrained by the needs of river operations during drought. Support of key in-stream assets and refugia is likely to remain a priority. Should conditions improve, water will be used strategically to support recovery processes, with a likely focus on outcomes for native fish and other vertebrate species, waterbirds and native vegetation.

3.2 WATERING PRACTICALITIES

3.2.1 DELIVERY OF ENVIRONMENTAL WATER

Delivery of water in the Lachlan river system is complicated by a network of regulating structures. These can be used to provide infrastructure assisted watering and include: the Block Bank Regulator which can be used to extend watering duration in Booligal Wetland; and the Torringanny Regulator which can be used to assist in the delivery of water to the lower reaches of the Merrimajeel Creek system.

Delivery is also constrained by release capacities from storages, channel capacities, risks to private infrastructure and the timing of irrigation deliveries within the system, including:

- A maximum release capacity of Lake Brewster of 3,000 ML/day.
- Flows above 2,400 ML/day in the Lachlan River upstream of Willandra Weir resulting in flows commencing in Willandra Creek.
- Flows exceeding 2,800 ML/day at Hillston may inundate private irrigation infrastructure.
- Flows exceeding 5990 ML/day inundate the low-level bridge in Cowra, but the main bridge is unaffected.
- The outlet valves at Wyangala Dam have a maximum capacity of 7,300 ML/day but the power station is constrained to between 2900 and 3100 ML/day.

4 MONITORING AND RESEARCH PRIORITIES

4.1 MONITORING AND EVALUATION

Within the MER Program, there are two streams of monitoring and evaluation activities:

1. Core monitoring and evaluation: this is the continuation of the LTIM monitoring and evaluation activities in the river system;
2. Contingency monitoring and evaluation: these are monitoring and evaluation activities that are implemented 'on demand' in response to specific events or watering actions in the river system;

The monitoring activities that will be delivered as part of the MER Program were prioritised using two criteria. These are monitoring and evaluation activities that:

1. ensure continuity of the long-term data set; and
2. will better inform environmental water delivery in the Selected Area;

In addition, monitoring and evaluation activities (or changes to monitoring and evaluation activities) that would link with priority research activities to add value were considered favourably.

4.1.1 CORE MONITORING AND EVALUATION

4.1.1.1 Establishing priority indicators and zones

In 2014, our team developed the LTIM Monitoring and Evaluation Plan (M & E Plan, Dyer et al. 2014) in line with the CEWO's Monitoring and Evaluation Requirements (Gawne et al. 2013a), the LTIM Logic and Rationale Document[1] (Gawne et al. 2013b) and the LTIM Project Generic Cause and Effect Diagrams[2] (MDFRC 2013). The M & E Plan described the approach to evaluation and included descriptions of monitoring indicators, sampling methods, timing and locations (Dyer et al. 2014). Priority was given to providing data for Basin evaluation and monitoring native fish populations, and stream metabolism within Zone L1 was the core of the M & E Plan. Regionally, evaluation focussed on questions relating to hydrology, floodplain and wetland vegetation condition and diversity; frogs and other vertebrates (turtles, waterbirds) and these indicators were monitored across Zone L1-L5.

4.1.1.2 Ensuring continuity of the long-term data set

The LTIM M & E Plan (Dyer et al. 2014) provides the foundation for our ongoing monitoring and evaluation which means a continued use of the LTIM Logic and Rationale Document (Gawne et al. 2013b) and the LTIM Project Generic Cause and Effect Diagrams (MDFRC 2013). To ensure the continuity of the emerging long-term data set, informing Basin evaluation remains the highest priority. This means that our core monitoring and evaluation activities continue monitoring larval and adult fish, and stream metabolism indicators within the lower Lachlan river system (Zone L1). The indicators that are retained for Selected Area evaluation within the core monitoring and evaluation program are hydrology and vegetation condition and diversity within the lower Lachlan

[1] https://www.environment.gov.au/water/cewo/publications/long-term-intervention-monitoring-project-logic-and-rationale-document
[2] https://www.environment.gov.au/water/cewo/publications/ltim-cause-effect-diagrams

river system (Zones L1-L5). In combination, the monitoring and evaluation of these indicators in the lower Lachlan river system (Zones L1-L5) uses the available funds for core monitoring activities.

4.1.1.3 Better informing environmental water delivery in the Selected Area

While at a broad scale, the indicators, the evaluation questions and sites/Zones monitored within the Lachlan Selected Area remain unchanged from the LTIM Project, a review of the LTIM M & E Plan involving the current project team, strategic contributors, CEWO delivery team representatives, NSW environmental water managers and key stakeholders, made the following recommendations for improvements to the monitoring program:

1. Tree condition surveys should be conducted every five years instead of annually

Rationale: the tree condition metrics recorded annually do not appear to be sensitive to watering on an annual timescale. It is expected that tree condition is a measure of the long-term response to environmental water and are better measured on a five year timeframe than annually. As tree condition metrics have been measured annually between 2014 and 2019, it does not need to occur again until 2024.

2. Revise the vegetation condition and diversity sites.

Rationale: The response of groundcover vegetation diversity and vegetation condition metrics are framed within the context of the watering history of the sites (Dyer et al. 2015, Dyer et al. 2016, Dyer et al. 2017, Dyer et al. 2018). The spread of sites does not provide replication for the most frequently watered sites and over samples sites that are rarely watered. A change to the sites within the catchment to reduce the number of rarely watered sites and increase the number of frequently watered sites would enable greater confidence in the response to environmental watering and has the potential to link to the proposed research program.

3. Elaborate the Selected Area evaluation questions to be more locally relevant

Rationale: The priority given to basin evaluation under the LTIM program resulted in the use of generic evaluation questions at the Selected Area Scale. These evaluation questions could be further developed and refined (‘unpacked’ or elaborated upon), given the experience of the LTIM program, to provide a set of questions that would better inform Selected Area evaluation. These would be nested within the original LTIM project questions, thus retaining continuity and not pre-empting the broader program review that is proposed during the course of the MER program.

These recommendations are addressed in the description of the Indicators (Section 5)

4.1.2 CONTINGENCY MONITORING AND EVALUATION: BETTER INFORMING ENVIRONMENTAL WATER DELIVERY IN THE SELECTED AREA

The CEWO have made an allocation to undertake monitoring and evaluation activities ‘on demand’ in response to specific events or watering actions in the river system. The indicators selected for contingency monitoring are not monitored every year. Under the LTIM Project, frogs and waterbirds were monitored at the request of the CEWO in response to conditions across the Lachlan river system. Waterbirds remain a priority for contingency monitoring under the MER Plan.

In addition, the review of the LTIM M & E Plan recommended that expanding the larval and adult fish, and stream metabolism evaluation to the mid-Lachlan would be a priority for better informing environmental water delivery in the Selected Area. The rationale for this was that adult and larval fish, and stream metabolism have been monitored in a single zone (L1) for the past five years to contribute to Basin scale monitoring priorities. This has meant that we have not had data to evaluate watering actions in the mid-Lachlan, yet the mid-Lachlan has frequently been the target for watering actions, particularly for fish. In 2018-19, short term intervention monitoring was implemented in the mid-Lachlan in a single zone (M1). It is likely that this mid-Lachlan reach will continue to be a priority for watering actions, particularly if the catchment remains dry over the coming three years. It is not possible to monitor larval and adult fish, and stream metabolism in the mid-Lachlan under the core monitoring budget, but given the strategic importance of monitoring in this reach, it is considered as part of the contingency monitoring and evaluation component of the MER Plan and is addressed further in Section 5.

4.2 RESEARCH

The Lachlan River has been the subject of relatively little research effort when compared to other sites in the Basin. The key wetlands, including the Booligal wetlands and the Great Cumbung Swamp have fewer than 200 published papers when compared to Barmah Forest (>500) and Chowilla (>1400). The channel environment has received even less attention and much of what we know of these systems has been derived from work by Chessman and the IMEF team and the RERP report. Over the last 10 years there has been research undertaken and published on flow modelling (Gilmore et al. 2009), geomorphology (Kemp 2004, 2010, Kemp and Rhodes 2010), wetland mapping (Ling et al. 2019), re-snagging (Martin et al. 2016), organic matter dynamics (Moran et al. 2013) wetland vegetation (Driver et al. 2010) and amphibians (Wassens and Maher 2011). More recently, the LTIM Project has adopted a strategy of engaging honours and PhD students in complementary projects which have contributed valuable new knowledge (Belton 2015, Higgisson et al. 2018, 2019a, Higgisson et al. 2019b). Within this context, the LTIM Project and MER Program make a significant contribution to what is known about the Lachlan River.

A large number of potential research activities have been identified through the LTIM Project and by key stakeholders. At a workshop in March 2019 involving the current project team, strategic contributors, CEWO delivery team representatives, NSW environmental water managers and other key stakeholders, potential research projects were prioritised based on two key criteria:

1. Potential to improve water management decisions at the Area scale
    a. Gaps specific to the Lachlan
    b. Knowledge generated in other areas, but with low confidence in its application to the Lachlan.
2. Potential to improve water management at the Basin scale
    a. Knowledge to support coordinated watering across Area
    b. Opportunities unique to the Lachlan that could then be applied to other Areas.

This process identified a suite of thematically based priority research projects as well as projects that cross multiple themes. A brief scope for the research is provided within Section 5 and Section 6 respectively. The research projects are prioritised in Section 6 and it is proposed that during the first 3 months of the MER Program, a more detailed research program is developed.

5 INDICATORS

The MER Program will focus on assessing the achievements of Commonwealth environmental watering across the whole Basin as well as outcomes specific to the Lachlan Selected Area. Evaluation is based around a suite of evaluation questions, both at the Basin scale and specific to the Selected Area. Basin evaluation questions were developed to assess the extent to which Commonwealth environmental water contributes to achieving Basin Plan objectives. These follow the hierarchical structure of the Outcomes Framework (Commonwealth Environmental Water Office 2013, Gawne et al. 2014):

1. Basin Plan objectives (Level 1 evaluation questions).
2. Basin Outcomes (Level 2 evaluation questions).
3. Expected Outcomes (Level 3 evaluation questions).

The Basin evaluation questions applicable to the Lachlan Selected Area are outlined in Table 3. In many instances, these questions differ from those presented in the foundation reports (Capon et al. 2015, Stewardson et al. 2015, Stoffels et al. 2016, Brooks 2018, Grace 2018). The evaluation questions specific to the Lachlan Selected Area are outlined in Table 4. The Selected Area evaluation questions used within the LTIM Project (Dyer et al. 2014) are retained for the MER Program, but for some indicators, additional questions are posed based on either an elaboration of the original questions (see Section 4.1.1.3) or the current foundation reports.

Table 3. List of Basin evaluation questions applicable to the Lachlan Selected Area.

LEVEL 1 EVALUATION QUESTIONS	LEVEL 2 EVALUATION QUESTIONS	LEVEL 3 EVALUATION QUESTIONS	
		LONG-TERM (5 YEARS)	SHORT-TERM (ONE YEAR)
What has Commonwealth environmental water contributed to biodiversity?	What did Commonwealth environmental water contribute to Ecosystem diversity?	What did Commonwealth environmental water contribute to sustainable ecosystem diversity? Were ecosystems to which Commonwealth environmental water was allocated sustained? Was water delivered to a representative suite of ecosystem types?	
		What did Commonwealth environmental water contribute to the condition of floodplain and riparian trees?	What did Commonwealth environmental water contribute to the condition of floodplain and riparian trees?
		What did Commonwealth environmental water contribute to vegetation community diversity? What did Commonwealth environmental water contribute to vegetation species diversity?	What did Commonwealth environmental water contribute to vegetation community diversity? What did Commonwealth environmental water contribute to vegetation species diversity?
		What did Commonwealth environmental water contribute to vegetation extent?	
	What did Commonwealth environmental water contribute to Species diversity?	What did Commonwealth environmental water contribute to native fish populations? What did Commonwealth environmental water contribute to native fish species diversity? What did Commonwealth environmental water contribute to fish community resilience? What did Commonwealth environmental water contribute to native fish survival?	What did Commonwealth environmental water contribute to native fish reproduction? What did Commonwealth environmental water contribute to native larval fish growth and survival?
			What did Commonwealth environmental water contribute to waterbird breeding? What did Commonwealth environmental water contribute to waterbird chick fledging?

LEVEL 1 EVALUATION QUESTIONS	LEVEL 2 EVALUATION QUESTIONS	LEVEL 3 EVALUATION QUESTIONS	
		LONG-TERM (5 YEARS)	SHORT-TERM (ONE YEAR)
			What did Commonwealth environmental water contribute to waterbird survival?
		What did Commonwealth environmental water contribute to waterbird populations? What did Commonwealth environmental water contribute to waterbird species diversity?	What did Commonwealth environmental water contribute to waterbird survival?
		What did Commonwealth environmental water contribute to other vertebrate populations? What did Commonwealth environmental water contribute to other vertebrate species diversity?	What did Commonwealth environmental water contribute to other vertebrate reproduction and recruitment? What did Commonwealth environmental water contribute to other vertebrate survival?
What has Commonwealth environmental water contributed to ecosystem function?	What did Commonwealth environmental water contribute to ecosystem connectivity?	What did Commonwealth environmental water contribute to hydrological connectivity?	What did Commonwealth environmental water contribute to hydrological connectivity?
		What did Commonwealth environmental water contribute to biotic dispersal?	What did Commonwealth environmental water contribute to biotic dispersal?
	What did Commonwealth environmental water contribute to ecosystem processes?	What did Commonwealth environmental water contribute to patterns and rates of primary productivity?	What did Commonwealth environmental water contribute to patterns and rates of primary productivity?
		What did Commonwealth environmental water contribute to patterns and rates of primary productivity? 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 patterns and rates of decomposition?
		What did Commonwealth environmental water contribute to patterns and rates of nutrient cycling?	What did Commonwealth environmental water contribute to patterns and rates of nutrient cycling?
What has Commonwealth	What did Commonwealth	What did Commonwealth environmental water contribute to populations of long-lived organisms?	

LEVEL 1 EVALUATION QUESTIONS	LEVEL 2 EVALUATION QUESTIONS	LEVEL 3 EVALUATION QUESTIONS	
		LONG-TERM (5 YEARS)	SHORT-TERM (ONE YEAR)
environmental water contributed to ecosystem resilience?	environmental water contribute to ecosystem resilience?	What did Commonwealth environmental water contribute to refuges?	What did Commonwealth environmental water contribute to refuges?
		What did Commonwealth environmental water contribute to recovery?	What did Commonwealth environmental water contribute to recovery?
	What did Commonwealth environmental water contribute to species resilience?	What did Commonwealth environmental water contribute to fish community resilience?	What did Commonwealth environmental water contribute to fish community resilience?
What has Commonwealth environmental water contributed to water quality?	What did Commonwealth Environmental water contribute to chemical water quality?	What did Commonwealth environmental water contribute to temperature regimes? What did Commonwealth environmental water contribute to dissolved oxygen levels?	What did Commonwealth environmental water contribute to temperature regimes? What did Commonwealth environmental water contribute to dissolved oxygen levels?

Table 4. Lachlan Selected Area evaluation questions.
The level 3 evaluation questions are the same as those from the LTIM program. Additional MER Evaluation questions have been provided to either 1) address the questions framed in the foundation reports 2) address questions specific to the Lachlan Selected Area. Sub questions provide more specific evaluation questions for each of the evaluation questions.

THEME	EVALUATION QUESTIONS	AREA SPECIFIC SUB QUESTIONS	SHORT-/LONG-TERM	INDICATORS	RELEVANT CAUSE AND EFFECT DIAGRAM
Hydrology [A]	**Level 3 LTIM Evaluation Question** What did Commonwealth environmental water contribute to hydrological connectivity?	How was longitudinal and lateral connectivity changed by the use of Commonwealth environmental water? What proportion of the flow in the river was environmental water and how did this change throughout the year?	Short Long	Hydrology (river and wetland)	Hydrological connectivity Hydrology
	Additional MER Evaluation Question What did Commonwealth environmental water contribute to habitat for native fish and other water dependent vertebrate species? What did Commonwealth environmental water contribute to hydrological variability?	How did river levels differ from those under normal operations? Did the provision of Commonwealth environmental water modify low flow variability? Did the provision of Commonwealth environmental water change the number of freshes in the river?	Short Long		
Vegetation [B]	**Level 3 LTIM Evaluation Question** What did Commonwealth environmental water contribute to vegetation species diversity?	What did Commonwealth environmental water contribute to individual plant species across the Selected Area including changes to species presence, distribution and cover?	Short Long	Vegetation diversity Hydrology (river and wetland)	Landscape vegetation diversity
	Level 3 LTIM Evaluation Question What did Commonwealth environmental water contribute to vegetation community diversity?	How did Commonwealth environmental water affect the composition and structure of particular vegetation communities? How did Commonwealth environmental water affect the presence, distribution and abundance of particular vegetation communities?	Short Long	Vegetation diversity Hydrology (river and wetland)	Landscape vegetation diversity

THEME	EVALUATION QUESTIONS	AREA SPECIFIC SUB QUESTIONS	SHORT-/LONG-TERM	INDICATORS	RELEVANT CAUSE AND EFFECT DIAGRAM
	Additional MER Evaluation Question What did Commonwealth environmental water contribute to native riparian and wetland vegetation communities?	What did Commonwealth environmental water contribute to populations of long-lived organisms (measured through cover and recruitment of tree species)? What did Commonwealth environmental water contribute to vegetation communities within Australian National Aquatic Ecosystem (ANAE) vegetation types, including changes in species richness, composition, cover and structure?	Short Long	Vegetation diversity Hydrology (river and wetland)	Landscape vegetation diversity Vegetation recruitment and extent
Stream Metabolism [C]	**Level 3 LTIM Evaluation Question** What did Commonwealth environmental water contribute to patterns and rates of primary productivity?	Can timing of environmental water be used to increase basal productivity responses? Can provision of autumn flows increase magnitude of productive responses to spring flows? How do productivity responses from environmental water differ from those from natural flow events? Are there characteristics of productivity responses from environmental water that increase the probability of seeing fish reproduction events? Is there evidence for nutrient limitation of primary productivity in the Lachlan River? Are there particular floodplain or in-channel features that are associated with changes in productivity rates when they receive water?	Short Long	Stream metabolism Hydrology (river)	Primary production
	Level 3 LTIM Evaluation Question What did Commonwealth environmental water contribute to patterns and rates of decomposition?	Can environmental water be used to mitigate the impacts of excessive decomposition (blackwater)? What factors increase the probability of a blackwater event arising from environmental water? Are there particular floodplain or in-channel features that are associated with changes in decomposition rates when they receive water?	Short Long	Stream metabolism Hydrology (river)	Decomposition
	Level 3 LTIM Evaluation Question		Short		Water quality

THEME	EVALUATION QUESTIONS	AREA SPECIFIC SUB QUESTIONS	SHORT-/LONG-TERM	INDICATORS	RELEVANT CAUSE AND EFFECT DIAGRAM
Water Quality [D]	What did Commonwealth environmental water contribute to temperature regimes?	What factors increase the probability of low oxygen events arising from environmental water? Can environmental water be used to mitigate the impacts of low oxygen events? Can environmental water be used to mitigate the impacts of salinity and low pH pulses? What factors increase the probability of high salinity, low pH or high turbidity events arising from environmental water?	Long	Water quality (dissolved oxygen, temperature) Hydrology (river)	
	Level 3 LTIM Evaluation Question What did Commonwealth environmental water contribute to dissolved oxygen levels?		Short Long		
	Additional MER Evaluation Question What did Commonwealth environmental water contribute to pH and to salinity and turbidity regimes?		Short		
Fish [E]	**Level 3 LTIM Evaluation Question** What did Commonwealth environmental water contribute to native fish populations?	What did Commonwealth environmental water contribute to sustaining native fish populations? How does the fish community vary in the lower Lachlan Selected Area on an annual time step in relation to abundance, biomass and size? Does this link to sequential flow events and the hydrological regime?	Long	Fish (species, abundance and size frequency in rivers) Hydrology (river) Water quality (temperature and dissolved oxygen)	Landscape fish diversity
	Level 3 LTIM Evaluation Question What did Commonwealth environmental water contribute to native fish species diversity?		Long		
	Level 3 LTIM Evaluation Question		Long		

THEME	EVALUATION QUESTIONS	AREA SPECIFIC SUB QUESTIONS	SHORT-/LONG-TERM	INDICATORS	RELEVANT CAUSE AND EFFECT DIAGRAM
	What did Commonwealth environmental water contribute to fish community resilience?				
	Level 3 LTIM Evaluation Question What did Commonwealth environmental water contribute to native fish survival?	What did Commonwealth environmental water contribute to sustaining native fish survival? Do Commonwealth environmental water delivery events result in detectable changes in the abundance, biomass and size (length) of the fish community in the lower Lachlan Selected Area?	Short		Fish condition
	Level 3 LTIM Evaluation Question What did Commonwealth environmental water contribute to native fish reproduction?	What did Commonwealth environmental water contribute to sustaining native fish reproduction?	Short		Fish reproduction
	Level 3 LTIM Evaluation Question What did Commonwealth environmental water contribute to native larval fish growth and survival?		Short		Fish larval growth and survival
Waterbirds (Option) [F]	**Level 3 LTIM Evaluation Question** What did Commonwealth environmental water contribute to colonial waterbird breeding?	How did Commonwealth environmental water contribute to colonial waterbird breeding the Lachlan Selected Area? What were the colonial waterbird responses to Commonwealth environmental watering?	Short	Waterbirds – breeding (colonial nesting species) Hydrology (wetlands) Vegetation type and condition	Waterbird recruitment and fledging
	Level 3 LTIM Evaluation Question What did Commonwealth environmental water contribute to colonial waterbird chick fledging?		Short		
	Level 3 LTIM Evaluation Question		Short		Waterbird reproduction

THEME	EVALUATION QUESTIONS	AREA SPECIFIC SUB QUESTIONS	SHORT-/LONG-TERM	INDICATORS	RELEVANT CAUSE AND EFFECT DIAGRAM
	What did Commonwealth environmental water contribute to waterbird survival?				
	Level 3 LTIM Evaluation Question What did Commonwealth environmental water contribute to waterbird survival?		Short		Waterbird survival and condition
	Additional MER Evaluation Question What contribution did the Lachlan Selected Area make to Basin wide colonial waterbird breeding?				
Other Vertebrates (Reported as by-catch from fish monitoring)	What did Commonwealth environmental water contribute to other vertebrate populations?		Long	Turtles (species and abundance) Hydrology (river)	Other vertebrate growth and survival Other vertebrate reproduction
	What did Commonwealth environmental water contribute to other vertebrate species diversity?		Long		
	What did Commonwealth environmental water contribute to other vertebrate reproduction and recruitment?		Short		
	What did Commonwealth environmental water contribute to other vertebrate survival?		Short		

THEME	EVALUATION QUESTIONS	AREA SPECIFIC SUB QUESTIONS	SHORT-/LONG-TERM	INDICATORS	RELEVANT CAUSE AND EFFECT DIAGRAM
	What did Commonwealth environmental water contribute to refuges?		Short Long		

[A] The foundation report (Stewardson et al. 2015) states this question as: "What did Commonwealth environmental water contribute to restoration of the hydrological regime?

[B] A further question was posed in the LTIM M&E Plan (Dyer et al. 2014): "What did Commonwealth environmental water contribute to vegetation extent?" But the sampling design could not address this question and nor has it been answered in any of the Evaluation reports and has been dropped from the questions to be answered under the MER Program

[C] A further question was posed in the LTIM M&E Plan (Dyer et al. 2014): "What did Commonwealth environmental water contribute to patterns and rates of nutrient cycling?" This question no longer appears in the foundation document, it has not been answered in any of the evaluation reports and has been removed from the questions to be answered under the MER Program.

[D] The only water quality evaluation questions in the foundation report (Grace 2018) are: "What did Commonwealth environmental water contribute to dissolved oxygen levels?" and "What did Commonwealth environmental water contribute to salinity regimes?". Questions of temperature no longer appear in the foundation document.

[E] The foundation report for fish (Stoffels et al. 2018) states only 3 questions: "What did Commonwealth environmental water contribute to sustaining native fish populations?" "What did Commonwealth environmental water contribute to sustaining native fish reproduction?" "What did Commonwealth environmental water contribute to sustaining native fish survival?"

[F] The original evaluation questions target 'waterbird breeding'. It is only the colonial waterbird breeding that has been the target of evaluation question and so the questions are now more specific.

The following sections outline the indicators being monitored within the Lachlan Selected Area. For each indicator, we highlight the Basin Scale evaluation questions that our monitoring will inform and define the Area specific evaluation questions that our monitoring will address. A summary of our approach to answering the Area specific evaluation questions is provided and additional details are included in each of the Standard Operating Procedures (SOP's) for monitoring the indicators (Appendix A).

For each indicator, we also describe priority knowledge gaps and scope the type of research required to address the knowledge gaps. The research options are not provided in detail as the research plan will be developed subsequently, but are provided with sufficient detail to prioritise the options.

A note about monitoring and evaluation methods

A central part of the LTIM Project was the evaluation of the outcomes of Commonwealth environmental water and its contribution to achieving the objectives of the Basin Plan. Basin-scale evaluation is informed by monitoring within the seven Selected Areas. To ensure that the needs of the Basin-scale evaluation were met by the Selected Area monitoring, three categories of indicators were developed (Hale et al. 2014). These were:

- Category I – Mandatory indicators and standard protocols which were required to inform quantitative Basin-scale evaluation. Indicators were to be applied in a consistent manner following the standard protocols defined within the Commonwealth Environmental Water Office Long term Intervention Monitoring: Standard Methods (https://www.environment.gov.au/water/cewo/publications/cewo-ltim-standard-methods);
- Category II – Optional indicators with mandatory standard protocols which may be used to inform quantitative Basin-scale evaluation in the future. When these indicators were selected for implementation at the Selected Area, the standard protocols defined within the Commonwealth Environmental Water Office Long term Intervention Monitoring: Standard Methods (https://www.environment.gov.au/water/cewo/publications/cewo-ltim-standard-methods) must be implemented; and
- Category III – Optional indicators with Selected Area specific protocols and mandatory reporting requirements. This includes Selected Area specific monitoring using locally appropriate methods.

5.1 ECOSYSTEM TYPE

The monitoring and evaluation of ecosystem type is a core monitoring and evaluation activity.

It is generally assumed that freshwater ecosystems of similar ecosystem type and geographical location will respond in a similar, predictable fashion to flow components. This is frequently the basis for translating management actions to areas for which response data are not available. By using a broad scale classification of river and wetland type it is possible to stratify the analysis of ecosystem responses to determine if sites of the same ecosystem type within a Selected Area respond in a similar fashion to watering.

5.1.1 EVALUATION QUESTIONS

Ecosystem type is a Category 1 indicator and is used Basin Evaluation. Ecosystem type is an input to the analysis of the response of Selected Area indicators to Commonwealth environmental water. Questions will be answered as part of the Basin Evaluation. No Area specific evaluation questions exist.

5.1.1.1 Basin-scale evaluation questions

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

5.1.1.2 Selected Area evaluation questions

None

5.1.2 MONITORING STRATEGY

The interim Australian National Aquatic Ecosystem (ANAE) classification framework will be validated at all monitoring sites to confirm the classification of ecosystem type.

5.1.3 EVALUATION

Where possible, the ANAE type will be used to stratify analyses to determine if sites of the same ecosystem type respond consistently to watering.

5.2 HYDROLOGY

The monitoring and evaluation of hydrology is a core monitoring and evaluation activity.

The provision of water to maintain and restore riverine environments is based on the premise that the hydrological regime is one of the fundamental drivers of the structure and function of riverine and floodplain ecosystems (Nilsson and Berggren 2000, Bunn and Arthington 2002). Flow drives physical processes, providing longitudinal and lateral connectivity, moving sediments and nutrients and providing a diversity of hydraulic conditions for aquatic biota (Bunn and Arthington 2002). Altering flow regimes, through various water resource development activities, markedly affects the health of freshwater ecosystems (Walker and Thoms 1993, Gehrke et al. 1995, Kingsford 2000) and thus returning elements of the natural flow regime is an important part of managing and restoring river health. It is in this context, that Commonwealth environmental water is used to modify the hydrological regime to achieve ecological outcomes. Quantification of the changes in the duration, timing and magnitude of environmental flows underpins the evaluation of all other indicators as well as enabling evaluation questions specific to the Lachlan Selected Area to be addressed.

5.2.1 EVALUATION QUESTIONS

The monitoring of hydrology in the Lachlan Selected Area will use Category 3 methods to address Selected Area evaluation questions (see also Table 4).

5.2.1.1 Area Evaluation

Within the Selected Area, changes in the duration, timing and magnitude of flow caused by the management of environmental water will allow the assessment of a range of evaluation questions.

1. What did Commonwealth environmental water contribute to hydrological connectivity?
    a. How was longitudinal and lateral connectivity changed by the use of Commonwealth environmental water?
    b. What proportion of the flow in the river was environmental water and how did this change throughout the year?
2. What did Commonwealth environmental water contribute to habitat for native fish and other water dependent vertebrate species?
    a. How did river levels differ from those under normal operations?
3. What did Commonwealth environmental water contribute to hydrological variability?
    a. Did the provision of Commonwealth environmental water modify low flow variability?
    b. Did the provision of Commonwealth environmental water change the number of freshes in the river?

5.2.2 MONITORING STRATEGY

Mean daily discharge (ML/day) and daily mean ‘stage’ (as relative water level in metres) data will be obtained from the WaterNSW site (http://realtimedata.waternsw.com.au/) for gauging sites within the Selected Area. The daily contribution (ML/day) of Commonwealth and NSW environmental water (ML/day) to the flow in the river will be obtained from Water NSW via the Commonwealth Environmental Water Office and the NSW Office of Environment and Heritage.

Wetland inundation information will be obtained from Sentinel imagery (https://apps.sentinel-hub.com/sentinel-playground/) and on-ground observations.

Detailed methods are outlined in the Standard Operating Procedure: Lachlan Selected Area Hydrology.

5.2.3 EVALUATION

The evaluation of the hydrological outcomes will use a combination of flow data, river height data, wetland inundation information and observations. The contribution of Commonwealth and NSW environmental water (ML/day) will be subtracted from the flow at the relevant water accounting locations to produce hydrographs illustrating the relative contribution to the flow. River levels in the absence of Commonwealth and NSW environmental water will be estimated from rating curves at each site.

5.2.4 RESEARCH

Priority knowledge gaps relating to hydrology in the Lachlan Selected Area are:

5.2.4.1 Understanding the natural flow regime in distributary reaches

The design of hydrographs for the delivery of water into the Merrowie, Merrimajeel and Muggabah Creek systems is constrained by flow records which start in 2003. To improve the design of the hydrographs and potentially achieve stronger outcomes for vertebrates and vegetation, flow models could be developed that would enhance our understanding of natural flow patterns in these creeks.

Key research questions: What are the natural flow regimes in the Merrowie, Merrimajeel and Muggabah Creek systems? How have flows in these systems been modified by regulation? What are the recommended flow components to return to these flow systems?

5.2.4.2 Scope of the research to address knowledge gaps

This knowledge gap requires hydrological models to be developed for the distributary creek systems. It is a desk-top exercise that is unlikely to be as simple as it sounds. It would require collaboration with the NSW water agencies (Water NSW, NSW DoI Water) and possibly the MDBA.

5.3 VEGETATION DIVERSITY

The monitoring and evaluation of vegetation diversity is a core monitoring and evaluation activity.

The diversity, type and condition of riparian and wetland vegetation communities are strongly influenced by the frequency, duration and timing of inundation (Brock and Casanova 1997, Nilsson and Svedmark 2002). Flooding interacts with plant life-history processes such as dispersal, germination, recruitment, survival, growth, and reproduction. Although some native wetland species can thrive in permanently wetted habitats, flooding of previously dry habitats is a major stimulus to production of water plants and their associated biota (e.g. Briggs and Maher 1985)). Temporal changes in the cover and richness of key plant species in the Lachlan Selected Area will be measured in relation to the provision of Commonwealth environmental water, taking into account the effects of landscape context, historical flows and land use. These data will be used to evaluate the outcomes of Commonwealth environmental water for vegetation across the Lower Lachlan river system.

5.3.1 EVALUATION QUESTIONS

The monitoring of vegetation diversity in the Lachlan Selected Area will use Category 2 methods to address both basin scale and Selected Area evaluation questions (see also Table 4).

5.3.1.1 Basin Evaluation

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

- What did environmental water contribute to species diversity?
    - How did Commonwealth environmental water affect the presence, distribution and abundance of individual plant species?
- What did environmental water contribute to vegetation community diversity?
    - How did Commonwealth environmental water affect the composition and structure of particular vegetation communities?
    - How did Commonwealth environmental water affect the presence, distribution and abundance of particular vegetation communities?

5.3.1.2 Area Evaluation

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

- What did Commonwealth environmental water contribute to native riparian and wetland vegetation communities?
    - What did Commonwealth environmental water contribute to populations of long-lived organisms (measured through cover and recruitment of tree species)?
    - What did Commonwealth environmental water contribute to individual plant species across the Selected Area including changes to species presence, distribution and cover?
    - What did Commonwealth environmental water contribute to vegetation communities within the interim Australian National Aquatic Ecosystem (ANAE) vegetation types, including changes in species richness, composition, cover and structure?

5.3.2 MONITORING STRATEGY

Vegetation data will be collected from fixed locations across the lower Lachlan Selected Area in Spring and Autumn (before and after the watering season) using Category 3 methods (Figure 5-1). The sampling design captures different vegetation communities from different watering histories. Sites are selected that have different elevations within the wetland and / or river from submerged communities in the river or wetland bed through to emergent or littoral vegetation at the edges of aquatic ecosystems.

Detailed methods are outlined in the Standard Operating Procedure: Lachlan Selected Area Vegetation Diversity and Condition.

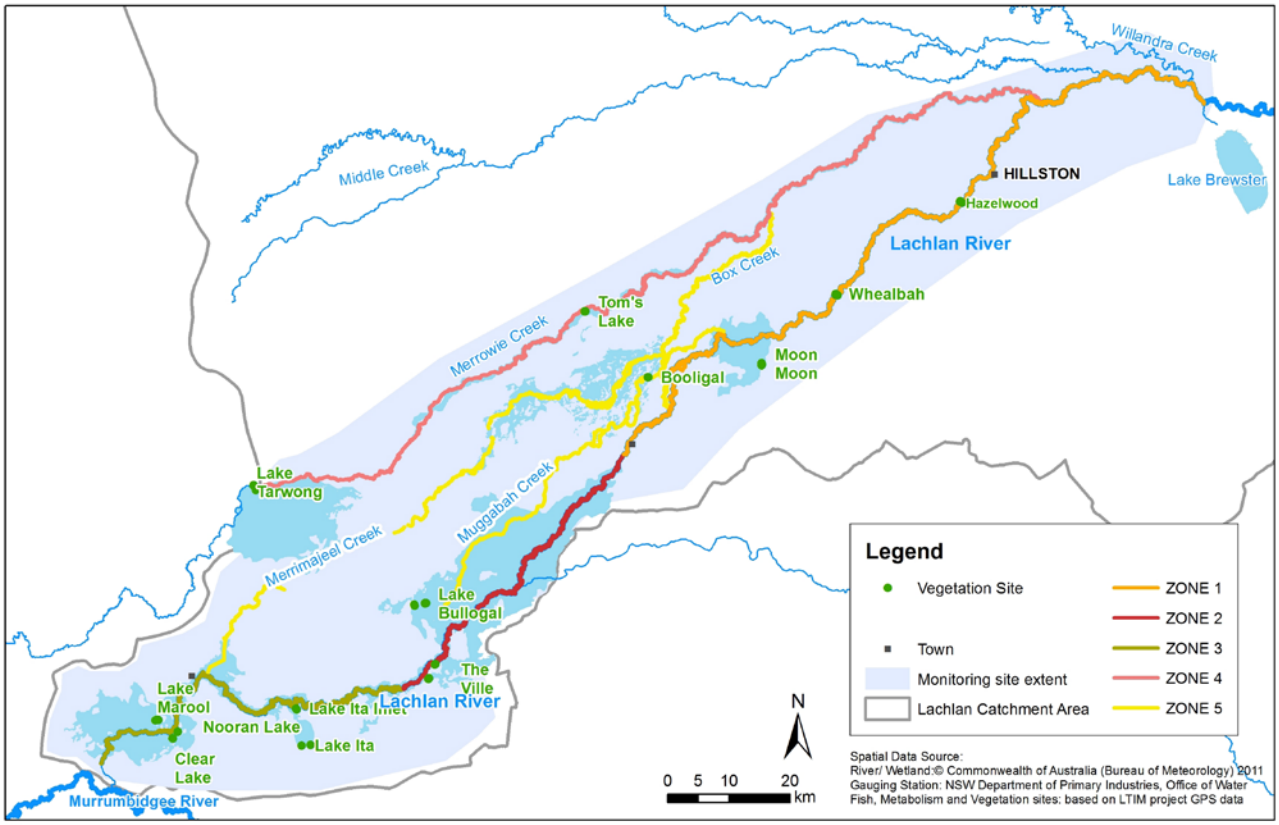

Figure 5-1. The Lower Lachlan river system showing the vegetation sites

5.3.3 EVALUATION

To address the Selected Area evaluation questions, the vegetation data from each year will be analysed both separately and in combination with the data collected over preceding years. Analysis will consider the prevailing weather patterns and the watering history of each site.

For each survey occasion, the measures of species richness, abundance, cover will be analysed with respect to the duration of watering using univariate and graphical methods to determine the contribution of Commonwealth environmental water to riparian and wetland species. Measures of community composition (species composition, functional types and nativeness) will similarly be analysed to determine the contribution of Commonwealth environmental water to vegetation communities. Multivariate analyses (using measures of dispersion from MDS plots) will be used to detect changes across multiple elements of the vegetation community in relation to the duration of watering.

The contributions to populations of long-lived organisms (the floodplain and riparian trees such as river red gum, black box and river cooba) means ensuring that there are new cohorts in the population. The recruitment of key riparian species (river red gum, black box, coolabah and river cooba) will be analysed with respect to the duration of watering using univariate and graphical methods to determine the contribution of Commonwealth environmental water to populations of long-lived organisms.

5.3.4 RESEARCH

Priority knowledge gaps relating to vegetation in the Lachlan Selected Area are:

5.3.4.1 Techniques to monitor reedbeds

The reed beds of the Great Cumbung Swamp have not been monitored as part of the LTIM Project for logistical and financial reasons. This means it has not been possible to evaluate the outcomes of the watering of the reed beds. Commonwealth environmental water has been provided to the reed beds multiple times in the past 5 years and it is expected that they will remain a priority into the future given recent changes in land ownership (the purchase of significant properties by The Nature Conservancy) and expected drought conditions over coming years. In addition, the Basin-wide environmental watering strategy (MDBA 2014) specifies objectives for stands of common reed and cumbungi in the Great Cumbung Swamp and the inability to monitor them is a notable omission. It has therefore been recommended that non-standard methods be developed to monitor the condition of the central reed beds.

Key research question/s: What are the key indicators of condition for reed beds? What is an appropriate monitoring program for stands of common reed and cumbungi and their response to watering?

5.3.4.2 Establishing benchmarks for groundcover vegetation in the Lachlan

The establishment of explicit, measurable objectives for wetland vegetation is a challenge faced by environmental water managers, in part because of the temporal variability in wetland vegetation. This is particularly challenging in the Lachlan because of the extremes of wet and dry cycles experienced in the catchment. Specific objectives for vegetation are required to underpin the development of flow recommendations that include details on intended timing, duration and depth of inundation and how these elements are required for the vegetation outcomes being targeted. This needs the establishment of vegetation benchmarks for wetland and riparian vegetation which are set within the context of the prevailing weather conditions.

Key research question/s: What are appropriate benchmarks for groundcover riparian and wetland vegetation in the Lachlan Selected Area? What are achievable objectives for groundcover riparian and wetland vegetation and how do they translate into the details of watering actions (timing, during and depth of inundation)?

5.3.4.3 Scope of research to address priority knowledge gaps

5.3.4.3.1 Monitoring of reedbeds

Recent scientific development suggest that drones and remote sensing technologies offer considerable promise for monitoring reed beds and research from Europe would provide a useful starting point for the development of locally relevant methods (Poulin et al. 2010, Corti Meneses et al. 2017, Corti Meneses et al. 2018). Drones for monitoring vegetation were trialled as part of the 2016-17 Lachlan LTIM, but the design was opportunistic and not well or strategically targeted. This research would systematically compare field based approaches to assessing reed bed extent and condition (ranging from measures of stem density, stem height through to morphologic metrics of the stand) with remotely sensed methods (both drone and satellite imagery) to establish pertinent remotely sensed metrics for assessing reed bed extent and condition. The benefits of the research would be three-fold:

1. During the development of the monitoring approach, data would be collected that would facilitate the evaluation of the reed-bed response to watering during the MER Program, thus enhancing the evaluation provided for the Lachlan Selected Area
2. Methods would be developed that would underpin monitoring in subsequent programs
3. Methods would be transferable to other areas in which water is provided to support stands of reeds.

5.3.4.3.2 Establishing vegetation benchmarks

This research would bring together current research (from EWKR and PhD student Will Higgisson), historical data sets, seedbanks, extant vegetation data from LTIM and MER along with knowledge of watering requirements to inform the establishment of benchmarks and objectives. It would primarily be a data synthesis project, but is likely to involve some predictive modelling to establish benchmarks.

The research would contribute to MER Basin Vegetation Theme priority research project ‘Benchmarks for non-woody vegetation’ with area specific synthesis and analysis. It would also underpin the development of flow recommendations for the Lachlan Selected Area that include details on intended timing, duration and depth of inundation and how these elements are required for the vegetation outcomes being targeted. This could be incorporated into the existing ‘river run’ approach to annual hydrograph planning.

5.4 STREAM METABOLISM AND WATER QUALITY

The monitoring and evaluation of stream metabolism and water quality is a core monitoring and evaluation activity in the lower Lachlan and an optional activity in the mid Lachlan.

The energetic base of food chains in freshwater systems is provided either by primary production (the energy fixed by photosynthesis occurring in plants and algae) or by organic matter which enters the water from terrestrial sources (such as leaves, wood and organic carbon dissolved in the water). These processes can be measured through continuous monitoring of changes in the concentration of oxygen in the water (described as measurements of open channel stream metabolism). Stream metabolism can be divided into two components; net primary production (NPP) which estimates photosynthetic productivity based on oxygen produced, and ecosystem respiration (ER) which estimates decomposition based on oxygen consumed.

Water quality measurements can assess indicators that can be measures of stress to organisms (e.g. salinity, pH and oxygen, see Table 5) or variables that may be used to understand processes which may drive patterns in stream metabolism (e.g. nutrient concentrations). Management-relevant factors that can be assessed through measuring stream metabolism and water quality are indicated in Table 5 (based on Cook et al. 2015).

Table 5. Water quality measurements, their indicators and management-relevant assessment

MEASUREMENT	INDICATOR	MANAGEMENT-RELEVANT ASSESSMENT
Turbidity	Water clarity	Can reduce basal productivity
Conductivity	Salinity	High = salinity risk
pH	Water acidity	Low = black water events
Chlorophyll-a	Algal biomass	High = algal ‘blooms’
Dissolved Organic C	Dissolved carbon in water	High = black water events
Nitrogen	Nutrient status	Can explain variability in basal productivity
Phosphorus	Nutrient status	
Dissolved oxygen	Oxygen status	Low = black water events
	Net primary production (NPP)	Basal productivity/algal blooms
	Ecosystem respiration (ER)	Decomposition
Temperature	Temperature	Can explain variability in basal productivity and contributes to understanding fish breeding.

5.4.1 EVALUATION QUESTIONS

The monitoring of dissolved oxygen in the Lachlan Selected Area uses Category 1 methods to address Basin scale evaluation questions. Other water quality data are assessed in order to determine potential effects of environmental water in the Selected Area (e.g. mitigating or generating salinity pulses, blackwater events) and in order to determine underlying processes that may be contributing to patterns of NPP and ER (turbidity, nutrient concentrations, algal biomass, dissolved organic carbon and temperature).

5.4.1.1 Basin Evaluation

The Basin evaluation questions relevant to stream metabolism and water quality are:

1. What did Commonwealth environmental water contribute to patterns and rates of decomposition?
2. What did Commonwealth environmental water contribute to patterns and rates of primary production?
3. What did Commonwealth environmental water contribute to temperature regimes?
4. What did Commonwealth environmental water contribute to dissolved oxygen levels?

A further Basin evaluation question is defined in the foundation report (Grace 2018):

5. What did Commonwealth environmental water contribute to pH levels and to salinity and turbidity regimes?

The monitoring of dissolved oxygen in the Lachlan Selected Area uses Category 1 methods to address basin scale evaluation Questions 1, 2 and 4 above, with decomposition patterns and rates assessed as ER and primary production patterns and rates as GPP. Nutrient and turbidity data are used to determine underlying processes that may be contributing to patterns of NPP and ER. Other water quality data addresses Questions 3 and 5 to determine potential effects of environmental water (e.g. mitigating or generating salinity pulses, blackwater events).

5.4.1.2 Selected Area Evaluation:

Within the Selected Area, water quality and metabolism responses to different duration, timing and magnitude of environmental flows allow the assessment of a range of other evaluation questions that sit beneath the overall Basin-wide evaluation questions.

1. What did Commonwealth environmental water contribute to patterns and rates of decomposition in the Lachlan River?
    a. Can environmental water be used to mitigate the impacts of excessive decomposition (blackwater)?
    b. What factors increase the probability of a blackwater event arising from environmental water?
    c. Are there particular floodplain or in-channel features that are associated with changes in decomposition rates when they receive water?

2. What did Commonwealth environmental water contribute to patterns and rates of primary production in the Lachlan River?
    a. Can timing of environmental water be used to increase basal productivity responses?
        i. Can provision of autumn flows increase magnitude of productive responses to spring flows?
    b. How do productivity responses from environmental water differ from those from natural flow events?
    c. Are there characteristics of productivity responses from environmental water that increase the probability of seeing fish reproduction events?
    d. Is there evidence for nutrient limitation of primary productivity in the Lachlan River?
    e. Are there particular floodplain or in-channel features that are associated with changes in productivity rates when they receive water?

3. What did Commonwealth environmental water contribute to pH and dissolved oxygen levels and to salinity and turbidity regimes?
    a. Can environmental water be used to mitigate the impacts of salinity and low pH pulses?
    b. What factors increase the probability of; high salinity, low pH, low oxygen or high turbidity events arising from environmental water?

5.4.2 MONITORING STRATEGY

The evaluation of the stream metabolism and water quality outcomes uses a combination of river height data, water quality data and stream metabolism data (dissolved oxygen measurements modelled to calculate GPP and ER). Sampling occurs at four sites (Wallanthery, Whealbah, Cowl Cowl and Lanes Bridge, see Figure 5-2). The intention is to continue monitoring these four sites as part of the core monitoring and evaluation activities of the MER Program. Additional monitoring in the mid Lachlan and at sites near the Great Cumbung Swamp may be addressed on request from the CEWO (for the mid Lachlan see Figure 5-4, page 49)

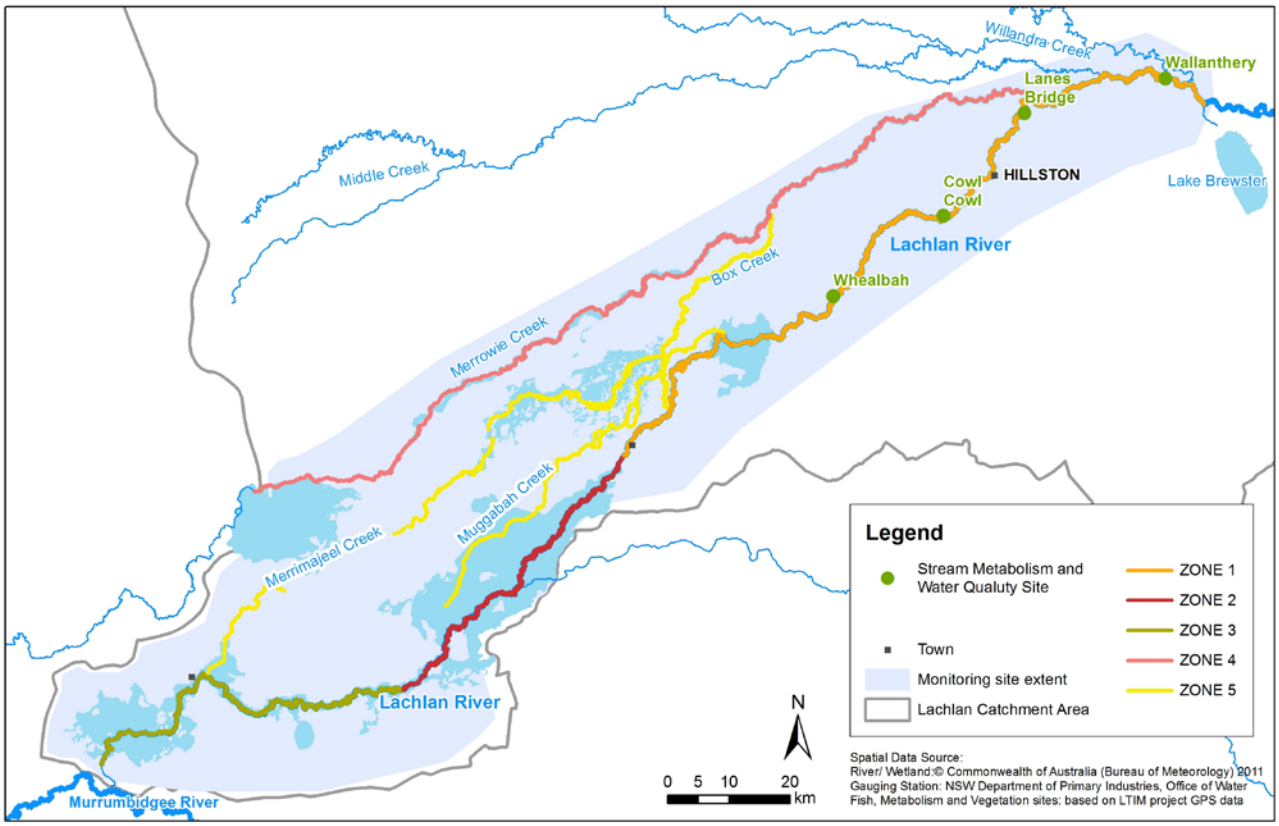

Figure 5-2. The Lower Lachlan river system showing the stream metabolism and water quality sites

5.4.2.1 Stream metabolism – Lower Lachlan

Stream metabolism is calculated based on continuous logging of dissolved oxygen and water temperature using MiniDOT sensors (Precision Measurement Engineering Inc., Vista, USA) logging at 10 min intervals. These optical loggers represent an improvement on the originally proposed galvanic probes (Ruhala et al. 2017).An oxygen logger was installed at each site in the middle of the water column. Annually, loggers are put in an O_2 saturated solution and then together in the stream for 1 hr to account for probe drift, and if required, linear corrections are applied prior to metabolism calculations. Photosynthetic active radiation (PAR) is measured in an adjacent unshaded location at 10-min intervals using photosynthetic irradiance loggers (Odyssey, Christchurch, New Zealand). Barometric pressure is logged with a Silva Atmospheric Data Centre Pro (Silva, Sollentuna, Sweden).

Detailed methods including modelling approaches are outlined in the Standard Operating Procedure: Lachlan Selected Area stream metabolism. This applies the most recent version of the BASE model (Grace et al. 2015 and associated updates to the associated R package).

5.4.2.2 Water quality

Water quality parameters (pH, turbidity, conductivity, chlorophyll-a, dissolved organic carbon (DOC), concentrations of nitrogen and phosphorus) are recorded in association with other sampling and are spot measurements taken approximately bimonthly. Conductivity, pH and turbidity were recorded using a handheld water quality meter. For chlorophyll, DOC, nitrogen and phosphorus, duplicate water samples are taken 2 m from the water's edge at 1 m depth. These were placed on ice and returned to University of Canberra for analysis for chlorophyll-a, DOC, total nitrogen, nitrate/ nitrite, total phosphorus, dissolved reactive phosphorus and ammonia.

It is proposed that the water quality monitoring be stratified in the following way:

1. That community members are engaged with and supplied with hand-held meters to enable weekly sampling of conductivity and pH, and sampling associated with events such as fish kills, natural spates, environmental flows and blackwater events (see Section 8.4).
2. That sampling of chlorophyll, DOC, turbidity and nutrients continues on a bi-monthly basis.

5.4.2.3 Stream metabolism and water quality in the mid Lachlan - options

Stream metabolism has been monitored in the mid Lachlan during 2018-19 under short term intervention monitoring (STIM) funding. This was undertaken in association with larval and adult fish monitoring with loggers temporarily installed at four sites (Figure 5-4, page 49). Continuing this monitoring could be conducted on demand (contingency monitoring or additional STIM) and would allow the assessment of the following:

- Relationships between environmental flows, productivity responses and fish responses in the mid-Lachlan.
- Longitudinal changes in metabolism responses to environmental flows moving along the Lachlan River.

In addition, two loggers have been installed in the lower Lachlan near Corrong during watering events in summer 2018-19 to monitor dissolved oxygen. This could be continued if support through citizen science (Communication and Engagement, section 8) could be obtained.

5.4.3 EVALUATION

Annual evaluation of watering actions addresses the three foundation questions as a cumulative understanding of the effects of environmental watering in that and previous years. Evaluation of particular watering actions characterises the watering action based on timing, magnitude and duration, and uses this to address the foundation questions and Selected Area evaluation questions.

Results for water quality are represented in two ways:

1. Correlations between flow and water quality parameters
2. As a narrative discussion of patterns through time

Results for stream metabolism are represented in two ways:

1. Correlations between water quality parameters and NPP, ER and NPP:ER
2. Correlations between flow and NPP, ER and NPP:ER
3. As a narrative discussion of patterns through time in response to environmental flows.

5.4.4 RESEARCH

5.4.4.1 Knowledge gaps identified from LTIM and MER workshop

A number of knowledge gaps have been identified in previous LTIM reports. In the large part these are due to a lack of data on responses to environmental flows of particular duration, magnitude or timing, or against a particular hydrological history. These can be addressed through monitoring of future environmental flows which are delivered for other purposes. A workshop with the MER Lachlan Selected Area team identified a range of knowledge gaps that can be addressed through a focussed research program.

5.4.4.2 Priority knowledge gaps for the Lachlan Selected Area

- **Influences of multiple interacting drivers in determining productivity responses to environmental flows.** Variability in the nature and magnitude of stream metabolism responses can be interrogated in more detail through modelling the effects of potential confounding variables, based on the approach of Von Schiller et al. (2017). The outputs of this modelling would provide more guidance to water managers on which non-flow factors need to be taken into account when planning environmental flows.
- **Differences in productivity responses between natural flow events and environmental flows.** There is clear evidence that natural flow responses differ from environmental flows (Acuña et al. 2004, Aristi et al. 2014, Dyer et al. 2015, Dyer et al. 2016, Dyer et al. 2017, Dyer et al. 2018). More detailed analysis of natural flows could identify factors that need to be managed for in environmental flow management in order to achieve desired responses.

5.4.4.3 Scope of research to address priority knowledge gaps

A. **Influences of multiple interacting drivers in determining productivity responses to environmental flows.**
Type of investigation: desktop modelling of monitoring data.
Output: What non-flow factors need to be managed to maximise productivity responses.

B. **Differences in productivity responses between natural flow events and environmental flows.**
Type of investigation: Additional field sampling to characterise water quality of natural flow peaks.
Output: How can environmental flows be managed to better replicate natural flow events.

5.5 FISH COMMUNITY

The monitoring and evaluation of the fish community is a core monitoring and evaluation activity in the Lower Lachlan and an optional activity in the mid-Lachlan.

Flow plays an important role in the life-cycle of native fishes from larval through to adult life stages. Water may inundate habitat needed for reproduction, triggering a spawning response, create a boost in primary production that improves recruitment success, improve habitat condition through maintaining natural geomorphic processes or natural refugia during drought periods, or stimulate in-stream migration. Temporal changes in the abundance and diversity of native fishes in the lower Lachlan Selected Area will be monitored within a single zone over the 3 year period as part of the monitoring of basin indicators. These data will be used to evaluate the outcomes of Commonwealth environmental water for riverine fish in a single zone of the Selected Area.

5.5.1 EVALUATION QUESTIONS

The fish community monitoring implemented within the lower Lachlan Selected Area is designed to elucidate the role of environmental water in promoting fish population processes at the Basin scale (Category 1 method), with analyses undertaken elsewhere. Where possible, collected data will draw links between annual flow delivery targeting native fish outcomes in the Lachlan, although we note that the primary aim behind the design of this method is for Basin-scale application.

5.5.1.1 Basin Evaluation

It is noted that the evaluation questions defined in the Foundation Report (Stoffels et al. 2016) differ from those in the original LTIM M&E Plan. The questions in the Foundation Report are therefore provided as subsidiary questions to the original suite of questions.

Long term (five year) questions:

- What did Commonwealth environmental water contribute to native fish populations?
    - What did Commonwealth environmental water contribute to sustaining native fish populations?
- 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) questions:

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

5.5.1.2 Selected Area Evaluation:

Long-term (five-year) Selected Area questions:

- How does the fish community vary in the lower Lachlan Selected Area on an annual time step in relation to abundance, biomass and size? Does this link to sequential flow events and the hydrological regime?

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

- Do Commonwealth environmental water delivery events result in detectable changes in the abundance, biomass and size (length) of the fish community in the lower Lachlan Selected Area?

5.5.2 MONITORING STRATEGY

5.5.2.1 Core monitoring and evaluation

Long term changes in fish community abundance, biomass and size-structure will be monitored using field data collected annually (March) in Zone 1 as part of the Basin Evaluation Category 1 method (Hale et al. 2014, standard methods reference). Fish community data will be collected annually (March) from 10 pre-selected in-channel sites in the lower Lachlan Selected Area, from Wallanthery to Hillston (Figure 5-3).

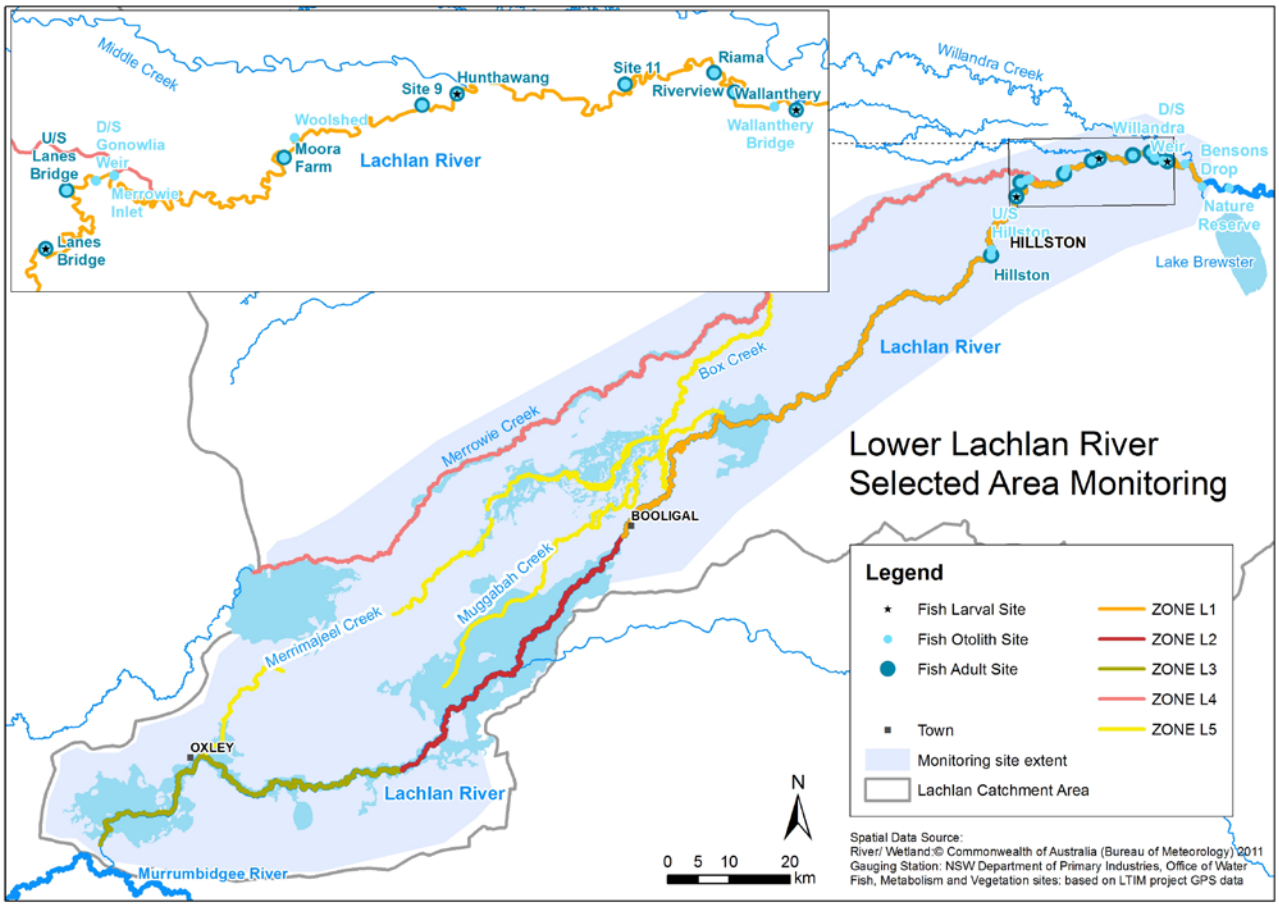

Figure 5-3. The Lower Lachlan river system showing the fish larval, otolith and fish adult sites.

A suite of passive and active gears including boat-electrofishing, unbaited bait traps, small and large fyke nets and baited opera house traps will be used. All captures (fish and other non-target taxa) will be identified to species level and released onsite, with the exception of the periodic species bony herring which will be retained for annual ageing (Hale et al. 2014). Individuals will be measured for length and weight, and where large catches of particular species occur, a sub-sample of individuals will be measured and examined for each gear type.

Detailed methods are outlined in the Standard Operating Procedure: Lachlan Selected Area riverine fish and Hale et al. (2014).

5.5.2.2 Optional monitoring and evaluation

Long term changes in fish community abundance, biomass and size-structure will be monitored using field data collected annually (March) at 10 sites on the mid-Lachlan between Forbes and Lake Brewster (Zone M1) using the same methods as those employed in the core monitoring (Figure 5-4).

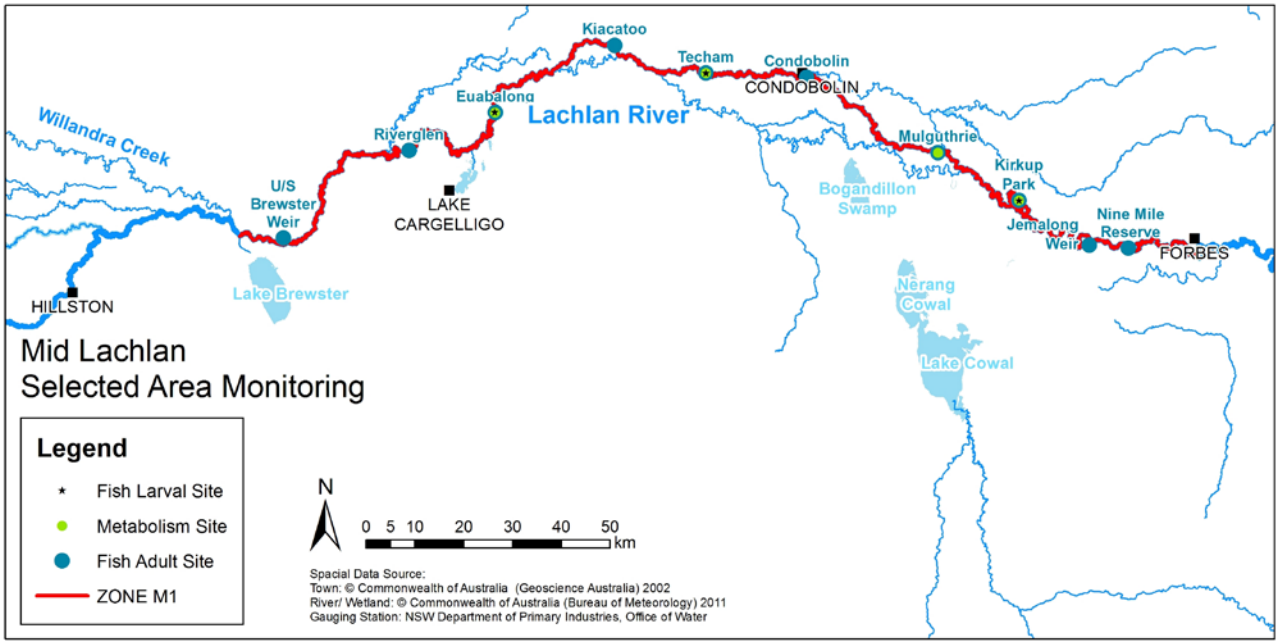

Figure 5-4. The Mid Lachlan river system showing the fish larval and fish adult sites as well new stream metabolism and water quality sites

5.5.3 EVALUATION

To determine differences between years, abundance and biomass data will be analysed separately using one-way fixed factor Permutational Multivariate Analysis of Variance (PERMANOVA; Anderson et al. 2008). Sustainable Rivers Audit (SRA) fish community condition indices (Expectedness, Nativeness, Recruitment) will also be calculated to quantify overall condition of the fish community assemblage (Robinson 2012).

5.5.4 RESEARCH

Knowledge gaps identified from LTIM and MER workshop

5.5.4.1 Priority knowledge gaps for the lower Lachlan Selected Area

Golden perch recruitment: There is a priority knowledge gap surrounding whether the golden perch currently classed as recruits in the lower Lachlan Selected Area are in fact natural recruits or are recently stocked individuals released by the NSW Government. Concerns have been raised about natural golden perch recruitment in the Lachlan River due to the absence of golden perch larvae from extensive multi-year sampling. In the case that limited natural recruitment is occurring (currently under investigation by University of Canberra PhD student Foyez Shams), further knowledge is required on how natural recruitment, rather than the incidence of young stocked fish, relates to Commonwealth environmental flow, which is not currently being addressed. **Key research question:** Do Commonwealth environmental water delivery events result in detectable changes in unstocked golden perch abundance?

Golden perch movement: Another priority knowledge gap relates to the link between Commonwealth environmental flow and golden perch movement in the lower Lachlan Selected Area. Golden perch typically swim long distances when triggered by flow events during spawning. If flows are currently insufficient to trigger movements or drown out barriers to movement in the system, they could be the underlying cause of poor natural golden perch spawning and recruitment in the system. Therefore there is a need to understand the nature of golden perch spawning-related movements and how they relate to Commonwealth environmental flow in the lower Lachlan Selected Area. **Key research question:** Do Commonwealth environmental water delivery events result in detectable changes in golden perch spawning-related movements?

5.5.4.2 Scope of research to address priority knowledge gaps

Golden perch recruitment: As is currently proposed, long term changes in golden perch recruitment will be assessed based on CPUE of new recruits or individuals with a length less than that of a one year old derived from data generated by this program or from scientific literature. In addition, to ascertain whether individuals originate from natural recruitment or stocking, fin clips from all golden perch considered to be recruits will be subjected to genetic marker analysis developed by Foyez Shams and also a similar program undertaken concurrently at the Basin scale (Fish Gen). The CPUE of individuals considered to be natural recruits from this work will be analysed with parametric univariate ANOVAs using year as the factor. This will provide a more accurate assessment of golden perch recruitment for the short- and long-term Selected Area questions.

Golden perch movement: Golden perch movement will be investigated by tagging 50 adults with acoustic tags (collected during one of the proposed March electrofishing sampling events) and monitoring these individuals at 30 acoustic receivers positioned along the Lachlan River. Receiver locations will encompass a river section that includes barriers to movement under low flow conditions, and the monitoring period will cover the golden perch spawning season. Movement (and potentially activity) of individuals will be tracked from receiver recordings and these will be analysed in relation to flow conditions (including Commonwealth environmental flow events) and co-varying light and temperature conditions. This will provide more information on how Commonwealth environmental water provision affects golden perch spawning and may lead to management actions tailored to enhance spawning-related outcomes for this species in the Lachlan River.

5.6 LARVAL FISH

The monitoring and evaluation of larval fish is a core monitoring and evaluation activity in the lower Lachlan and an optional activity in the mid Lachlan. A common goal of many environmental flow regimes is the maintenance and enhancement of the native fish community (King et al. 2010). This strategy is based on the premise that aspects of the flow regime are linked to key components of the life history of fish, including pre-spawning condition and maturation, movement cues, spawning cues and behaviour, and larval and juvenile survival (e.g. Junk et al. 1989, Humphries et al. 1999, King et al. 2003, Balcombe et al. 2006). Since the strength of recruitment, is largely driven by spawning success and growth and survival of young, understanding how the flow regime influences the early life history of fishes is critical to managing fish populations (King et al. 2010).

5.6.1 EVALUATION QUESTIONS

Monitoring of larval fish in the Lachlan Selected Area uses Category 1 methods to address basin scale evaluation questions. The data collected are also used to address Selected Area evaluation questions and is used to evaluate environmental watering actions with expected native fish outcomes in the Selected Area.

5.6.1.1 Basin Evaluation

- **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?
  - 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 species diversity?

5.6.1.2 Selected Area Evaluation

Selected are evaluation of Commonwealth Environmental Water contribution to native fish larvae will made against short term (annual) and longer term (5 year) questions:

Action specific evaluation.

- **Short-term (one year) evaluation questions:**
  - What did Commonwealth environmental water contribute to native fish reproduction in the lower Lachlan River catchment?
  - What did Commonwealth environmental water contribute to native larval fish growth and survival in the lower Lachlan River catchment?

- **Long-term (five year) evaluation questions:**
  - What did Commonwealth environmental water contribute to native fish populations in the lower Lachlan River catchment?
  - What did Commonwealth environmental water contribute to native fish species diversity in the lower Lachlan River catchment?

As well as this, monitoring will also inform the success of specific watering actions within Zone 1 where native fish reproduction was an expected outcome.

5.6.2 MONITORING STRATEGY

5.6.2.1 Core monitoring and evaluation

Larval fish will be monitored in a single zone in the Selected Area (Figure 5-3, page 48) which is typified by being a higher gradient tributary zone with a larger proportion of native fish present than other zones in the Selected Area. Specifically, this monitoring regime aims to detect the contribution of Commonwealth Environmental Water to enhancing native fish spawning and recruitment each zone (where reasonable populations of the target native species are already present).

Sampling will be undertaken at three riverine sites across five fortnightly sampling trips spanning September – December each year. The timing of sampling will bet targeted around watering actions with expected outcomes for native fish spawning, with considerations for seasonal requirements of target species. The target species include representative from each of the three representative guilds:

- Equilibrium: Murray cod (*Maccullochella peeli*) and freshwater catfish (*Tandanus tandanus*)
- Periodic: Golden perch (*Macquaria ambigua*) and bony herring (*Nematalosa erebi*)
- Opportunistic: Australian smelt (*Retropinna semoni*) and flathead gudgeon (*Philypnodon grandiceps*).

Larval fish will be sampling in flowing habitats using larval drift nets and in slackwater habitats using light traps, both set overnight. Captured fish will be preserved, then transported back to the laboratory to be identified, counted and measured (length). Detailed methods are outlined in the Standard Operating Procedure: Lachlan Selected Area larval fish.

5.6.2.2 Optional monitoring and evaluation

Larval fish would be monitored in a single zone in the mid-Lachlan between Forbes and Lake Brewster (Zone M1) using the same methods as those employed in the core monitoring (Figure 5-4, page 49).

5.6.3 EVALUATION

Commonwealth Environmental watering actions will be evaluated at annual and cumulative time scales, set to both Selected Area evaluation questions, and specific water action objectives where expected outcomes included native fish reproduction. Evaluations will be made on an annual basis (to answer short term evaluation questions and watering action objectives) and again over a longer-term basis (to answer long term evaluation questions around populations and diversity). To determine differences between years, larval fish community will be analysed using one-way fixed factor Permutational Multivariate Analysis of Variance (PERMANOVA; Anderson et al. 2008).

5.6.4 RESEARCH

5.6.4.1 Priority knowledge gaps for the Lachlan Selected Area

Based on the first 5 years of monitoring, we have identified two priority knowledge gaps in relation to understanding the processes that drive ecological responses to flow for the Selected Area in terms of native fish reproduction

1) Link between stream productivity and growth in larval fish
2) The lack of spawning and recruitment of golden perch in Selected Area?

Key research questions:

1) *Is restricted movement, because of instream barriers, contributing to the lack of spawning and recruitment of golden perch in the lower Lachlan River Selected Area?*

During monitoring undertaken over the past five years, there has been no detection of natural golden perch spawning or recruitment in the Selected Area. This is despite a targeted flow being released in 2015 aimed at promoting a spawning response from golden perch. A potential contributing factor to this lack of spawning is barriers to movement of golden perch with the Selected Area. Golden perch are known to undertake spawning related movements in both upstream and downstream directions (Reynolds 1983, O'Connor et al. 2005, Koster et al. 2014, Koster et al. 2017). There are several large structures (weirs) which would act as barriers to movement of golden perch with the Selected Area. Understanding the movement requirements of adult golden perch during the spawning window and how they interact with instream barriers will further shed light on the reproductive requirements for this species within the Selected Area, and the lower Lachlan river as a whole.

5.6.4.2 Scope of research to address priority knowledge gaps (limited to 3 research projects unless small scale investigation)

1) *Is restricted movement, because of instream barriers, contributing to the lack of spawning and recruitment of golden perch in the lower Lachlan River Selected Area?*

An acoustic tracking study is proposed to determine if barriers to movement of golden perch is contributing to the lack of spawning. Specifically, adult golden perch (n = 50) will be tagged with acoustic transmitters and their movements monitored in relation to the presence of instream barriers (e.g. weirs). Directionality and aggregations below or above barriers will provide valuable insight into golden perch reproductive behaviour in response to flow releases during the spawning window (September – January). Receivers will be donated as in kind from NSW DPI (major partner in this research project), so major costs will be acoustic tags, logger deployment and downloading. Ideally the study reach will be located where there is a high density of adult golden perch (informed by LTIM, STIM and NSW DPI data) and the presence of multiple weirs that likely act as barriers, and a reach likely to receive pulses of flow during the spawning season (September – January).

5.7 WATERBIRD BREEDING

The monitoring and evaluation of waterbird breeding is a contingency monitoring and evaluation activity.

The links between colonial waterbird breeding success and hydrological conditions have been well established (Kingsford 1995, Kingsford and Johnson 1998, Kingsford et al. 2008, Brandis 2010, Brandis et al. 2011a). Colony monitoring provides a critical link between water delivery and measurable outcomes. The collection of quantitative data on the breeding success of colonial waterbirds is essential for future understanding, real-time monitoring and predictions of conditions for management.

5.7.1 EVALUATION QUESTIONS

The monitoring of colonial waterbird breeding in the Lachlan Selected Area uses Category 2 methods to address Selected Area evaluation questions (See also Table 4).

5.7.1.1 Basin Evaluation

Basin scale evaluation questions.

- What did Commonwealth environmental water contribute to waterbird populations?
- What contribution did the Lachlan Selected Area make to Basin wide colonial waterbird breeding?

5.7.1.2 Selected Area Evaluation:

Long-term questions:

- How did Commonwealth environmental water contribute to colonial waterbird breeding the Lachlan Selected Area?
- What contribution did the Lachlan Selected Area make to Basin wide colonial waterbird breeding?

Short-term, watering action specific questions

- What did Commonwealth environmental water contribute to colonial waterbird breeding in the Lachlan Selected Area?
- How did Commonwealth environmental water contribute to colonial waterbird breeding the Lachlan Selected Area?
- What were the colonial waterbird responses to Commonwealth environmental watering?

5.7.2 MONITORING STRATEGY

Detailed methods are outlined in the Standard Operating Procedure: Lachlan Selected Area waterbird breeding.

Breeding surveys

Event based monitoring of colonial waterbird breeding will be undertaken at the Booligal Wetlands. A combination of aerial, drone and ground surveys will be used to identify the specific location of the colony or colonies. Aerial surveys will only be used if the timing corresponds with that of the Eastern Australia Aerial Survey of Waterbirds in October each year. Alternatively all surveys will be ground based either on foot or using small boats to get around the colonies. Ground surveys will be used, determine nesting vegetation type, waterbird species breeding and diversity, total number of nests and the stages of nesting. Drone imagery will be used to map colony boundaries, map and count nest numbers.

For the duration of breeding by Straw-necked ibis, Glossy ibis, Australian White ibis, or Royal Spoonbills a subset of marked nests will be visited fortnightly to measure reproductive success for these species. These species typically nest in colonies within the channelized lignum. These species have been shown to be sensitive to changes in water levels (Brandis et al. 2011a), therefore regular monitoring at each stage of chick development (fortnightly visits) is crucial for assessing the contribution of Commonwealth Water contributed to waterbird breeding.

Monitoring will occur every two weeks to obtain a measure of overall breeding success. Surveys will be undertaken by canoe. Surveys of lignum nesting species (Ibis, Spoonbills) will continue fortnightly until chicks have fledged and it is no longer possible to associate chicks with specific nests (Brandis et al. 2011a). A total of six colony surveys will be conducted.

To minimise disturbance to the colony all ground surveys of the colonies will be limited to two periods, either in early morning (6-11 am) or late afternoon (3-8 pm) to avoid causing heat stress to nesting birds and their offspring. This approach has worked effectively in previous studies of large waterbird colonies in the Lower Murrumbidgee which recorded high levels of nesting success (Brandis et al. 2011b). As straw-necked ibis are particularly sensitive to sudden changes in water level real-time information on the status of nesting birds and water levels is needed during breeding events to support adaptive management of environmental water (Brandis et al. 2011a, Brandis et al. 2011b).

The breeding period for straw-necked ibis, from laying to chicks leaving their nests and taking short flights (flapper stage), is around 45-53 days (Brandis et al. 2011a). If monitoring is scheduled monthly and the first survey is at egg stage, the second survey a month later will be at a development stage where chicks are off the nests and success rates for individual nests cannot be measured. To ensure that basin and Selected Area objectives can be evaluated, we plan to undertake ground surveys at fortnightly intervals, with the first survey taking place after eggs are laid, thus ensuring accurate estimates of the number of nests successfully fledged and mean number of chicks per nest for a subsample of nests. The three-month breeding period is assumed to be a large enough window to cover the period from birds pairing up, laying and incubating eggs, rearing chicks and cover the period of post-fledging dependency in the three ibis species (Brandis and Bino 2016).

Colony mapping

During the first colony survey, as close as possible to colony establishment, the boundary of the colony will be mapped using a differential GPS mounted on a boat to provide a framework for random sampling of a subset of nesting sites. Where a nesting site is defined as a group of nests on a clump of lignum separated from another clump of lignum by open water or non-flattened vegetation. A representative sub-set of nests will be monitored for the three month breeding period. All nests will be recorded with GPS and marked using coloured tape and given an unique identifier as per methods developed by Brandis et al. (2011a). Selected nests will be monitored throughout the breeding period from egg to fledgling development stages through repeat field surveys by trained observers.

Drone imagery will be captured during the early stages of nesting, preferably while adults are incubating eggs on nests. This allows for a more accurate count of nests. Drone imagery will be used to map the colony boundary (in addition to ground based mapping), count and map nest locations. This provides an accurate count of the total number of nests and colony extent (Lyons et al. 2018).

Hydrology and Water Quality

In addition to reproductive success data hydrological indicators relevant to waterbird breeding will be measured. These include measurement of water depth and replicate spot measurements of water quality (dissolved oxygen, turbidity, conductivity, and temperature) at each nesting site.

Reasons for Nest Desertion/Failure

Known predators at colonies are humans, feral pigs, dingos (wild dogs), foxes, cats, Australian raven, and raptors. Any evidence or observation of nest contents or adult bird predation by these or other species should be recorded. Also, mass nest desertion can occur if water levels drop suddenly around the nests or if the ground below the nest dries out (or if islands become connected to the main shore, for ground-nesting species), and these events and the likely triggers for desertion/nesting abandonment should be recorded.

Disease is known to cause significant morality in waterbird colonies, particularly avian botulism. Observations of disease will also be recorded and estimates of mortality.

Evaluation of results

Evaluation of watering actions will occur on an event-based schedule rather than annually. Colonial waterbird breeding does not occur annually and relies upon relatively large volumes of water often as a result of natural flooding. During the period 2015-2019 there were two breeding events occurring in the same year during the same flow event. If more than one colonial waterbird breeding event occurs during MER then they can also be evaluated cumulatively.

During a waterbird breeding event researchers communicate with water managers following/during each survey time to provide information on the colony and water conditions within the colony. This allows water managers to make real time decisions regarding water delivery to support colonial waterbird breeding.

5.7.3 RESEARCH

5.7.3.1 Knowledge gaps identified from LTIM and MER workshop

Waterbird research gap 1: Great Cumbung Swamp

It was identified at the Lachlan SA workshop that very little is known about the Great Cumbung Swamp. Historically it has been recorded as an important waterbird breeding site, however records of breeding have declined. It was proposed that a desktop study of the Great Cumbung could be made that collated historical data relating to waterbird breeding, vegetation types and distribution, land management practices and flow regimes. An analysis of these data could be made to look at changes over time and to better understand the ecological and hydrological functioning of the Great Cumbung Swamp. It is also an important area near the confluence of the Lachlan and Murrumbidgee Rivers, with inundation possible from the Murrumbidgee. It is also in close proximity to important breeding sites in the Lowbidgee.

As an end of system wetland, the Great Cumbung Swamp is likely to be receiving less water that natural flow regimes would have delivered. This change in flow regime is likely reflected in the decline in waterbird breeding at this site. An historical analysis of waterbird breeding, vegetation (nesting habitat) and flows, would provide information on the water requirements for successful colonial waterbird breeding at the Great Cumbung. These data will inform water and land managers and lead to the restoration of the Great Cumbung as a key waterbird site.

6 INTEGRATED RESEARCH

6.1 RESEARCH PROJECTS

While indicator specific research projects have been identified in Section 5, three research projects have been identified that cut across multiple indicators. These are described in the following sections.

6.1.1.1 Environmental water, groundwater and the influence on vegetation condition

Groundwater is thought to play a significant role in supporting riparian and wetland vegetation in the Lachlan River system, particularly within the Lower reaches of the river system. Expert elicitation and review as part of a modelling exercise by Barbour (2015) suggests that the presence of groundwater can reduce the decline in condition of river red gums during dry periods. Thus the presence of accessible groundwater extends the duration of drying that red gum woodlands can experience without a decline in condition. This relationship is well founded theoretically, but lacks empirical data that would enable the information to be operationalised in terms of environmental flow planning. Further, the relationship between flow in the river channel and groundwater replenishment is poorly understood. This means that it is not possible to deliver environmental water in such a way as to support the groundwater resource, which is in turn supporting riparian and wetland vegetation. While the vegetation sites used in the LTIM program were those that were thought to have minimal groundwater influence (see Section 3.5 of the standard methods, Hale et al 2014) , it has become evident throughout the LTIM program that groundwater is a possible contributor to tree condition throughout the lower Lachlan wetlands and riparian areas, particularly during periods of drought. Tree condition data collected as part of the LTIM Project, combined with an analysis of groundwater could begin to provide information that would better support environmental flow planning. There is opportunity to link this research with the Basin Scale research into tree condition to build stronger models of flow and tree condition. This could involve the provision of complementary data or the provision of staffing resources to the Basin Scale program and the use of the lower Lachlan Selected Area as a case study.

Research question/s: What is the relationship between groundwater depth and vegetation condition in the lower Lachlan catchment? Can environmental water be used to support groundwater levels that in turn support important riparian and wetland vegetation?

Scope of research:

Type of investigation: Combination of tree condition data with groundwater levels from bores across the catchment to build condition relationships between tree condition and groundwater. Analysis of groundwater data and flow data to build models of flow and groundwater replenishment for key sites within the catchment.
Output: What environmental flow regimes best support groundwater that in turn supports riparian and wetland vegetation.

Other links: The draft Long Term Watering Plan (LTWP) for the Lachlan Catchment[3] considers that '*the lower Lachlan Groundwater source plays an important role in supporting terrestrial and aquatic ecosystems, particularly during extended dry periods where groundwater can be critical for maintaining refuges'*. Objectives within the Long Term Watering Plan are directed at maintaining groundwater dependent vegetation communities and maintaining groundwater levels through the provision of watering regimes that recharge shallow groundwater aquifers. The strategic use of water to recharge groundwater or support groundwater resources during drought relies on understanding the relationships between tree condition and groundwater.

6.1.1.2 Water level and habitat inundation

Over the past 5 years, environmental water has been provided in the main channel of the Lachlan River to generate food resources or protect nesting habitats for fish. This has involved 1) the provision of a small fresh to inundate in-channel habitats and mobilise carbon and nutrients and 2) maintaining water levels to prevent nesting habitat from drying during critical spawning times. The water level management has, to date, been based on assumptions about the water levels required to achieve these outcomes. It is thought that variability in basal productivity responses to environmental flows may be associated with watering and the amount of water reaching key features in channel (e.g. benches), return flows from wetlands, and accumulations of organic matter in the channel (Acuña et al. 2004, Aristi et al. 2014). This can be determined through mapping of such features and assessing inundation for particular environmental flow events. The outputs of this modelling would provide more guidance to water managers on how environmental flows can be targeted to inundating particularly productive habitats in an optimal way. Mapping of in-channel habitats has been conducted by DPI Fisheries and it has been noted in numerous LTIM annual reports that it would be valuable to analyse existing in-channel habitat mapping and cross sectional data from the river to better inform the water level required to maintain native fish nesting habitats. There have not been sufficient resources available to undertake an interrogation of the existing reports and data sets to determine their value. It is possible that water level management may be more effectively targeted the inundation of key habitats.

Key research questions: What water level rises are required to inundate key habitats to generate a pulse in productivity? Are there particular floodplain or in-channel features that are associated with changes in productivity rates when they receive water? Where are key nesting habitats in relation to water level in key reaches of the river?

[3] https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Water/Water-for-the-environment/lachlan-long-term-water-plan-part-a-180583.pdf

Scope of research:

Type of investigation: Analysis of existing channel mapping data and comparison with existing monitoring (stream metabolism) data. Possibly augmented with remote sensing analysis of channel and floodplain features inundated by flows, with potential ground truthing.
Output: What channel and floodplain features can be targeted to increase productivity responses. Which sections of the river channel have the best in-channel habitat and are there sections of the river channel where improvements could be made.

6.1.1.3 Productivity and fish responses

In four of the five years monitoring so far (as well as on multiple occasions within a watering year), Commonwealth Environmental Water has been released to increase stream productivity to enhance food resources for native fish. Although the link between an increased discharge and increased stream productivity is reasonably well established, it is unclear whether basal productivity responses to environmental flows are associated with responses in higher vertebrate consumers, including larval fish. Fish growth information can be obtained from otoliths collected from larval fish with otolith increment widths used as a proxy for growth and matched to corresponding measurements of stream productivity. Modelling the relationships between fish and metabolism monitoring data would provide more guidance to water managers on how environmental flows can be targeted to achieving fish responses. Establishing and better understanding this link will able water managers to best target watering actions where stream productivity and, in turn, larval fish growth are objectives.

Key research questions: Is there a relationship between stream productivity and larval fish growth?

Scope of research:

Type of investigation: desktop modelling of monitoring data.
Output: How can environmental flows be managed to ensure basal productivity responses are transferred to fish responses.

This research would use MER Program data as well as data collected from the LTIM Project. Increment widths from otoliths could be obtained from larval samples retained by the University of Canberra from the LTIM Project and otoliths collected from larval fish collected during MER Program can be processed. Australian smelt would be used as the model fish species, as they have been shown to deposit daily otolith increments, and that those increments were reasonably well linked to length and condition (Tonkin et al. 2008a, Tonkin et al. 2008b). Australian smelt larvae are also present during productivity pulses which have generally been delivered in late September – December in the Lachlan River Selected Area. This project would build on currently collected data, including data collected as part of the 2018-19 LTIM variation on otolith processing and require a small investment in post processing and modelling.

6.2 PROPOSAL FOR A PORTFOLIO APPROACH TO THE RESEARCH

Eleven priority knowledge gaps were identified for the Lachlan Selected Area (see Sections 5 and 6 and summary in Table 7). These have been grouped thematically in Table 7 to illustrate the components that could be developed into a research program for a research fellow. These have also been ranked in order of priority based on the discussions at the workshop, review of the knowledge gaps that have made environmental watering decisions difficult in the past 5 years, and projected needs over the coming 3 years. It has also been informed by the development of the Basin-scale research program to minimise overlap and/or identify areas for collaboration.

Experience from EWKR and other programs is that research is most productive and effective when dedicated resources are directed at answering research questions. It is therefore proposed that a fractional post-doctoral appointment at the University of Canberra be made for 3 years, to address a portfolio of research questions. The recommended priority is the establishment of techniques to monitor the response of reed beds to the provision of environmental water. The research plan to address this needs is provided as Appendix D.

7 SUMMARY OF MONITORING, EVALUATION AND RESEARCH ACTIVITIES

7.1 MONITORING AND EVALUATION

Core monitoring and evaluation will be a continuation of the LTIM monitoring conducted in the lower Lachlan river system. Contingency monitoring and evaluation will be undertaken at the request of the CEWO and may be conducted throughout the mid and lower Lachlan.

Table 6 outlines the monitoring schedule, the location of monitoring activities for both core and contingency monitoring activities.

It is expected that during the three years of the monitoring program, waterbirds, mid-Lachlan stream metabolism and mid-Lachlan riverine fish community will be monitored once under contingency monitoring.

7.2 RESEARCH

A detailed research plan is included as Appendix D.

Table 6. Monitoring schedule for the Lachlan MER Program.

	ZONE	DATA CONTRIBUTES TO THE EVALUATION OF RESPONSES TO COMMONWEALTH ENVIRONMENTAL WATERING		MONITORING FREQUENCY	SITES	EXPECTED SCHEDULE
		SELECTED AREA	WHOLE OF BASIN SCALE			
CORE MONITORING AND EVALUATION ACTIVITIES						
Ecosystem type	All	✓	✓	Once only	All sites for other indicators	Establishment of ANAE type at all new sites expected to be completed Dec 2019
Riverine fish	L1	✓	✓	ANNUAL	Basin Evaluation: 10 fixed sites within Zone L1	Annual sampling between March and May
Larval fish	L1	✓	✓	ANNUAL	3 fixed riverine sites in Zone L1	Annual sampling 5 times during breeding season (September to February)
Stream metabolism	L1	✓	✓	CONTINUOUS REGULAR	Four fixed sites matched to riverine fish sampling sites in Zone L1	Continuous monitoring of dissolved oxygen and temperature. Approx. 6 weekly sampling of nutrients and water quality attributes.
Hydrology (River)	L1 Mid Lachlan Year 5	✓	✓	CONTINUOUS	Gauging sites	
Vegetation diversity and condition	L1-L5	✓		SPRING AND AUTUMN	12 fixed sites	
CONTINGENCY MONITORING AND EVALUATION ACTIVITIES						
Waterbird breeding	L1	✓		EVENT-BASED (on request from the CEWO)	One fixed site – likely Booligal wetland	Fortnightly surveys of bird breeding triggered by breeding events

Riverine fish	M1	✓	✓	ANNUAL	Basin Evaluation: 10 fixed sites within Zone M1	Annual sampling between March and May
Larval fish	M1	✓	✓	ANNUAL	3 fixed riverine sites in Zone M1	Annual sampling 5 times during breeding season (September to February)
Stream metabolism	M1	✓	✓	CONTINUOUS REGULAR	Four fixed sites matched to riverine fish sampling sites in Zone M1	Continuous monitoring of dissolved oxygen and temperature. Approx. 6 weekly sampling of nutrients and water quality attributes.

Table 7. Summary of research priorities in the Lachlan Selected Area.

RANK	PROJECT	JUSTIFICATION
Research informing the evaluation of vegetation responses – focus Lachlan Selected Area		
1	Project 1. Techniques to monitor reedbeds (see Section 5.3.4.1 and Appendix D)	The current lack of monitoring of reed beds in the Great Cumbung Swamp is a notable omission from the Lachlan LTIM Project and ongoing M & E Plan. The reed beds of the Great Cumbung Swamp are mentioned specifically within the Basin-wide environmental watering strategy and they have been targeted with environmental water over the past 5 years. It is expected that they will remain a priority into the future given recent changes in land ownership (the purchase of significant properties by The Nature Conservancy) and expected drought conditions. Monitoring them requires non-standard methods and this would be a valuable addition to monitoring approaches in the Basin. This research was not deemed a priority at the Basin Scale
	Project 2. Establishing benchmarks for groundcover vegetation in the Lachlan (see Section 5.3.4.2	The establishment of vegetation benchmarks will be addressed by the Basin Scale research program but there is potential for co-contribution from a research fellow to contribute to establishing benchmarks or using the Lachlan Selected Area as a case study.
	Project 3. Water level and habitat inundation (see Section 6.1.1.2	This is a small project that will draw together existing data sets and could form part of any of the research portfolios. For a small investment in synthesizing existing data, this project will provide valuation information to support in-channel watering actions.
	Project 4. Environmental water, groundwater and the influence on vegetation condition (see Section 6.1.1.1)	This is a scalable research project that could be scoped to link with the Basin Scale research program which is investigating remote sensing techniques for tree condition or interrogate existing data sets to determine if empirical relationships exist between tree condition in the Lachlan Selected Area and groundwater levels.
Research informing watering for productivity responses – focus Lachlan Selected Area		
2	Project 5. Productivity and fish responses (see Section 6.1.1.3)	This project will specifically be addressed by the Basin Scale food webs research project. It would provide an opportunity for collaboration and co-investment to expand the research and use the Lachlan Selected Area as a specific case study.
	Project 6. Influences of multiple interacting drivers in determining productivity responses to environmental flows (see Section 5.4.4.2)	This research is relevant at the Basin Scale and is likely to form future research projects at that scale. This research at the Selected Area scale could inform conceptual development within the food webs project and ongoing research needs in this area.
	Project 7. Differences in productivity responses between natural flow events and environmental flows (see Section 5.4.4.2)	This research is relevant at the Basin Scale and is likely to form future research projects at that scale. This research at the Selected Area scale could inform conceptual development within the food webs project and ongoing research needs in this area.
Research informing Golden perch recruitment in the Lachlan Selected Area		

RANK	PROJECT	JUSTIFICATION
3	Project 8. Golden perch recruitment (see Section 5.5.4.1)	Golden perch are present in the Lachlan river, but do not appear to have spawned naturally in the Lower Lachlan over the past 5 years. The on-going use of environmental water to support fish breeding requires a greater understanding of Golden perch spawning in the Selected Area These projects would combine to address some of the potential drivers. This research would naturally follow the research of Foyez Shams (UC PhD Student) who is investigating natural vs stocked recruitment of Golden perch in the Lachlan Selected Area. Foyez is likely to finish in late 2019 and his research would inform the development of a research program that would relate his identification of naturally recruited and stocked fish to environmental watering actions.
	Project 9. Golden perch movement and links to recruitment (see Section 5.5.4.1)	
Research informing the management of water in the Great Cumbung Swamp for birds		
4	Project 10. Waterbirds in the Great Cumbung Swamp (see Section 5.7.3.1)	The changing land tenure in the Great Cumbung Swamp combined with its likely role as refuge in a dry landscape means that understanding how the Swamp might be changing as a bird breeding site and how environmental water might support is important. This is a small research project and may form a future priority when it could be combined with data from vegetation (see project 1).
Research informing flow components to support distributary channels		
5	Project 11. Understanding the natural flow regime of distributary channels (see Section 5.2.4.1)	While an important knowledge gap, building hydrological models has limited research value. It could be progressed if there was broader need to understand distributary flows and thus attract co-investment with any Basin Scale hydrological research.

8 COMMUNICATION AND ENGAGEMENT

Additional information about communication and engagement activities in the Lachlan that are funded through the MER Program are included as Appendix E.

8.1 INTRODUCTION

There are a diversity of views and interest groups across the Murray-Darling Basin and the long-term success of environmental watering programs requires strong relationships with stakeholders, including local communities. The CEWO recognise the importance of effective communication and engagement in building relationships and achieving their goals for environmental watering across the basin. Thus communication and engagement activities are an integral part of the MER Program within Selected Areas.

Under the LTIM Project, the Lachlan Selected Area had resources dedicated to Communication and Engagement (C&E) that supported two components to communication and engagement activities. The first was internal project communication and was associated with the delivery of the monitoring and evaluation activities. This involved the project team, the CEWO, key water delivery stakeholders and other operational stakeholders. The second was external communication and engagement and involved stakeholder groups outside of the core operation of the LTIM Project including landholders, affected communities and the general public. Both are critical to the success of ongoing environmental watering programs.

External communication products in the Lachlan Selected Area LTIM C&E Theme focused on informing key stakeholders of watering events and monitoring activities, and then reporting back on LTIM Project observations and outcomes. External engagement activities were more opportunistic in nature, based on the C&E Theme Leaders existing communication and relationship networks across the Lachlan Catchment, and involved participation in, and support of, community events.

The objectives of the external LTIM C&E activities were to:

- Inform and provide opportunity for feedback (involve) from stakeholders to inform environmental water events at all phases (planning, implementation, MER). The underlying message is your local knowledge and history with the landscape is valued.
- Maintain ongoing access to long term monitoring sites through respectful landholder interactions and land access protocols, and by sharing results and information.
- Develop and consolidate a network of diverse stakeholder groups and local influencers with trust-based relationships; which allows for a productive exchange of local knowledge and discussion of how informs Basin-scale objectives.
- Highlight the value of LTIM for informing decision making when planning watering events (e.g. raise awareness around the processes for environmental water planning such as Technical Advisory Groups (TAGs) and use of expert opinion and observational data).
- Establish a reputation as a program which also supports local community events and priorities (i.e. invests in communities as well as their local environment where possible).

The ultimate goal of the external C&E activities under the LTIM Project was to influence attitudes towards use of environmental water in the Lachlan, leading to more collaborative environmental management or delivery, as well as opportunities to improve environmental water outcomes via complimentary land management.

This MER C&E Plan is a continuation of the LTIM C&E Plan. It builds on the foundations of the LTIM Project, incorporates key recommendations from a review of the Lachlan C&E activities and aligns with the broader C&E objectives of the CEWO.

8.2 OBJECTIVES FOR COMMUNICATION AND ENGAGEMENT WITHIN THE MER PROGRAM

There are two components to C&E activities in the Lachlan Selected Area. The first is operational project communication which relates to the activities associated with the delivery of the core monitoring and evaluation component of the MER Program. This involves the project team, the CEWO, key water delivery stakeholders and other operational stakeholders. The operational project communication activities are designed so that we can work with our primary stakeholders to achieve the objectives outlined in Table 8.

Table 8. Objectives for operational communication activities in the Lachlan Selected Area.

Objectives:
C1. Facilitate smooth and efficient implementation of the MER Plan.
C2. Facilitate engagement and support on-going relationships among core stakeholders.
C3. Disseminate learning and results from project activities.
C4. Contribute to on-going adaptive management associated with environmental watering.
C5. Foster opportunities for collaboration among core stakeholders to optimise the use of public funds for monitoring, evaluation and research in the Lachlan Selected Area and across the Basin.

The second is external communication and engagement which involves stakeholder groups outside of the delivery of the MER Plan and includes landholders, affected communities and the general public. The CEWO defines four broad objectives for external C&E activities around environmental water (Table 9). These have guided the development of external C&E activities within the Lachlan Selected Area and form the overarching objectives for our program.

Table 9. Objectives and outcomes for external communication and engagement activities. From a presentation provided by the CEWO Communication and Engagement Team.

Objectives: **O1. To increase awareness, understanding and value of water for the environment and its benefits** **O2. To promote water for the environment as being normal and necessary part of river operations and a health environment** **O3. To secure support, acceptance and advocacy for water for the environment** **O4. To increase credibility and trust in the management of water for the environment and CEWO**		
Awareness outcomes	**Attitudinal outcomes**	**Behavioural outcomes**
AW1. Awareness and understanding different types of water, that waterways have changed of time and they don't run naturally AW2. Awareness and understanding of water for the environment AW3. Awareness of benefits of water for the environment AW4. Understanding roles and responsibilities	AT1. Trust, reassurance and confidence in water for the environment and the CEWO AT2. Acceptance of water for the environment and its management AT3. Support and interest in water for the environment AT4. Value placed on waterway	B1. Collaboration/cooperation B2. Advocacy B3. Involved/active when needed B4. Rebuttal – calling out information that is incorrect.

This communication and engagement plan outlines the approach to both operational and external C&E in section 8.3 and 8.4 respectively.

8.3 OPERATIONAL PROJECT COMMUNICATIONS

8.3.1 PRIMARY STAKEHOLDERS

Our primary stakeholders are listed in Table 10 and are those who are:

- directly involved in the delivery of the MER Plan (the project team, Table 16, page 97)
- landholders who support ongoing access to MER sites
- involved in the delivery of environmental water within the Lachlan Selected Area
- involved in the delivery of the broader MER Program (Basin teams, other Selected Area teams, the CEWO MER Team)

Table 10. Primary stakeholders for the Lachlan Selected Area MER Program

Stakeholder Groups	
M & E Delivery	Project Team (See Table 16, page 97)
Operational Stakeholders	CEWO – Lachlan Delivery Team Lachlan environmental water manager Regional operations group with responsibility for the Lachlan River watering Members of the Lachlan Environmental Water Advisory Group (EWAG) Key members of other state agencies including NSW OEH Science Team, DoI Water and Water NSW
MER Program teams	Basin MER Team Other Selected Area MER Teams CEWO MER Program Team
Key Landholders	Landholders who provide access to monitoring sites.

8.3.2 OPERATIONAL COMMUNICATION ACTIVITIES

A range of activities have been identified that meet the aims of the operational project communications. These have been grouped into four streams of activities based on the stakeholder groups and are described in the following sections and outlined in Table 11.

8.3.2.1 Delivery

Internal communication within the project team comprises a mix of informal contact (conversations, e-mails) and formal activities (teleconferences, face to face meetings and workshops and published documentation). Informal communication within the project team will be key to building relationships within the team that will facilitate the smooth and efficient implementation of the MER Program. A series of internal project activities are scheduled throughout the life of the project to ensure that monitoring is conducted in a coordinated and efficient fashion, and that project team members are able to learn from each other's field experiences, data collection and evaluation. These activities are outlined in Table 11 and include contracted reporting requirements and includes the establishment and operation of the Lachlan Selected Area Working Group.

8.3.2.2 Operational stakeholders

Communication with the operational stakeholders is through a range of forums that provide opportunities for the exchange of information and intelligence that supports the implementation of the MER Program. Under the LTIM Project, the LTIM Reference Group proved difficult to establish and garner commitment from members. This was because a range of forums (such as the Lachlan EWAG and Technical Advisory Groups, TAGs) already existed that involved the same group of key actors meeting to exchange information and intelligence. While less time efficient, it became far more effective for the LTIM team to participate in these forums. Throughout the life of the MER Program, the MER team will continue to engage in these activities. Additional activities are also scheduled to enhance the collaboration and interaction between the MER team and Operational Stakeholders. These activities are outlined in Table 11 with additional information provided in Appendix E.

8.3.2.3 MER Program Teams

During the LTIM project, relationships have been built between Selected Area teams and the Basin Team that have facilitated learning and contributed to the successful delivery of the overall program. They have also contributed to cross program learning that has advanced the science of environmental flow management as evidenced by the recent submission of several publications. The maintenance of these relationships remains an important priority for the MER Program, as does the establishment of relationships with the new Basin MER Team. Thus a series of communication and engagement activities are scheduled throughout the life of the project to ensure that opportunities for learning are maximized and relationships are strong. Activities within this stream also include those required for the Basin Flow-MER Team and are outlined in Table 11 with additional information provided in Appendix E.

8.3.2.4 Key Landholders

Much of the monitoring activities undertaken within the Lachlan Selected Area is conducted on private property and the maintenance of relationships with these landholders is central to the ongoing success of the program. Communication and engagement with these key landholders involves a mix of informal (phone calls, e-mails and conversations) and formal activities (provision of data and reports) and these are detailed in Table 11 with additional information provided in Appendix E. Central to this is the establishment of landholder access protocols which are outlined in Section 8.6.

Table 11. Operational project communication activities for the Lachlan Selected Area.
The funding source for these is identified as either the Project Management (PM) budget or the Communication and Engagement (C&E) budget

ACTIVITY	OBJECTIVE	OBJECTIVE ADDRESSED [4]	WHO	LOCATION/ METHOD	RESPONSIBILITY	TIMING
ACTIVITY STREAM: DELIVERY						
Monthly project meetings (PM)	Regular contact between project leader and the CEWO contact. Project updates to • ensure project is tracking as expected • deal with any issues arising from the monitoring • communicate early observations from monitoring	C1, C2, C3, C4	CEWO contact and project leader/s	Face to Face in Canberra	Timing will be coordinated by the project leader	Monthly
Selected Area working group meetings (PM)	Regular contact between project partners and sub-contractor personnel to • establish and revise workplans • ensure project is tracking as expected • deal with any issues arising from the monitoring • communicate early observations from monitoring • coordinate activities	C1, C2, C3, C4	Theme leaders, CEWO Delivery Team,	Teleconference chaired by the project leader.	Timing will be coordinated by the project leader.	Two per year around key monitoring or reporting times or as required. See also **
Quarterly Progress Reports (PM)	Quarterly written progress reports provided to the CEWO – see Section 9.2	C1	Project leader	Written project status report	Project leader to coordinate	Last business day of September, December, March and June each year
Quarterly Outcomes Newsletter (PM)	Quarterly written outcomes report designed to communicate with a public audience – see Section 9.2	C3 O1 and O4	Project team	Written outcomes report	Project leader to coordinate	3rd business day following the end of September, December,

[4] . Refer to Table 8 and Table 9 for links to the objectives

ACTIVITY	OBJECTIVE	OBJECTIVE ADDRESSED [4]	WHO	LOCATION/ METHOD	RESPONSIBILITY	TIMING
						March and June each year
Annual Summary and Technical Report (PM)	An annual report (Summary and Technical) will be provided to the CEWO – see Section 9.1	C3 O1 and O4	Theme leaders	Written outcomes report	Coordinated by the project leader	Draft – Aug 30 Final – Oct 31 First report – 2020 Final report - 2022
ACTIVITY STREAM: OPERATIONAL STAKEHOLDERS						
Lachlan EWAG meetings (C&E)	Exchange of information and intelligence that supports the implementation of the MER program and environmental water delivery in the catchment	C1, C2, C3, C4 and C5 O1, O3 and O4	Project leader or representative	Face to Face EWAG meeting	Timing arranged by EWAG Secretariat	Quarterly
TAG meetings (C&E)	Technical advisory group meetings associated with specific watering actions.	C1, C2, C3, C4 and C5 O1, O3 and O4	Project leader or relevant theme representative	Teleconferences	Timing arranged by NSW OEH regional operations group	Assume 3 per year over duration of project
Operational MER Stakeholder Forum (C&E)	Annual meeting of the Selected Area Working Group members plus key operational stakeholders to: • share observations and outcomes from the monitoring • explore opportunities for collaboration • coordinate activities • ensure agencies are briefed and aware of activities as well as observations and outcomes from environmental watering	C1, C2, C3, C4 and C5 O1, O3 and O4	Theme leaders, CEWO Delivery Team, other key stakeholders	Face to Face meeting	Following an EWAG meeting	Annually
ACTIVITY STREAM: MER PROGRAM TEAMS						

ACTIVITY	OBJECTIVE	OBJECTIVE ADDRESSED [4]	WHO	LOCATION/ METHOD	RESPONSIBILITY	TIMING
Steering Committee Meetings (PM)	To provide regular contact between Project leaders across Selected Areas and the Basin Team	C1, C2, C3, C4 and C5	Project leader	Teleconference	Timing will be coordinated by the CEWO	2 per year
Annual forum (PM)	To • provide regular contact between Project team members across Selected Areas and the Basin Team • Share methods and learning across the teams • Discuss evaluation across Selected Areas	C1, C2, C3, C4 and C5	Four attendees from the project team	Canberra	Timing will be coordinated by the CEWO	July each year
Flow MER Stories (C&E)	Develop two stories per year that relates to Flow-MER communicating observations / findings from the Selected Area	O1, O2, O4	C&E Lead or Team member as relevant	Written report	Collaboration with the Basin MER C&E Team	Two per year
Content for calendar of events (C&E)	Upload calendar of monitoring, research, communication and engagement activities to inform the CEO MER Team and other MER teams	C1	Project leader	Key dates uploaded to calendar	Collaboration with the Basin MER C&E Team	As needed
An Aboriginal specific story relevant for NAIDOC week, Flow-MER and CEWO (C&E)	Develop an Aboriginal specific story that relates to Flow-MER and CEWO	O1, O2, O4	C&E Lead	Written Report	Collaboration with the Basin MER C&E Team	Around NAIDOC week or as otherwise negotiated with the Basin Flow MER Team
Thematic working groups meeting (PM)	To enable collaboration between Selected Area Teams and Basin teams	C1, C2, C3, C4 and C5	Theme leads	Workshops, assuming that the majority of meetings will be outside of Canberra	Collaboration with the Basin MER C&E Team	TBA, expect 1 meeting for each of 3 themes per year.

ACTIVITY	OBJECTIVE	OBJECTIVE ADDRESSED [4]	WHO	LOCATION/ METHOD	RESPONSIBILITY	TIMING
Practitioner forum (C&E)	To enable collaboration between Selected Area Teams and operational stakeholders across the MDB	C3, C4 and C5	Relevant team members	Assuming 1 in each of Adelaide, Albury and Moree.	Basin MER C&E Team	Annually
Collaboration meeting (C&E)	To foster the collaboration between Selected Area Teams. • provide regular contact between Project team members across Selected Areas and the Basin Team • Share methods and learning across the teams • Discuss evaluation across Selected Areas	C1, C2, C3, C4 and C5	Selected Area leads and other relevant team members	Workshops around the Selected Areas.	Selected Area Leads	Annually (expected February to enable 6 monthly face to face meetings of the SA leads)
ACTIVITY STREAM: KEY LANDHOLDERS						
Landholder Access Protocols (LAPs) (C&E)	Develop and comply with landholder access protocols	C1	Field teams; C&E staff	Written access protocol Field Team	Field teams	Duration of project
Landholder update (C&E)	Provide the landholders with tailored feedback following the field campaigns to • Close the loop on sampling information • Provide information to landholders tailored to their area of interest	C1, C2, C3 O1, O2, O4	Field teams; C&E staff	Written reports and data (including photographs)	C&E staff	Following field work and on public release of reports.

8.4 EXTERNAL STAKEHOLDER COMMUNICATION AND ENGAGEMENT

8.4.1 EXTERNAL STAKEHOLDER GROUPS

There are four main external stakeholder groups in the Lachlan Selected Area, these are:

- landholders and land managers.
- external water resources groups (e.g. Environmental Watering Advisory Group EWAG, Lachlan Customer Service Committee (Lachlan CSC)).
- participating communities (including indigenous communities).
- non-targeted general public.

8.4.2 EXTERNAL COMMUNICATION AND ENGAGEMENT STRATEGIES

Communication and engagement strategies have been tailored to address the objectives defined by the CEWO (Table 9) with a focus on Objectives 1 and 2.

O1: To increase awareness, understanding and value of water for the environment and its benefits: Requires evidence and case studies around events or series of events to illustrate benefits, recognising relevance of example to target audience. Benefits to be defined and best illustrated using examples of cooperative partnerships around recognised projects or asset, and if possible, changed for respective audiences to focus on local assets of relevance as well as relevance to Basin Scale Evaluation.

O2: To promote water for the environment as being a normal and necessary part of river operations and a healthy environment: 'Normalising water for the environment' has been a strategy within OEH C&E and adopted as part of MER. This includes regular Community Updates that articulate the role and objectives of environmental water delivery, and build upon watering events and outcomes over a watering year or season. It also includes community events or field days which demonstrate or discuss the local ecological values watering supports and highlight to community ways in which they can contribute to a shared vision. Given the high level objectives below (O3. and O4.) based around building trust and credibility for people and processes involved in environmental water delivery, and its validity, MER will continue to utilise and support the successful existing LTIM, OEH/ CEWO and affiliated local networks, while responding to new opportunities.

Q3. To secure support, acceptance and advocacy for water for the environment and O4. To increase credibility and trust in the management of water for the environment and CEWO are directed at securing support and increasing credibility and trust. As noted in Table 9, (page 69), they require first increased capacity (knowledge/skill building) and attitudinal change, and hence will occur to different extent across stakeholder groups after varying lengths of time. Relationships and or familiarity also be important in building advocacy, credibility and trust. Taking on an advocacy role, in particular in small farming communities, can be direct (spokesperson) or indirectly through supporting environmental management and monitoring projects (participating LTIM/MER landholder) through access, and word of mouth or email promotion. Trust of environmental management in the Lachlan begins with trust of environmental water managers.

8.4.2.1 Learning from the LTIM Project

Communication products in the Lachlan Selected Area LTIM C&E Theme focused on informing key stakeholders of commencing watering events and monitoring activities. Outcomes observed or key results from the LTIM Project were reported to key stakeholders. Communication products were tailored for stakeholder audiences, with a focus on operational information (hydrograph) for those who may be directly impacted by changing river levels (e.g. move pump, order on top of flow to improve pumping efficiency, or move stock if risk of bogging or loss of access track, land inundated).

A focus on monitoring activities and results was provided for those who expressed an interest in the ecology and adaptive management of environmental water based on LTIM and other research and monitoring programs. For example, articles on waterbird breeding and aquatic vegetation have appeared in Lower Lachlan landholder newsletters.

The LTIM Project was also mentioned in several local media articles, and directly engaged with over 30 recreational fishers and two clubs when enlisting the assistance of individual members of the public to collect fin clips and otoliths for a LTIM related PhD Project.

Engagement activities were more often opportunistic in nature, based on the C&E Theme Leaders existing communication and relationship networks across the Lachlan Catchment. The majority of events were by either by invitation (guest speaker at conference or meeting), display or activity as part of established event (Hillston Hook Line and Sinker and Condobolin Schools Enviro Day) or supported Indigenous involvement in environmental water management (Booberoi Creek and Hillston NAIDOC Day).

In combination, these activities have resulted in more collaborative environmental water management with the Booberoi Water Users Group, Lower Lachlan Landcare, Torriganny, Muggabah and Merrimajeel Trust, Ngiyampaa nation, mid-Lachlan irrigators, and the lower Lachlan Great Cumbung Swamp landholders via State and Commonwealth environmental water management liaison.

A number of activities have also been recently started in the Lachlan (by either OEH and supported by LTIM) in anticipation of being potentially incorporated into MER:

- Events and activities that bring stakeholders, community, scientists together to foster relationships and engagement and sharing of local knowledge and expertise, for example, Mt Boorithumble Weekend and Lower Lachlan Cumbung Tour.
- Indigenous engagement in environmental water management, for example, Booberoi Creek, Murrin Bridge CDP Program, EWAG representation and requests for water, and Ngiyampaa Case Study and Water Resource Plan.
- Citizen science where this delivers an engagement outcome or complements and contributes to monitoring and research. For example, WaterWatch and WaterBugBlitz group established at Murrin Bridge (Aboriginal Community Development Program (CDP) team) and Lake Cargelligo landholders and administered by Local Landcare Coordinator Initiative (LLCI).

- The production of user friendly products for target audiences that make monitoring and research observations and outcomes accessible and useful to stakeholders. The Lachlan MER C&E Team will look to build on the success of other Selected Area and CEWO products in terms of newsletter and social media strategy.

There is opportunity for the CEWO and OEH network collaboration to continue evolving from a grass roots focus, maturing into opportunities to deliver a more strategic MER messaging.

8.4.2.2 External stakeholder engagement delivery model

The model established by LTIM and delivery partners, OEH and CEWO from 2014 to present has been reviewed and subsequently refined for delivery under the MER Program. While retaining most elements of the previous LTIM model, there is a significant change in staffing arrangements and responsibilities.

The previous C&E Theme Leader, Dr Lenehan, Office of Environment and Heritage (OEH) will retain an advisory role (planning, collaboration, technical support, local networks etc), and will assist deliver activities in-kind where there are overlaps with OEH projects. However, primary responsibility for delivering external stakeholder communication and engagement activities will be contracted to Dr Adam Kerezsy, (Dr Fish Contracting, http://adamkerezsy.com/?page_id=1379 based at Lake Cargelligo). Dr Kerezsy has delivered engagement events, event-based fish monitoring demonstrations, landholder engagement, local media and ABC radio on behalf of OEH and LTIM over the past three years. While based in the mid Lachlan, Dr Kerezsy will be assisted by OEH and University of Canberra to transfer that successful model of engagement to the lower Lachlan via individual LTIM landholder relationships and Lower Lachlan Landcare network.

The University of Canberra team will remain integral as ambassadors of the project when in the field and communicating with participating landholders; as sources of real-time observations and input to decision making forums; and as 'experts' for field or demo days with local community and landholders. Their contribution to both internal and external communication demands has increased over the span of LTIM, and is particularly challenging when aiming to provide timely feedback on monitoring outcomes to landholders and community.

Activities, in particular Citizen Science programs, will be delivered where possible in partnership with Landcare groups or schools.

Stakeholders are given opportunities to become involved via:

- direct contact (email, phone call) with MER and delivery partner staff (OEH/ CEWO); all communication productions have an environmental water manager as a contact for further information.
- opportunities to engage during MER staff presence at established community events and demonstration days, such as fishing competitions, school education days, Booberoi monitoring, Landcare events etc.

- LTIM/ MER participating landholders and/or stakeholder representatives invited to observe and talk to researchers during monitoring, and get direct feedback on observations and opportunities to provide input.
- open invitation to community to participate in MER workshops via promotion networks (i.e. Citizen Science projects or engagement events funded to some extent by MER).
- contact with local contractor (Dr Kerezsy) and associated local networks and delivery partners.
- information sources such as media, reports, newsletters, webpages.
- social media (Twitter, Facebook).

8.4.3 EXTERNAL COMMUNICATION AND ENGAGEMENT ACTIVITIES

External communication and engagement activities have been assigned a priority as follows.

> Priority 1 activities – form the basis of our external engagement activities and are agreed at the commencement of the MER Program. These form a body of work that provides the foundation for the external engagement.
>
> Priority 2 activities – are optional activities which can be delivered on demand and essentially form a 'shopping list' of C&E activities that can be undertaken.

In establishing the external communication and engagement activities, it was recognised that it is important that MER C & E retain some flexibility to respond rapidly to opportunities or invitations as they arise. Responding to the MER target stakeholders needs is the first step in developing more sustainable partnerships based on a mutual benefit and understanding. These 'deeper' relationships yield greater awareness, attitudinal and behavioural change. On this basis an allocation has been made within the Priority 1 activities for indigenous engagement and for coordination and reporting which enable a small amount of ad-hoc activity to be performed (refer separate budget document).

As the MER objectives are broader than LTIM/MER activities with messaging focused on normalising water for the environment, we expect MER C&E Strategy to coordinate and leverage considerable in-kind from OEH and CEWO communications and engagement activities.

Activities are divided into four activity streams (Table 12):

- Communication products
- Community events
- Media
- Citizen Science

Additional information is provided in Appendix E.

Table 12. External communication activities for the Lachlan Selected Area. These are defined as Priority 1 (1) or Priority 2 (2) activities.

ACTIVITY	DESCRIPTION	TARGET AUDIENCE	EXPECTED OUTCOME[5]	RESPONSIBILITY
ACTIVITY STREAM: COMMUNICATION PRODUCTS				
Community update (1)	OEH produces regular community updates around watering events and outcomes. There is opportunity in each update to outline MER activities and contributions to decision making.	All stakeholders: Update is distributed through a variety of 'email groups' including lower Lachlan Landcare landholders, EWAG, recreational fishers, Landcare, Lake Cowal Foundation, water user groups, Lachlan Valley Water, councils, NPWS and a wide variety of project steering groups (e.g. Lower Lachlan Feral Pig Steering Committee).	AW3, AW4, AT1 Demonstrate to those with a 'stake' in water management responsible planning and use of available water, and a commitment to open communication. Builds trust if maintain regular communication, and also demonstrates awareness of the needs of other water users. Communicates and builds familiarity around respective roles and responsibilities.	University of Canberra and OEH to facilitate incorporation into OEH document.
Displays at prominent local venues (1)	During LTIM via OEH, a number of prominent venues such as motels, cafes, tourism centres, and hotels in participating towns (Booligal, Hillston and Lake Cargelligo) hung prints of stunning images from environmental events, such as the 2016 floods straw-necked ibis breeding event, Lake Brewster pelicans. Objective would be to revisit those or new venues with new material, and also leave a 'Brochure' explaining the event and role of water for environment including planned water events. Drought is a sensitivity to promoting environmental values; however, it is worthwhile having discussion	Visitor centre and council staff and volunteers, participating communities, general community.	AW1, AW2, AW3, AW4, AT2 Normalising water for environment; promoting multiple benefits. Raising awareness and changing attitudes by creating intrinsic value from local natural environment (i.e. appreciation and respect for natural world). Providing a positive contribution to promoting local values.	C&E Theme Leader

[5] Links to Table 1

ACTIVITY	DESCRIPTION	TARGET AUDIENCE	EXPECTED OUTCOME[5]	RESPONSIBILITY
	with some venues (e.g. tourism) to maintain momentum.			
ACTIVITY STREAM: COMMUNITY EVENTS				
Condobolin Schools Enviro Day (2)	Annual event organised by Condobolin Landcare involving over 200 school students from the district (September 2019).	School students, staff and other presenters – opportunity for students to take 'something home' that raises awareness and provokes discussion.	AW1, AW2, AW3, AT2 Opportunity to tap into strong messaging about sustainable use of natural resources, and to promote the role of water for the environment to maintain ecosystem services.	C&E Theme Leader and OEH SEWO
Hillston Hook Line and Sinker (August 2019) or Lake Cargelligo Fisharama (1)	Annual event organised by local recreational fishing clubs. LTIM has attended HHLS with display and activities for past 4 years.	Hillston or Lake Cargelligo participating community and recreational fishers.	AW1, AW2, AW3, AW4, AT2, AT3 Opportunity to raise awareness around the Fish and Flows concept and highlight other guilds such as small bodied natives and floodplain specialists. Opportunity to present LTIM/MER observations or hypotheses to community.	C&E Theme Leader and OEH SEWO
Booberoi Creek Engagement Weekend (1)	OEH with assistance from CEWO and LTIM hosted a Booberoi Creek Engagement Weekend February 2019. The focus was fish monitoring, but there was demand to repeat the event on an annual basis and expand into aquatic vegetation and waterbirds. This is an opportunity to highlight MER stream metabolism, and larval and adult fish monitoring in the region, and further engage landholders in the management of their creek.	Booberoi Creek landholders and Ngiyampaa nation who have all been involved in delivery of CEWO and planned environmental water since November 2017 (5 events to date).	AW1, AW2, AW3, AW4, AT2, AT3, AT4 Build on the increased awareness of local landholders of the value of their creek beyond stock and domestic delivery, and their willingness to assist in monitoring and implementing watering events to maximise outcomes. Will move participants from awareness and attitude changes, which have occurred under LTIM, to active participation in planning, monitoring and evaluating environmental flow events. Increase commitment from landholders to change land use practices or manipulation of weirs to improve environmental outcomes (e.g.	C&E Theme Leader, CEWO and OEH

ACTIVITY	DESCRIPTION	TARGET AUDIENCE	EXPECTED OUTCOME[5]	RESPONSIBILITY
			remove boards from weirs to facilitate return flows to the Lachlan confluence).	
Murrin Bridge Wetland Pumping and Demonstration Site (1)	OEH propose to deliver water into a small oxbow lagoon on Murrin Bridge Aboriginal community near Lake Cargelligo. Opportunity to demonstrate LTIM vegetation monitoring techniques and participate in a cultural event.	Aboriginal community, Lake Cargelligo and Murrin Bridge community, local leaders and water managers.	AW1, AW2, AW3, AW4, AT2, AT3, AT4 Improve understanding of water for environment through active participation in a demonstration project.	C&E Theme Leader, OEH SEWO, CEWO
Lower Lachlan landholder and community demo day (2)	Propose to replicate the mid Lachlan model to Lower Lachlan-Great Cumbung landholders. Contract Dr Fish for fish sampling in key Booligal and Cumbung sites and invite landholders to attend; two locations. Also incorporate demonstration of any drone techniques developed for reed bed monitoring. Similar to Mt Boorithumble Booberoi Weekend and Lower Lachlan Tour.	All lower Lachlan landholders, council and interested parties.	AW1, AW2, AW3, AW4, AT2 Demonstrate the rationale of MER and watering events; improve exchange of information and perspectives; provide forum for developing collaborations.	C&E Theme Leader, OEH SEWO, CEWO
Demo or Schools Day with Local Land Services (2)	Liaise with Local Land Services officers Andrea Cashmere (Hillston) and Jasmine Wells (Condobolin) to either organise a local community demo day or identify opportunity to present MER at existing LLS events. Hilston has previously expressed interest in Lake Brewster – aim to organise community 'small wet bug' type tour for Olive Perchlet monitoring Brewster weir pool and ell-tailed catfish (threatened species day). Alternatively, fish and birds day with Condobolin Landcare and Warren Chad.	All participating towns and community, schools, Local Land Services and other government agencies, interested parties.	AW1, AW2, AW3, AW4, AT2 Demonstrate the rationale of MER and watering events; improve exchange of information and perspectives; provide forum for developing collaborations. Highlight local threatened species and key threats.	C&E Theme Leader, OEH SEWO,

ACTIVITY	DESCRIPTION	TARGET AUDIENCE	EXPECTED OUTCOME[5]	RESPONSIBILITY
ACTIVITY STREAM: MEDIA				
Twitter (1)	Staff in the current Lachlan LTIM program actively tweet about the LTIM work using hashtag #LTIM The Lachlan LTIM/OEH C&E Theme Leader has also supplied images directly to CEWO Twitter	Difficult to define as has not been analysed.	AW1, AW2, AW3, AT3 At most will raise awareness about the existence of the MER program and highlight local values. Twitter can be a powerful communication tool but often requires a point of tension or controversy, and hence is often not suitable for attitudinal and behavioural change.	LTIM/MER Team, C&E Theme Leader, OEH SEWO
Facebook (2)	LTIM supported several events and video productions which featured on community Facebook pages (e.g. Hillston Naidoc Week) and has links to community pages (Landcare, Lake Cowal Foundation, Hillston Hook Line and Sinker etc)	Interest groups such as recreational fishers, Landcare networks, environmental education centres, broader community	AW1, AW2, AW3, AT3 Raise profile of MER and water for environment; engage audience while providing support to their interest.	C&E Theme Leader, OEH SEWO
Websites and Promotion (1/2)[6]	The Lachlan MER Project will contribute to the CEWO website, social media platform and the Dept of Environment Youtube channel. Key images from field trips will be made available for social media and CEWO websites. LTIM and OEH has connections with local community digital platforms, such as Lower Lachlan Community Services website, Rex Express Regional Screens, The Corridor Project etc. In June 2019, the LTIM/MER project was invited to feature on Lower	Participating communities, regional communities in general.	AW1, AW2, AW3 Greater awareness of environmental water activities in participating communities.	OEH and University of Canberra to establish template or format; C&E Theme Leader to update and expand as opportunities arise.

[6] Note that this activity is almost boundless. Some can be done in association with existing reporting/communication activities whereas others will require investment of significant resources.

ACTIVITY	DESCRIPTION	TARGET AUDIENCE	EXPECTED OUTCOME[5]	RESPONSIBILITY
	Lachlan Community Services Lake Cargelligo website. Task is for C&E Theme Leader to go through LTIM catalogue of high quality digital media products and synthesis/organise into a reference package. This is a not insignificant task. Also contract Mal Carnegie Photographic Services to accompany MER field team and/or CEWO in Great Cumbung Swamp and obtain high quality digital products for promotion (Drone, video and stills).			
You Tube (2)	A significant amount of footage has been generated as part of the LTIM program and may be generated during MER. This material can be made available to the Dept of Environment Youtube channel	Interested groups but difficult to define as has not been analysed	AW1, AW2, AW3 Greater awareness of environmental water activities in participating communities.	OEH and University of Canberra to establish template or format; C&E Theme Leader to update and expand as opportunities arise.
Relevant or topical articles in local newspapers; potentially a series around an event or season. (1)	Four targeted articles per year for the Lake News, Ivanhoe and Hillston Spectator, Condobolin Argus, Forbes Advocate, Cowra Guardian. Suggested timing is to follow the Quarterly Outcomes Newsletter but should not preclude opportunistic articles following key monitoring / research activities.	Local participating communities.	AW1, AW2, AW3, AW4, AT2, AT3 Targeted articles with consistent and simple message: build around a theme to build familiarity.	C&E Theme Leader
ABC radio (2)	C&E Theme Leader has networks with radio; can explore opportunities to put story forward	Regional NSW and participating communities; landholders	AW1, AW2, AW3, AW4, AT2, AT3 Awareness raising and contribute to attitudinal change.	C&E Theme Leader
ACTIVITY STREAM: CITIZEN SCIENCE				

ACTIVITY	DESCRIPTION	TARGET AUDIENCE	EXPECTED OUTCOME[5]	RESPONSIBILITY
Collection of water quality data (1)	OEH has established a WaterWatch and WaterBugBlitz team at Murrin Bridge Aboriginal community and Lake Cargelligo. The group is administered by Lake Cargelligo Landcare, and Central West Local Land Services (LLS, Jasmine Wells) and Condobolin Landcare have expressed interest in forming a similar group. OEH will gauge interest from the Booligal to Hay community (schools, Landcare, landholders) at 19 June 2019 Lower Lachlan meeting to establish a lower Lachlan group.	Engaged landholders, community groups or schools who wish to contribute local observations and data to the MER program.	AW1, AW2, AW3, AW4, At1, AT2, AT3, B1, B3 Raise awareness around factors influencing water quality (e.g. land use) and improve MER and water managers understanding of what is 'normal' and where water for the environment can improve water quality outcomes. Requires active participation (behavioural) and provides a forum for community input into watering objectives and outcomes (exchange of ideas and more creative and collaborative solutions).	C&E Theme Leader and OEH SEWO (with potential links to Landcare and LLS)
WaterBugBlitz and BioBlitz (2)	Community Citizen Science Event with Cargelligo Wetlands and Lakes Council (Robinson Crusoe Island) and Murrin Bride CDP team for community event coordinated by Landcare. Opportunity for Dr Kerezsy to present his Lake Cargelligo nursery ground results and management implications etc. Support research into Lake Cargelligo values. If Lower Lachlan WaterWatch goes ahead, incorporate into project targeting Booligal school.	Lake Cargelligo and Booligal community	AW1, AW2, AW3, AW4, At1, AT2, AT3, B1, B3 Raise awareness of value of food chain and watering actions which target stream metabolism – further explains the Why behind water for the environment.	C&E Theme Leader

8.4.4 ABORIGINAL ENGAGEMENT

The broad objective for Aboriginal engagement at a basin scale is to: “Integrate Aboriginal culture throughout all engagement and communications activities by ensuring language, place names and cultural references (where agreed) are fundamental parts of our strategy and delivery. Ensure all intellectual property is protected, and agreements established where knowledge transfer occurs.” (MER Stakeholder Engagement and Communications Team Scoping Document).

OEH Senior Environmental Water Officer (SEWO, currently Dr Lenehan) is involved in the Community of Practice to support and improve Aboriginal engagement across the Murray-Darling Basin. OEH and LTIM also has existing partnerships with Aboriginal communities for planning, delivering and monitoring environmental water, and consistent representation on the Lachlan EWAG. LTIM supported Hillston NAIDOC Day in 2017 and the Murrin Bridge Aboriginal community wetland monitoring training.

OEH in-kind contribution will be to liaise with Bradley Moggridge (Aboriginal representative on the Basin Scale Stakeholder, Engagement and Communication Team) to review existing LTIM and OEH Aboriginal engagement projects to enhance outcomes for the project and inclusion of Aboriginal people.

In terms of Basin-scale objectives, LTIM and OEH has an established relationship with Wiradjuri language teachers and has begun the discussion around inclusion of Wiradjuri language into communication projects. The MER Program will also incorporate language, place names and cultural references from each nation in consultation with OEH and local aboriginal people. It is noted that the draft Ngiyampaa Water Resource Plan is available and will become a future reference for language use and place names.

Cultural site survey of Booberoi Creek and site identification training would be a priority engagement project building on current Aboriginal community involvement in delivering water and monitoring outcomes.

8.4.5 RISKS

There is a high risk associated with ‘outsourcing’ relationships and trust building to the MER team in that realised benefits become more associated with the monitoring team or individual rather than the project and the CEWO. This risk will be discussed and managed by confirming key messages, appropriate branding, and by involving Commonwealth staff in a key engagement events to build an organisational relationship with landholders.

8.4.6 REPORTING AND EVALUATING

An annual stakeholder communication and engagement report will be prepared that details the activities undertaken and evaluates the activities in relation to the expected outcomes. Case studies will be central to the evaluation and will demonstrate how high level objectives are being met by the MER C & E activities.

Highlights of the C & E activities will also be described within the quarterly reports.

8.5 COMMUNICATION AND ENGAGEMENT SUPPLEMENT A: OUTCOMES, KEY MESSAGES AND EXAMPLES

The intended outcomes from the external communication and engagement activities, and associated key messages and examples have been summarised in Table 13 for awareness raising, Table 14 for attitudinal change and Table 15 for behavioural change objectives.

Communication and engagement activities conducted as part of the MER in the Lachlan Selected Area are designed to assist the CEWO in meeting these broad objectives.

Table 13 Awareness raising objectives and key messages.

AWARENESS RAISING	BROAD OBJECTIVE	EXAMPLE	KEY MESSAGES
A1	Promote MER monitoring activities and outcomes so more people know about the project.	Larval catfish caught near Hillston and Condobolin during annual larval fish monitoring. Silver perch caught in mid-Lachlan.	The CEWO has made a substantial long-term investment and is committed to learning about the Lachlan, and adaptively managing their portfolio. MER informs evidence-based decision making. That is, to better understand the impacts and outcomes of e-water delivery to wetlands, the CEWH has established a Long Term Intervention Monitoring (LTIM) programme to monitor and evaluate the ecological responses to environmental watering across the Murray Darling Basin.
A2	Highlight local values, assets and functions from monitoring field activities; and any key lessons learnt or discoveries.	Murray Cod with healthy age cohort over 4 years in X reach. Unspecked hardyhead confirmed in Booberoi Creek adding to small-bodied native fish diversity and demonstrating value of wetland inundation.	The CEWO is increasing their knowledge of local values through monitoring and research - but is also seeking to incorporate local advice and priorities into planning.
A3	Explain how those local values, assets and functions contribute to Lachlan Catchment and Basin-scale priorities (e.g. Long Term Watering Plan and Basin Watering Strategy).	Lower Lachlan floodplain (e.g. Booligal Wetlands and Great Cumbung Swamp) provide roosting, foraging, and breeding opportunities for waterbirds and is connected to the LowerBidgee floodplain.	Interpreting patterns or trends in the natural word is made difficult by the number of complex interactions, and by the scale of observation and available data (i.e. local and regional; site-based outcomes and extrapolating to landscape scale). The CEWO has a responsibility to consider how Lachlan portfolio can contribute to Basin-scale outcomes.
A4	Emphasis how every watering event is another opportunity to evaluate and refine those objectives and watering requirements, and continue to build on that body of knowledge; and how important MER Program and researchers (who now have 5 years' experience in catchment) are for guiding that process.	Opportunity to develop a Case Study showing how LTIM improved the design of watering events e.g. how Fish and Flows (developed at Basin scale) is being implemented and informing Lachlan fish flows.	MER has retained the same personnel as LTIM who now have 5 years experience in the field at those sites. The Team is committed to assisting CEWO deliver an efficient and effective environmental watering program in the Lachlan.

AWARENESS RAISING	BROAD OBJECTIVE	EXAMPLE	KEY MESSAGES
A5	Awareness and understanding of the role of water for the environment in supporting a suite of species and processes, both in their local wetland or creek, and at the Lachlan Catchment scale.	• Vegetation condition is maintained, and plant species richness increases in wetlands that receive environmental water on a regular basis (Reed Bed as future Case Study). • Environmental water is critical for ensuring the success of colonial-nesting bird breeding events which require large areas to be inundated and for water levels to be maintained for specific periods of time (3 to 4 months) (Booligal Case Study). • Environmental water provides habitat for threatened and migratory waterbirds, especially shorebirds and waders. • Freshwater turtles are more abundant in permanent wetlands (e.g. Lake Cargelligo and Booberoi Creek wetlands).	The cross-disciplinary nature of the project, with fish, frog, turtle, vegetation, stream metabolism (water quality, primary production) with scientists, landholders and managers collaborating for a more efficient and cost-effective monitoring programme allows for improved understanding of whole-of-ecosystem processes. Where possible, CEWO will seek multiple benefits from watering (including multi-species or multi-sites as well as supporting community values).
A6	Awareness of benefits of water for the environment more broadly (i.e. beyond local benefits).	E.g. Environmental watering actions target selected wetlands, floodplain complexes and riverine reaches and achieve outcomes by maintaining, to the greatest extent possible, water regimes that mimic natural cues to trigger movement, breeding and enhance survival.	
A7	Understanding respective roles and responsibility in communicating and participating in managing natural resources.		Successful environmental water delivery relies on good communication, clear demarcation and understanding of respective roles and responsibilities, and collaboration. The CEWO and its delivery partner OEH have good working relationships with other key agencies, such as WaterNSW, DPI Fisheries and DOIW.

Table 14 Objectives associated with attitudinal change.

ATTITUDINAL OUTCOMES	BROAD OBJECTIVE	EXAMPLE
AT1	Build trust, reassurance and confidence in water for the environment and CEWO (i.e. we do know what we are doing). CEWO staff are known by name.	CEWO staff are known to participating communities and landholders. CEWO is committed to long-term collaborative relationships with communities and has retained the LTIM/MER University of Canberra Team who are familiar to landholders and vice versa, and who are developing a 'hands-on' understanding of the lower Lachlan and its challenges as well as opportunities. After more than 5 years of delivering water, the CEWO has matured in its understanding of operational considerations and has a strategic plan.
AT2	Acceptance that field observations and long-term monitoring, as well as event-based monitoring, inform event planning and review. However, knowledge gaps remain and hence community/individuals can contribute to ongoing learning.	Use Case Study to illustrate.
AT3	Local values highlighted and become a point of pride and custodianship.	Lake Brewster prints displayed in The Shed and Hillston Tourism Centre, and Lachlan Valley Motel. Lachlan Shire Council promoted Lake Brewster wetland plant success story on website.
AT4	Open to productive and respectful discussions around use of environmental water holdings under a range of conditions (e.g. providing drought refuge for waterbirds).	OEH invited to present on environmental water at Lower Lachlan Landholders/Landcare meeting (19 June 2019); Merrimajeel Creek proposal.

Table 15 Objectives associated with behavioural change.

BEHAVIOURAL OUTCOMES	BROAD OBJECTIVES FOR PARTICIPATING LANDHOLDERS AND COMMUNITIES
B1	Engage with MER researchers in the field and support ongoing access and use of information.
B2	Disseminate communication productions and provide constructive feedback.
B3	Participate in engagement events and contribute to monitoring projects and outcomes.
B4	Participate in Citizen Science monitoring programs (e.g. water quality).
B5	Contribute to planning and watering actions (real-time observations).
B6	Collaborate to enhance watering outcomes (e.g. complimentary land management, use of infrastructure).
B7	Articulate to local community their involvement in water for the environment, and any positive experience or outcomes.

8.6 COMMUNICATION AND ENGAGEMENT SUPPLEMENT B: PROTOCOLS

8.6.1 WORKING WITH PRIVATE LANDHOLDERS

The Land Access Protocol (LAP) or access arrangement includes details of when, where and how any member of the M&E Provider team will access land and how operations or monitoring activities will be conducted while on affected landholder property. No M&E Plan activities will be undertaken without having first negotiated a written LAP, which will be conducted face-to-face on a “one-on-one” basis by the communications team and M&E provider leader between 17 April and 30 June 2014. The LAP will be as comprehensive as required, and may also include privacy issues, no access locations and/ or periods, where on the land activities will be undertaken and how those areas will be accessed, nature of the activities undertaken, conditions and/or restrictions that must be observed (e.g. closing gates, dry weather only roads), dispute resolution, and how the arrangement may be changed in the future.

It is expected that the format of LAPs will be similar to those already in use with the LTIM Project.

9 REPORTING

This section focuses on the written reporting requirements of the project. Presentations which also provide a mechanism for reporting outcomes are addressed in Section 8.

We will comply with the contracted schedule of reporting activities. This includes annual and quarterly reporting.

9.1 ANNUAL REPORTING

At the end of each monitoring year, we will provide an annual Selected Area evaluation report consistent with the contracted requirements and the Operations Manual. The report will be in two parts: a Summary Report and a Technical Report.

Annual Summary Report: The summary report will be a short report written for a public audience as per contracted requirements. The focus of the report will be the outcomes of the evaluation which are relevant to environmental water and research outcomes may be used as 'highlights' where the findings have implications for the future management of water.

Annual Technical Report: The technical report will be a longer and more technical report suited to a technical and academic audience. It will comprise a set of chapters for each monitoring theme and will follow standard scientific publication format. Outcomes from the research will be presented as separate chapters and will also follow standard scientific publication format.

Draft reports will be provided on the 30th September and final reports by the 30th December each year. It is expected that the format of these reports will be most similar to the 2017-18 reporting (Dyer et al. 2018).

9.2 QUARTERLY REPORTING

At the end of each quarter, we will provide a progress report consistent with the contracted requirements and the Operations Manual. We will also provide a quarterly outcomes newsletter. Details of each report are as follows:

Quarterly Progress Report: The progress report will be provided on the last business day of each quarter (March, June, September and December) and will be designed to communicate:

- Progress against the MER Plan including core monitoring and research activities
- Projected requirements for contingency monitoring and research activities
- Upcoming monitoring and research activities, including opportunities for CEWO staff to participate
- Any issues that may impact the delivery of the MER Plan and measures to address the issues
- A summary of communication activities

It is expected that the format of these reports will be similar to the quarterly reports provided during the LTIM Project and an example report is provided at Appendix 2.

Quarterly Outcomes Newsletter: The quarterly outcomes newsletter will be provided on or before the 3rd business day ***following*** the end of each quarter. The timing of this report is set so that time series graphs can include the full quarter of data and thus decreases the requirement to rework figures. These newsletters will be designed to communicate with a public audience and will contain:

- A description of monitoring and research activities undertaken in the quarter
- Observations, findings and outcomes relevant to environmental watering
- Photos and visual aids relevant to demonstrating outcomes
- Highlights from communication and engagement activities including any key social media content, e.g. twitter, published by the MER team or in partnership with the CEWO.
- Case studies relevant to the monitoring and research activities

It is expected that the format of these reports will be similar to the quarterly observations reports which have been provided during the LTIM Project.

10 PROJECT MANAGEMENT

10.1 PROJECT GOVERNANCE

The project is being delivered by a team comprising staff from three Universities and four state agencies. The University of Canberra is the lead agency and is contracted by the Commonwealth Environmental Water Office to deliver the project. The University of Canberra will sub-contract project team members from partner organisations. To ensure that the project meets its obligations, governance structures have been developed to ensure clear definition of accountability and decision pathways Figure 10-1.

10.1.1 ACCOUNTABILITY: ROLES AND RESPONSIBILITIES

Project lead: The project is lead from the University of Canberra by Associate Professor Fiona Dyer. Fiona has administrative responsibility for the overall delivery of the project. She will coordinate the project team, manage the budget, provide the main point of contact with the CEWO representatives and ensure that the milestones are met. Fiona will be supported at the University of Canberra by Ben Broadhurst and a part time research assistant. Ben will deputise for Fiona at meetings as needed.

Project team: Monitoring and evaluation activities will be delivered by a project team which has been divided into themes. Each theme is led by a senior scientist (Figure 10-1).

Theme leaders: Theme leaders have responsibility to ensure that the field activities, data delivery and reporting for each theme are delivered on time, to budget and to an acceptable level of quality. They will manage the day to day operational activities associated with collecting data. They are also responsible for ensuring that health, safety and environmental risks are managed appropriately. Theme leaders will work with the project lead to provide an integrated evaluation of the environmental outcomes of Commonwealth environmental water.

Quality management: Theme based data management, data analysis and reporting will be conducted by the project team. Central management of data sets will be the responsibility of the data custodian and the quality of the deliverables will be assured through peer review by the Basin Team. Peer reviewers will report to the project lead via the CEWO and theme leaders will be responsible for ensuring that any issues are addressed.

10.1.2 ISSUE RESOLUTION

Ensuring best practice project management should help reduce the number and severity of issues that arise during implementation of the project, however, given that it isn't possible to plan for every eventuality, it is important to ensure that there are issue resolution processes in place, not just to ensure delivery but to sustain the collaborative relationships on which the project depends. The key steps in the Lachlan's issues resolution process involve facilitating communication between the affected parties to identify the cause of the issue, explore options for its resolution and seek agreement on a suite of actions to address the issue and ensure delivery of the affected outputs. Responsibility for resolving issues lies initially with the theme lead and ultimately with the project leader.

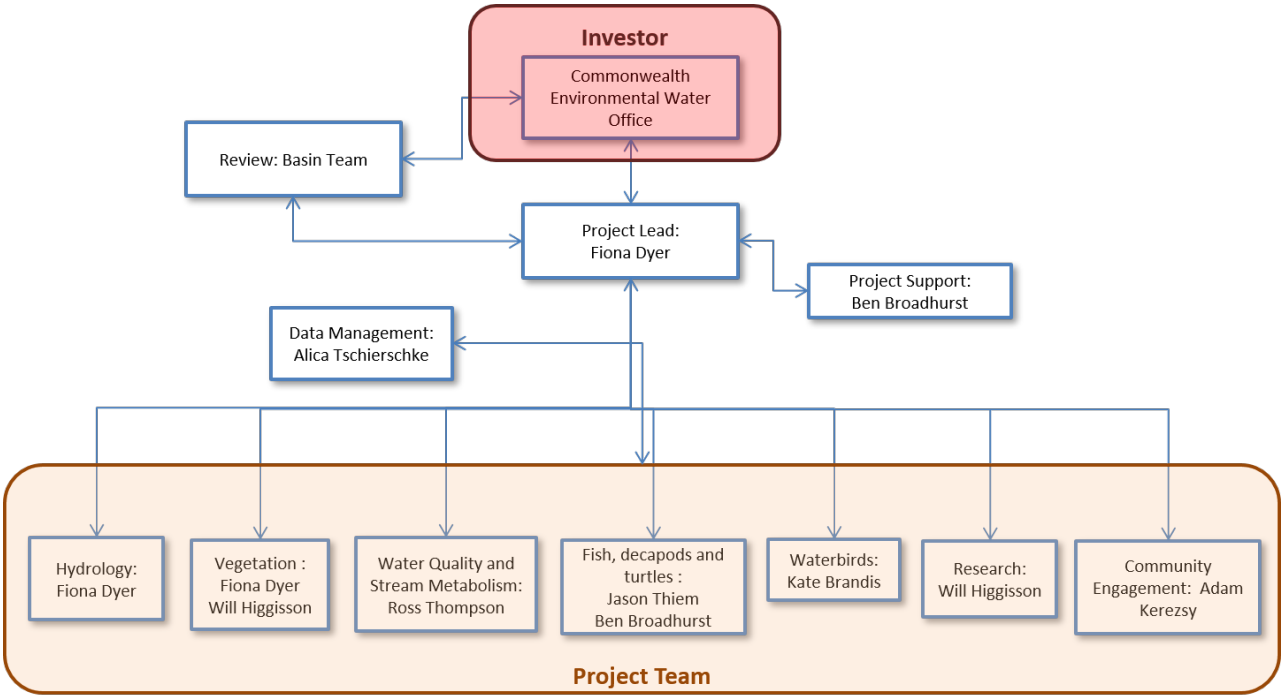

Figure 10-1. Project governance structure: Lachlan MER Program

10.2 PERSONNEL

Table 16. List of team members and their contribution to the Lachlan Monitoring Evaluation and Research Plan.

TEAM MEMBER	CONTRIBUTION
UNIVERSITY OF CANBERRA	
Assoc. Prof. Fiona Dyer	Project leader, hydrology and vegetation
Prof. Ross Thompson	Stream metabolism and water quality
Mr Ben Broadhurst	Project delivery and larval fish monitoring
Ms Alica Tschierschke	Data management, mapping, vegetation monitoring and project support
Dr Will Higgisson	Vegetation, research and project support
Mr Rhian Clear	Fish monitoring and project support
Mr Ugyen Lhendup	Fish monitoring and project support
NSW OFFICE OF ENVIRONMENT AND HERITAGE	
Dr Joanne Lenehan	Water delivery, engagement and communication
Dr Rachael Thomas	Inundation mapping and landscape vegetation metrics
NSW DEPARTMENT OF PRIMARY INDUSTRIES (FISHERIES)	
Dr Jason Thiem	Fish community monitoring;
Dr Daniel Wright	Fish community monitoring;
NSW DEPARTMENT OF INDUSTRY (WATER)	
Dr Patrick Driver	Vegetation and eco-hydrology
Ms Sharon Bowen	Vegetation monitoring
UNIVERSITY OF NSW	
Dr Kate Brandis	Waterbirds
CHARLES STURT UNIVERSITY	
Assoc. Prof. Skye Wassens	Frogs
Mr Damian Michael	Frogs
OTHERS	
Dr Adam Kerezsy	Community Engagement

10.3 RISK ASSESSMENT

A risk assessment for the project has been conducted to minimise risk to:

- People: the health and safety of individuals (and teams) undertaking monitoring activities.
- Environment: risks to the environment and aquatic ecosystems as a result of monitoring activities.
- Stakeholders: agencies involved in the MER Program (e.g. CEWO, OEH, etc.), land holders, research institutions, etc.
- Monitoring activities: disruption to monitoring schedule or results.
- Project objectives: encompass a broad category of risks, including risks that monitoring activities will not be able to be implemented, risks that evaluation activities will not be able to identify the contribution of Commonwealth environmental water, and risks to the ability of MER Providers to deliver high quality, timely Area Evaluations.

A standard method to assess risk has been used. This method considers the likelihood of the hazard occurring (refer to Table 17 for more detail), and the consequence of the hazard (refer to Table 18 for additional detail) to determine risk. Control measures are put in place to reduce the likelihood and/or consequence to produce a residual risk rating. These control measures are referred to as a hierarchy of controls, e.g.:

- Elimination: remove the hazard, e.g. get rid of a dangerous machine.
- Substitution: replace the hazard with a safer alternative, e.g. replace the machine with a safer one.
- Isolate: isolate the hazard from people, e.g. keep machine in a closed room and operate remotely.
- Engineering: control the hazard e.g. attach guards to the machine to protect users.
- Administration: change the way people work, e.g. train workers to operate machine safely.
- Personal protective equipment (PPE): wear PPE, e.g. gloves, goggles, lifejackets etc.

A summary risk register to people, environment, stakeholders, monitoring activities, and project objectives, are provided in Table 20 – Table 24, respectively. In addition, each activity proposed for the MER Program has an associated Safe Method Work Statement (SMWS) which is presented in detail in the Workplace Health and Safety (WHS) Plan. Each institution involved in the project has also provided Health and Safety Protocols for their designated field work. See the WHS plan (Appendix 3) for additional information.

Table 17. Categorisation of likelihood of risks

LIKELIHOOD	DESCRIPTION
Almost certain	Is expected to occur in most circumstances
Likely	Will probably occur
Possibly	Might occur at some time in the future
Unlikely	Not expected to occur
Rare	May occur under exceptional circumstances

Table 18. Categorisation of consequence

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

Table 19. Risk Matrix

	NEGLIGIBLE	MINOR	MODERATE	MAJOR	CRITICAL
ALMOST CERTAIN	Low	Medium	High	Severe	Severe
LIKELY	Low	Medium	Medium	High	Severe
POSSIBLE	Low	Low	Medium	High	Severe
UNLIKELY	Low	Low	Low	Medium	High
RARE	Low	Low	Low	Medium	High

Table 20. Risk register to people for common risks across activities

ACTIVITY	POTENTIAL HAZARD	INHERENT RISK			CONTROL MEASURES	RESIDUAL RISK		
		LIKELIHOOD	CONSEQUENCE	RISK		LIKELIHOOD	CONSEQUENCE	RISK
General	Snake bite	Possible	Moderate	Medium	Wear long pants or gaiters. Avoid a snake if it is in your path – do not try and move/scare it. Ensure first aid kit includes compression bandages.	Unlikely	Moderate	Low
General	Slips, trips, falls	Possible	Moderate	Medium	Wear appropriate footwear. Take care when walking on uneven surfaces. Take the safest route to a location.	Unlikely	Moderate	Low
General	Temperature extremes	Possible	Moderate	Medium	Wear appropriate PPE. Take rests and drink water in hot conditions. Observe others for signs of stress.	Unlikely	Moderate	Low
General	Car accidents while driving to remote location	Possible	Major	High	If driving on unsealed roads undertake 4WD training. Take regular breaks to ensure drivers stay alert. Be aware of wildlife.	Unlikely	Major	Medium
General	Falling branches	Possible	Moderate	Medium	Look up. Be aware of location of dead branches. Do not work under canopy in strong winds.	Unlikely	Moderate	Low
General	Bee / insect bite	Possible	Moderate	Medium	Take care and be observant. Avoid ant's nests and bee/wasp nests. Do not place hands under rocks, logs or into dense vegetation. First Aid kit on site. Insect repellent worn and on site. Wear PPE. If allergic bites/stings carry medication and alert others to your condition.	Unlikely	Moderate	Low
General	Injury causing open wounds	Possible	Moderate	Medium	Staff trained in first aid. Adequate and appropriate first aid equipment on site. All workers to be familiar with the location and contents of first aid kits. Inspect first aid kits regularly, and replace missing material.	Unlikely	Moderate	Low

ACTIVITY	POTENTIAL HAZARD	INHERENT RISK			CONTROL MEASURES	RESIDUAL RISK		
		LIKELIHOOD	CONSEQUENCE	RISK		LIKELIHOOD	CONSEQUENCE	RISK
General	Becoming lost / stranded	Possible	Minor	Low	Where practicable, fieldworkers should avoid working alone, especially if working in remote locations. Each employee working in remote areas should be able to navigate competently. Where appropriate, topographic maps, compass and/or GPS should be carried. Ensure all workers are supplied with appropriate communication and emergency signalling devices (e.g. radio, satphone or EPIRB) & are familiar with their use. Carry sufficient food, water and fuel. Maintain a communication plan. Check local road/weather conditions before trip. On extended or remote tasks, Travel itinerary must provide description of fieldworkers movements and contact details (e.g. Radio selcall or satphone no.)	Unlikely	Minor	Low
General	Infection with Ross River virus or Murray River encephalitis	Possible	Major	High	Avoid sampling at dawn and dusk. If sampling during this period can't be avoided, then appropriate PPE should be worn, e.g. long sleeves/pants, and insect repellent should be used.	Unlikely	Major	Moderate
Camping	Burns and scalds	Possible	Minor	Low	At least one member of each field team must have appropriate first aid training. Be aware of burn hazards when bush camping / cooking.	Unlikely	Minor	Low
Aquatic surveys	Drowning	Possible	Critical	Severe	Take care when walking along river banks and wear a life jacket near fast flowing water. When working in water take care not to exceed height of waders or waist. Do not work in areas of fast flowing water. Wear a life jacket when using boats.	Unlikely	Critical	High
Aquatic surveys	Unstable river banks	Possible	Moderate	Medium	Work in a safe stable area.	Unlikely	Moderate	Low

ACTIVITY	POTENTIAL HAZARD	INHERENT RISK			CONTROL MEASURES	RESIDUAL RISK		
		LIKELIHOOD	CONSEQUENCE	RISK		LIKELIHOOD	CONSEQUENCE	RISK
Aquatic surveys	Boat crash	Possible	Major	High	Boat operators must be familiar with the requirements of safe boating (see MSB Safe Boating Handbook) and adhere to licensing requirements. Obey navigation rules and drive to the conditions. Carry safety equipment specified by The Boating (Safety Equipment) Regulation NSW and the MSB Safe Boating Handbook. Before setting out, ensure that another person has been informed of where and how long the trip will be, particularly if operating in remote or hazardous areas, and boat and safety equipment has been checked for seaworthiness. Check there are no fuel leaks. Check local weather forecast and conditions have been taken into consideration and adequate maps, charts or navigational aids are consulted if in unfamiliar waters.	Unlikely	Major	Medium
Equipment	Use / moving heavy equipment e.g. lifting a boat on / off trailer	Possible	Minor	Low	Maintain good posture and body movements. Use correct lifting procedures.	Unlikely	Minor	Low

Table 21. Risk register to environment

ACTIVITY	POTENTIAL HAZARD	INHERENT RISK			CONTROL MEASURES	RESIDUAL RISK		
		LIKELI-HOOD	CONSEQUENCE	RISK		LIKELIHOOD	CONSEQUENCE	RISK
Captured and handling of biota during monitoring activities	Injury or mortality to biota	Possible	Major	High	Appropriate capture and handling procedures (following protocols approved by ethics committees and outlined in sampling permits)	Unlikely	Moderate	Low
Accessing monitoring sites	Destabilisation of banks, trampling / driving over vegetation causing damage.	Possible	Minor	Low	When driving stay on formed tracks where possible. When on foot treading carefully around vegetation where possible.	Unlikely	Minor	Low
Accessing monitoring sites	Damage to un-sealed roads during/following rain.	Possible	Moderate	Medium	Obeying road council enforced and landholder advised road closure. Checking access with landholder prior to entering unsealed road on private land. Staying on formed roads during moderate / heavy rainfall (>5 mm)	Unlikely	Moderate	Low
Accessing monitoring sites	Hitting wildlife with vehicle	Possible	Major	High	Drive to conditions outlined in relevant SWMS documents (Appendix 3). Avoid driving at dawn or dusk. Take care when driving during periods of low light.	Unlikely	Major	Medium
Accessing monitoring sites	Vehicles bringing in weeds / exotic seeds	Possible	Moderate	Medium	Before leaving home base check vehicle to dirt/weeds/seeds and wash down if necessary.	Unlikely	Moderate	Low
Re-fuelling of boats	Spillage of fuel into the environment causing localised pollution hazard	Possible	Minor	Low	Follow of SWMS for re-fuelling (Appendix 3). Re-fuelling to be conducted well away from waterways (>100 m).	Unlikely	Minor	Low
Waterbird monitoring	Observer disturbance causes abandonment of nests	Possible	Minor	Low	Follow appropriate survey procedures (following protocols approved by ethics committees and outlined in sampling permits)	Unlikely	Minor	Low

Table 22. Risk register to stakeholders

ACTIVITY	POTENTIAL HAZARD	INHERENT RISK			CONTROL MEASURES	RESIDUAL RISK		
		LIKELIHOOD	CONSEQUENCE	RISK		LIKELIHOOD	CONSEQUENCE	RISK
Stakeholder engagement	Stakeholders not informed / engaged in the project	Possible	Major	High	Actively engage with stakeholders as per the stakeholder engagement plan detailed in Section 7.2.	Unlikely	Major	Medium
Site access	Restricted access by landholders	Possible	Major	High	Actively engage with stakeholders as per the stakeholder engagement plan detailed in Section 7.2. Establish appropriate “back-up” sites, and shift to these if necessary.	Unlikely	Moderate	Low
Land management	Land management practises (including fire) affecting vegetation transects	Possible	Moderate	Medium	Agreement with landholders that the study sites are managed in a way that will not compromise the study design. The project team will activate response based monitoring in the event of fire to assess impact on indicators. See also stakeholder management plan in Section 7.2. Establish appropriate “back-up” sites, and shift to these if necessary.	Unlikely	Minor	Low

Table 23. Risk register to monitoring

ACTIVITY	POTENTIAL HAZARD	INHERENT RISK			CONTROL MEASURES	RESIDUAL RISK		
		LIKELIHOOD	CONSEQUENCE	RISK		LIKELIHOOD	CONSEQUENCE	RISK
Flooding	Interference with study design.	Possible	Moderate	Medium	The project team will activate response based monitoring of flood events to assess impact on indicators.	Unlikely	Moderate	Low
Ecological responses	Unexpected changes.	Possible	Minor	Low	The project team has constructed conceptual diagrams of controlling processes associated with indicators to minimise this.	Possible	Minor	Low
Indicators	Not detecting change.	Possible	Moderate	Medium	The project team has constructed conceptual diagrams of controlling processes associated with indicators to minimise this.	Possible	Minor	Low
Environmental events	Events such as blackwater or drought affecting results.	Possible	Moderate	Medium	The project team will activate response based monitoring of such events to quantify impact on monitoring program indicators.	Possible	Minor	Low
Invasive species	Invasive animals CRC carp control program influencing results.	Possible	Minor	Low	Based on the study design for riverine, wetland and larval fish indicators, the reduction in carp is unlikely to significantly influence results.	Unlikely	Minor	Low
Monitoring area	The large scale of the study area impacts on monitoring program being undertaken successfully	Possible	Moderate	Medium	The project team seeks to utilise local knowledge in the form of CMA partners in the Lachlan River catchment. The project team is well equipped to adequately plan for the large scale of the study area. Planning activities have included a site visit to provide the project team with on-ground perspective of the entirety of the study area.	Unlikely	Minor	Low

Table 24. Risk register to project objectives

ACTIVITY	POTENTIAL HAZARD	INHERENT RISK			CONTROL MEASURES	RESIDUAL RISK		
		LIKELIHOOD	CONSEQUENCE	RISK		LIKELIHOOD	CONSEQUENCE	RISK
Environmental watering	Inadequate water availability	Possible	Major	High	There is no way to minimise this risk. The project team will assume that adequate water will be available for release scenarios.	Possible	Major	High
Watering delivery	Delivery scenarios are not met	Possible	Moderate	Medium	Clear communication between the project team and water providers will provide the project team with flow release forecast scenarios. This clear communication will also aid in project planning to utilise available water delivery.	Unlikely	Minor	Low
Budget	Unexpected events requiring additional or changed monitoring regime	Possible	Moderate	Medium	The budget associated with each component of the MER Program includes costing for response based monitoring.	Unlikely	Moderate	Low
Budget	Reduction of in-kind support	Unlikely	Moderate	Low	The large number of institutions that comprise the project team ensures that it is somewhat robust to small and moderate reductions of in-kind support.	Unlikely	Minor	Low
Budget	Reduction in budget results in reduction in sampling intensity or the removal of some indicators from the evaluation process.	Possible	Moderate	Medium	The project team will revisit the conceptual models and assess which of the monitoring activities could potentially be altered to reduce costs. The potential use of value-adding components such as post-graduate projects may assist in absorbing budget reductions.	Possible	Minor	Medium
Project management	High workloads of project team members impacting on availability for monitoring and evaluation.	Possible	Moderate	Medium	The project team are experienced in managing workloads associated with large scale project. See section 7.1.1.	Unlikely	Minor	Low
Project management	Changes in project leadership impacts on monitoring, evaluation and project delivery.	Unlikely	Major	Medium	There are a number of experienced members of the project team that could absorb any change to the leadership structure.	Unlikely	Moderate	Low

ACTIVITY	POTENTIAL HAZARD	INHERENT RISK			CONTROL MEASURES	RESIDUAL RISK		
		LIKELIHOOD	CONSEQUENCE	RISK		LIKELIHOOD	CONSEQUENCE	RISK
Project management	Changes to institutions or staff impacts on monitoring, evaluation and project delivery.	Unlikely	Minor	Low	Structural and staff changes are not uncommon and the project team will have experience in how to manage this. The size and expertise of the project team renders it robust to such changes.	Unlikely	Minor	Low
Project management	Timeline pressures impacts on monitoring, evaluation and project delivery.	Possible	Moderate	Medium	The project team are experienced in managing workloads associated with this scale of project. See Section 7.1.1 for capabilities.	Unlikely	Minor	Low
Data access	Access to previous datasets is restricted, thus impacting on evaluation and project delivery.	Possible	Minor	Low	The project team comprises many institutions that already have datasets from the Lachlan. The professional networks of the project team place it in a sound position to formalise agreements with other dataset holders	Unlikely	Minor	Low
Data management	Data management and sharing procedures deteriorate across the project team impacting on evaluation and project delivery	Possible	Major	High	A centralised coordination based at a single institution will decrease risks associated with data management across institutions.	Unlikely	Major	Medium

10.3.1 ROLES AND RESPONSIBILITIES FOR RISK MANAGEMENT

In addition, the project team recognises that the MER Program has occupational health and safety risks associated with carrying out on-ground monitoring activities. SWMS have been developed for each of the field monitoring activities that address risks specifically related to fieldwork of their program and these are included in WHS Plan. The theme leaders are responsible for ensuring that all staff will comply with the SWMS. It is noted that the project team contains experienced researchers who have previously operated under the SWMS risk management framework for the activities to be undertaken (many of whom will have worked on the LTIM Project previously).

10.4 QUALITY PLAN

This quality assurance plan documents quality control and quality assurance procedures for activities at the Selected Area.

10.4.1 EQUIPMENT

Much of the equipment used to collect data for both Basin and Selected Area Evaluation requires ongoing maintenance and calibration. An outline of equipment to be used and details of maintenance and calibration required for each piece of equipment is provided in Table 25.

Table 25. Equipment to be used in the Lachlan MER Program including maintenance and calibration schedule

EQUIPMENT	USE	MAINTENANCE / CALIBRATION	FREQUENCY	WHO	LOG KEPT	INDICATOR
General Oceanics Mechanical Flow-meter	Monitor volume of water sampled by drift and tow nets	Maintenance as per manual	Monthly during sampling	University of Canberra	Yes	Fish (larval)
500 micron Drift nets	Capture larval fish in drift and by tow in required	Check for holes, patch if required	Prior to each sampling event	University of Canberra	Yes	Fish (larval)
Modified quatrefoil light-traps	Capture larval fish	Check for holes / cracks / gaps, patch is required	Prior to each sampling event	University of Canberra	Yes	Fish (larval)
Boat and backpack electrofishing equipment	Capture of fish	Serviced and assessed for safety and to ensure that gear is working efficiently	Prior to each sampling event	External specialist contractor; NSW DPI / University of Canberra	Yes	Fish (river)
Fine mesh fyke net	Capture small-bodied fish	Check for holes, patch if required	Prior to each sampling event	NSW DPI Fisheries	Yes	Fish (river)

EQUIPMENT	USE	MAINTENANCE / CALIBRATION	FREQUENCY	WHO	LOG KEPT	INDICATOR
Coarse mesh fyke net	Capture medium-large bodied fish	Check for holes, patch if required	Prior to each sampling event	NSW DPI Fisheries	Yes	Fish (river)
Turbidity meter	Spot turbidity readings for larval fish monitoring	Calibrated using standardised solutions	Prior to each sampling event	University of Canberra	Yes	Fish (larval)
PAR logger	Stream metabolism	Calibration in the field following methods outlined in standard operating procedure	During downloading (approximately quarterly)	University of Canberra	Yes	Stream metabolism
Dissolved oxygen sensor & logger	Measuring dissolved oxygen in the water	Cleaning of sensor membrane in the field during download	During downloading (approximately quarterly)	University of Canberra	Yes	Stream metabolism
Water Quality meter	Monitor temperature, pH, electrical conductivity, turbidity & dissolved oxygen.	Internally calibrated using known standardised solutions	Prior to each sampling event	University of Canberra	Yes	Water quality, Stream Metabolism

10.4.2 DATA COLLECTION (FIELD AND LABORATORY) – SAMPLES AND MEASURES

Relevant permits and ethics authorisation will be obtained prior to the commencement of data collection estimated to be June 2014 (see Table 26).

Table 26. Permit and ethics requirements for the Lachlan MER Program

INDICATOR	ETHICS AUTHORISATION REQUIRED? BY WHO?	PERMIT REQUIRED FOR SAMPLING? FROM WHO?	WHO IS RESPONSIBLE TO OBTAINING RELEVANT AUTHORISATIONS?
Fish (Larval)	Yes, University of Canberra Animal Ethics Committee	Yes, NSW DPI Fisheries Sampling permit	Ben Broadhurst – University of Canberra
Fish (River)	Yes, NSW DPI Ethics or University of Canberra Animal Ethics Committee	Yes, NSW DPI Fisheries Sampling permit	Jason Thiem & Danny Wright – NSW DPI Fisheries or Ben Broadhurst – University of Canberra
Vegetation	None	NSW Scientific License	Fiona Dyer – University of Canberra
Birds (Breeding and Diversity)	Yes, UNSW Animal Care and Ethics Committee (ACEC).	Yes, NPWS permit	Kate Brandis – University of New South Wales

Tortoises/Turtles	Yes, NSW DPI Ethics or University of Canberra Animal Ethics Committee	Yes, NSW DPI Fisheries Sampling permit	Jason Thiem & Danny Wright – NSW DPI Fisheries or Ben Broadhurst – University of Canberra

Specific data quality controls listed are in Table 27. Training is required for some techniques and details of staff who have undertaken training will be recorded in the training log (refer to section 10.4.4). Data will be recorded onto datasheets (waterproof paper) in the field and scanned in at the first available opportunity. A back-up of the scanned datasheets will be held at the lead institution (University of Canberra). Samples collected in the field will be preserved and processed in accordance with methods outlined below. Samples will be held for the duration of the MER Program at theme leaders' institutions.

Table 27. Specific data collection quality control considerations for each indicator

INDICATOR	QUALITY CONTROLS IN PLACE FOR DATA COLLECTION
Vegetation diversity and condition	• All observers must undergo training prior to undertaking monitoring surveys, including calibration against experienced observers (i.e. observers who have undertaken training in plant species identification and who have had previous experience undertaking vegetation diversity assessment) to ensure standardisation of measurements.
Fish (River & Larvae), Decapods and Tortoises	• NSW DPI electrofishing operators are certified under the NSW DPI Electrofishing Training schedule (Wooden et al. 2013) and operate under the requirements of the Australian Code of Electrofishing Practice. • University of Canberra electrofishing operators operate under the requirements of the Australian Code of Electrofishing Practice. • Providers must have relevant boat licenses. • Electrofishing equipment is serviced by the manufacturer (Smith-Root Pty Ltd) on an annual basis. • Fisheries and ethics permits are to be kept with providers while sampling. • All capture gear (fyke nets, drift nets and light traps) will be checked for holes as part of every field trip. Any net with a hole will be repaired or replaced. • Range checks in place to ensure that outlier or aberrant data is queried. • A select sample of voucher specimens of those species groups typically difficult to identify in the field (see Muschal et al. 2010, MDBA 2012) will be preserved for ID verification in the laboratory. • A sub-sample of 10% of otoliths will be read twice to validate the readings. • Larval fish will be preserved in 90% ethanol. Identification of larval fish to species will be undertaken by the same experienced processors (processors with previous experience with identification of larval fish) where possible. 10% of samples will be double processed (processed again by a different observer) to ensure quality control.
Waterbird breeding and Waterbird diversity	• All Waterbird assessments within a Selected Area, where possible, will be undertaken by the same experienced observers (i.e. observers who have undertaken field and aerial surveys of waterbirds previously) to maintain consistency over time. All observers must undergo training prior to undertaking monitoring surveys, which will include calibration against experienced observers to ensure standardisation of measurements. • Identification of difficult to see species will often differ between observers. To minimise the variance associated with different observers, a minimum of two staff are assigned to Waterbird assessments, particularly when aerial methods are used. Where there are significant differences in original observer scores, observers will discuss their rationale and where appropriate adjust scores to mutually agreed values. For aerial surveys this will be done immediately after flights to get agreement on species identifications.
Stream metabolism & Water quality	• All water quality samples will be collected, stored and analysed according to (American Public Health Association (APHA) 2014) protocols by a NATA accredited laboratory. • All laboratory analyses will be carried out to NATA standards including analysis of blanks. Samples will be held for a maximum time as indicated in the appropriate protocols in the SOP document. • All loggers will be calibrated as indicated in the protocols outlined in the SOP document
Hydrology (Channel & Wetland)	• Quality assurance and quality control protocols implemented by the hydrographic agencies responsible for the gauging stations will be relied up for flow data from existing gauging stations

INDICATOR	QUALITY CONTROLS IN PLACE FOR DATA COLLECTION
Waterbird breeding and Waterbird diversity	• Water level loggers records absolute pressure, which is later converted to water level readings using software which takes into account atmospheric pressure. To compensate for barometric pressure changes, a barometric reference will be used. The barometric reference used for the stream metabolism measurements will be used. • Water level sensors may drift during deployment. To check for sensor drift, a reference level is taken at the beginning and end of the deployment. • Protect the logger. The logger can be damaged by shock and must always be handled with care. The logger may lose its calibrated accuracy or be damaged if it is dropped. Proper packaging will be used to protect the logger during transporting or shipping. • Inspect the logger for biofouling. Biological growth on the face of the pressure sensor will throw off the pressure sensor's accuracy. Organisms that grow inside the sensor nose cone and on the sensor itself can interfere with the sensor's operation and eventually make the sensor unusable. The logger will be checked for biological growth when downloading data. • For wetlands, spot measurements of water depth during field visits and notes on the extent of inundation will be used to verify the NSW OEH mapping of inundation extent and wetland connection. • All Waterbird assessments within a Selected Area, where possible, should be undertaken by the same experienced observers to maintain consistency over time. All observers must undergo training prior to undertaking monitoring surveys, including calibration against experienced observers to ensure standardisation of measurements. • Identification of difficult to see species will often differ between observers. To minimise the variance associated with different observers, a minimum of two staff are assigned to Waterbird assessments, particularly when aerial methods are used. Where there are significant differences in original observer scores, observers will discuss their rationale and where appropriate adjust scores to mutually agreed values. For aerial surveys this should be done immediately after flights to get agreement on species identifications.

10.4.3 DOCUMENT MANAGEMENT

Overall document management and final document custodianship will lie with the lead organisation (University of Canberra). Theme leaders will be responsible for providing all updated documents to University of Canberra for back-up (Table 28). Reviewing of documents (to ensure quality and fit for audience targets being met) will take place internally within each theme leader's institution, then of the overall document by the theme leaders. It is assumed that the annual reports will be reviewed by the Basin MER team and

Table 28. Document management procedures for the Lachlan MER Program.

DOCUMENT TYPE	PREPARED BY	DETAILS OF REVIEW	REVIEWED BY
Progress/Status reports	Project lead -Fiona Dyer with input from theme leaders	None	
Quarterly reports	Project lead -Fiona Dyer with input from theme leaders	Internal review	**Theme leaders**
Annual reports	Project team, led by Fiona Dyer	Initially internal review will be undertaken by theme leaders prior to document being submitted for external review 1 month prior to submission to CEWO. The external review will then be due back to the project team 2 weeks after submission to reviewer to allow time for review to be addressed.	**Theme leaders (Internal review) & external review (see above to criteria in selecting external reviewer/s)**

10.4.4 TRAINING

A number of the methods to be used in Basin-scale evaluation have training requirements (e.g. field assessments of tree stand condition), so document evidence or include logs of training (Table 29).

Table 29. Training requirements for field assessments.

METHOD	TRAINING	STAFF WHO WILL HAVE COMPLETED TRAINING	TRAINING DUE
Boat & backpack electrofishing	Electrofishing principles and techniques – provided by US Fish and Game Department	All Boat and Backpack electrofishing operators (lead by Ben Broadhurst at University of Canberra and Ian Wooden at NSW DPI Fisheries)	End of February 2020
Boat operation	Boat licence	All staff operating power boats	31st August 2019

10.4.5 AUDITING

CEWO will be establishing whole-of-project audit procedures. Self-auditing will be conducted (led by University of Canberra - Fiona Dyer and Ben Broadhurst and implemented by theme leaders) annually to ensure that the quality plan specifications are being met.

Specifically:

- Standard operating methods are being adhered to.
- Data management is following prescribed methods.
- Document control procedures are in place.
- Training is updated and completed where necessary.
- Gear maintenance has been conducted and logged (where appropriate).

Self-audits will be undertaken in June each year. Following the audit a review of the quality plan will be undertaken and an update created. Amendments to the quality plan will be recorded in a document log (Table 30). Preparation of amendments will be undertaken by the project team and approved by the project leader and the CEWO.

Table 30. Log of amendments of the Lachlan MER Program quality plan

REGISTER OF AMENDMENTS					
Date of approved amendment	**Page**	**Version No.**	**Description of amendments**	**Prepared by**	Approved by

11 DATA MANAGEMENT

Data management for the MER Program is guided by the following principles:

- **Good governance:** Leadership and coordination is essential to ensure the effective management of data for the MER Program
- **Allocation of resources:** The Lachlan Selected Area has appointed a data manager (Alica Tschierschke, Table 16, p. 97) to ensure the quality and security of the data set
- **Custodianship:** Data custodians are trustees that do not 'own' data but responsibly manage and maintain it for use by a wider community of users. Data are maintained in one location as the authoritative source for the dataset.
- **Shared responsibility:** Those collecting the data are responsible for the quality of the data. The CEWO is responsible for the integrity of the dataset. Data users are responsible for wise and appropriate use of the data.
- **High quality data:** Comprehensive but achievable quality assurance and quality control (QA/QC) procedures ensure the collection of high-quality data that is fit for purpose.
- **Standards and interoperability:** Consistent adherence to data standards facilitates links with related or complementary data and preserves the utility and comparability of data through time.
- **Metadata:** Accurate metadata accompanying each dataset provides contextual information on where, who, how and why the data were collected, and documents known assumptions or limitations to guide interpretation.

11.1 DATA COLLECTION, STORAGE AND MANAGEMENT

Theme leaders are responsible for collating raw and processed data relevant to both Basin and Selected Area Evaluation. A copy of the raw data (that is not to be altered) will be held by the lead organisation (University of Canberra). Raw data collected by the lead organisation will be copied and stored within 1 month of collection of data (i.e. downloading of loggers or field data sheets). Raw data collected by partner agencies will be copied and stored according to partner protocols.

Derived data supplied to the CEWO for Basin scale evaluation will adhere to LTIM data standards and will be uploaded according to the protocols established by CEWO. Derived data will be provided by partner agencies once internal QA/QC procedures have been completed. Derived data from the lead organisation will be subject to internal QA/QC procedures. All derived data will be stored by the lead organisation in an internal data base that is backed up daily.

It is a requirement of NSW scientific licenses and permits that data collected are uploaded to the Bionet Atlas (http://www.bionet.nsw.gov.au/) and data relating to fish captures is to be supplied to NSW DPI. We will comply with these requirements.

Data sharing between theme leaders and between Selected Areas may occur and will be based upon written agreements between the parties.

11.1.1 UPLOADING OF DATA TO MDMS

Derived data supplied to the CEWO for Basin scale evaluation will adhere to MER data standards and will be uploaded according to the protocols established by CEWO and in accordance with the contracted timeframes. All data will be reviewed by the project data manager prior to uploading to MDMS.

11.2 DOCUMENT MANAGEMENT

Overall document management and final document custodianship will lie with the lead organisation (University of Canberra). Theme leaders will be responsible for providing all updated documents to University of Canberra for back-up (Table 31).

Review of material for annual and quarterly reports (to ensure quality and fit for audience targets being met) will take place internally within each theme leader's institution, and by the project leader. Quarterly reports will be reviewed by the CEWO and then updated prior to finalisation. Annual reports will be reviewed by the CEWO and by the Basin evaluation team. Comments will be addressed with formal responses and the report revised.

Table 31. Document management procedures for the Lachlan MER Program.

DOCUMENT TYPE	PREPARED BY	DETAILS OF REVIEW	REVIEWED BY
Progress/Status reports	Project lead -Fiona Dyer with input from theme leaders	None Internal review	Theme leaders CEWO
Quarterly reports	Project lead -Fiona Dyer with input from theme leaders	External review	
Annual reports	Project team, led by Fiona Dyer	Initially internal review will be undertaken by theme leaders prior to document being submitted to submission to CEWO.	Theme leaders (Internal review) & Basin evaluation team

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13 APPENDICES

A. **Standard operating procedures for indicators monitored (SOP)**
B. **Progress report template**
C. **Workplace Health & Safety Plan (WHS)**
D. **Research Plan**
E. **Communication and Engagement Plan**