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Commonwealth Environmental Water Holder

FLOW Monitoring Evaluation Research

Mid-Murray Area

Commonwealth Environmental Water Holder's Science Program (Flow-Monitoring, Evaluation and Research)

Monitoring, Evaluation and Research Plan 2024-2029

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Cover art credit: Rebecca Salcole (nee Harris), Wiradjuri woman (Commonwealth Environmental Water Office, 2022). The artwork represents the people, plants and animals of the Murray-Darling Basin.

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Acknowledgement of First Nations people

The Flow-MER Program team acknowledges the First Nations communities of the Murray–Darling Basin and pays respect to Elders past and present. We acknowledge First Nations people as the Traditional Owners of the land, water and sky Country across the Basin and value the expertise, wisdom and enduring connections that have informed their care for Country over millennia.

We recognise the intrinsic connection of First Nations people to Country, and we value the enduring cultural, social, environmental, spiritual, and economic connection to the rivers, wetlands, and floodplains of the Basin.

We are committed to working with First Nations people across the Murray-Darling Basin to build relationships in a meaningful and genuine way.

Contents

1 Introduction

The Commonwealth Environmental Water Holder (CEWH) is responsible under the *Water Act 2007* (Cth) for managing Commonwealth environmental water holdings. The holdings must be managed to protect or restore the environmental assets of the Murray–Darling Basin, and other areas where the Commonwealth holds water, so as to give effect to relevant international agreements. The Basin Plan (2012) further requires that the holdings must be managed in a way that is consistent with the Basin Plan's Environmental Watering Plan. The *Water Act 2007* (Cth) and the Basin Plan also impose obligations to report on the contribution of Commonwealth environmental water to the environmental objectives of the Basin Plan. Monitoring, evaluation and research are critical for supporting effective and efficient use of Commonwealth environmental water. Monitoring, evaluation and research will also provide important information to support the CEWH meet their reporting obligations.

In June 2014, the CEWH commenced the Long Term Intervention Monitoring Project (LTIM Project) which facilitated the monitoring and evaluation of the contribution of Commonwealth environmental water delivery in the Murray–Darling Basin over five years from July 2014 to June 2019. Over the period from 2014 to 2019 the CEWH also funded the Murray-Darling Basin Environmental Water Knowledge and Research Project (EWKR Project) that aimed to improve the science available to support environmental water management in the Murray–Darling Basin. The CEWH Flow-MER Program (2019 to 2024) was an extension of the LTIM and EWKR projects, with monitoring, evaluation and research activities undertaken within a single integrated program.

The Flow-MER Program will conclude in June 2024. The CEWH's Flow-MER2.0 Program will commence in July 2024 and builds on the past 10 years of CEWH science projects including the LTIM, Flow-MER and EWKR Project.

A key feature of Flow-MER2.0 Program is to embed First Nations knowledge and science into the future science program to ensure environmental watering is underpinned by the best available knowledge. Another of the key changes in the Flow-MER2.0 Program is the expansion from seven Selected Areas in the LTIM and Flow-MER Programs to ten Areas in the Flow-MER2.0 Program.

The Edward/Kolety-Wakool Selected Area as defined in the LTIM/Flow-MER Programs (Watts et al. 2014, Watts et al. 2023) has been expanded for the Flow-MER2.0 Program to encompass the Murray River from Hume Dam to Mildura. This newly defined area will hereafter be referred to as the Mid-Murray Area (see description in Section 2).

This document "Mid-Murray Area Monitoring, Evaluation and Research Plan 2024-29" (hereafter referred to as the Mid-Murray MER Plan) outlines activities to be undertaken to evaluate the outcomes of Commonwealth environmental water in the Mid-Murray Area. The Mid-Murray MER Plan is consistent with approaches presented in the Basin-scale Evaluation Approach (McInerney et al. 2024), Research Strategy (King et al. 2024), Data Management Strategy (Brooks et al. 2023), Knowledge Exchange Strategy (DCCEEW 2024a) and First Nations People MER Strategy (DCCEEW 2024b).

The Mid-Murray MER Plan focuses on four of the five specified environmental MER themes relevant at the Basin Scale: River flows and connectivity, Native vegetation, Native fish, and Cultural outcomes. The Waterbirds Basin Scale theme is not included in the Mid Murray Plan, and reasoning for its exclusion are outlined in section 4.2. The Plan also outlines activities monitoring and research activities at the Area-scale.

2 Mid-Murray Area description

2.1 Geographical description of the Mid-Murray

The Mid-Murray River system, as defined by Flow-MER2.0 Program, "encompasses the main stem of the Murray River from downstream of Hume Dam to Lock 11 including adjacent low-lying wetlands and floodplains. It includes the Edward/Kolety–Wakool River system which begins in the Millewa Forest and travels north and the northwest before discharging into the Murray River, forming a wedge between the Edward/Kolety (EKW) River to the north, the Murray River to the south and their confluence to the west near Kyalite. The Edward/Kolety–Wakool River system includes a complex network of interconnected creeks including the Edward/Kolety River, Wakool River, Yallakool Creek, Colligen–Niemur Creek and Merran Creek".

A map of the Mid-Murray Area (Figure 2.1) shows the two major rivers, Murray River and Edward/Kolety River, and other major tributaries of this system. The map includes the location of major towns and major weirs in this Area. The major tributaries that flow into this system include the Kiewa River, Ovens River, Broken Creek, Goulburn River, Campaspe River and Loddon River in Victoria, and the Billabong Creek, Yanco Creek and Murrumbidgee River in New South Wales. There are also many ephemeral or intermittent creeks, including Cockrans-Jimaringle Creek, Tuppal Creek, Bullatale Creek, Thule Creek, Murrain-Yarrien Creek, Yarrien Creek, Whymoul Creek, and Buccaneit-Cunninyeuk Creek. These Creeks have important ecosystem functions, enabling connectivity between the larger rivers and tributaries within the system.

The Mid-Murray Area has a rich and diverse Indigenous history. Many First Nations people maintain strong connections to the country. We recognise their responsibilities and respect the knowledge they share with us to care for Country. We acknowledge the Elders and knowledge holders of this place whose knowledge and wisdom has ensured the continuation of culture and knowledge.

The Mid-Murray contains diverse and rich natural environments. The Mid-Murray is home to a vast estate of river red gum forest, wetlands and floodplains lining the Murray River including Barmah-Millewa, Gunbower, Koondrook-Perricoota Forests and Werai Lands. Collectively, these forests support 550 plant and 270 animal species, including threatened species such as the Australasian bittern, superb parrot, Mueller daisy, swamp wallaby grass, silver perch and Murray and trout cod (CEWH 2024). The Mid-Murray includes areas of national environmental significance; Millewa Forest, Koondrook-Perricoota Forest and Werai Lands make up the NSW Central Murray Forests Ramsar site. Other Ramsar sites in the Mid-Murray Area are Barmah Forest, Gunbower Forest, and Hattah-Kulkyne Lakes.

The Mid-Murray Area has significant cultural, economic and social values. Its waterways provide water for domestic use, and support diverse agriculture, tourism and recreational activities and, Aboriginal cultural values and practices. Regulation and modification of the river's natural flow regime, including over-extraction of water for consumptive use, has led to considerable ecological decline. Under regulated conditions flows the main rivers and tributaries in the Mid-Murray Area remain within the channel, whereas during high flows there is connectivity between the river channels, floodplains and forests (Figure 2.1).

The Murray River is highly significant in terms of its environmental, cultural, economic and social contributions and receives the largest volume of environmental water of any ecological asset within the Murray–Darling Basin (MDB).

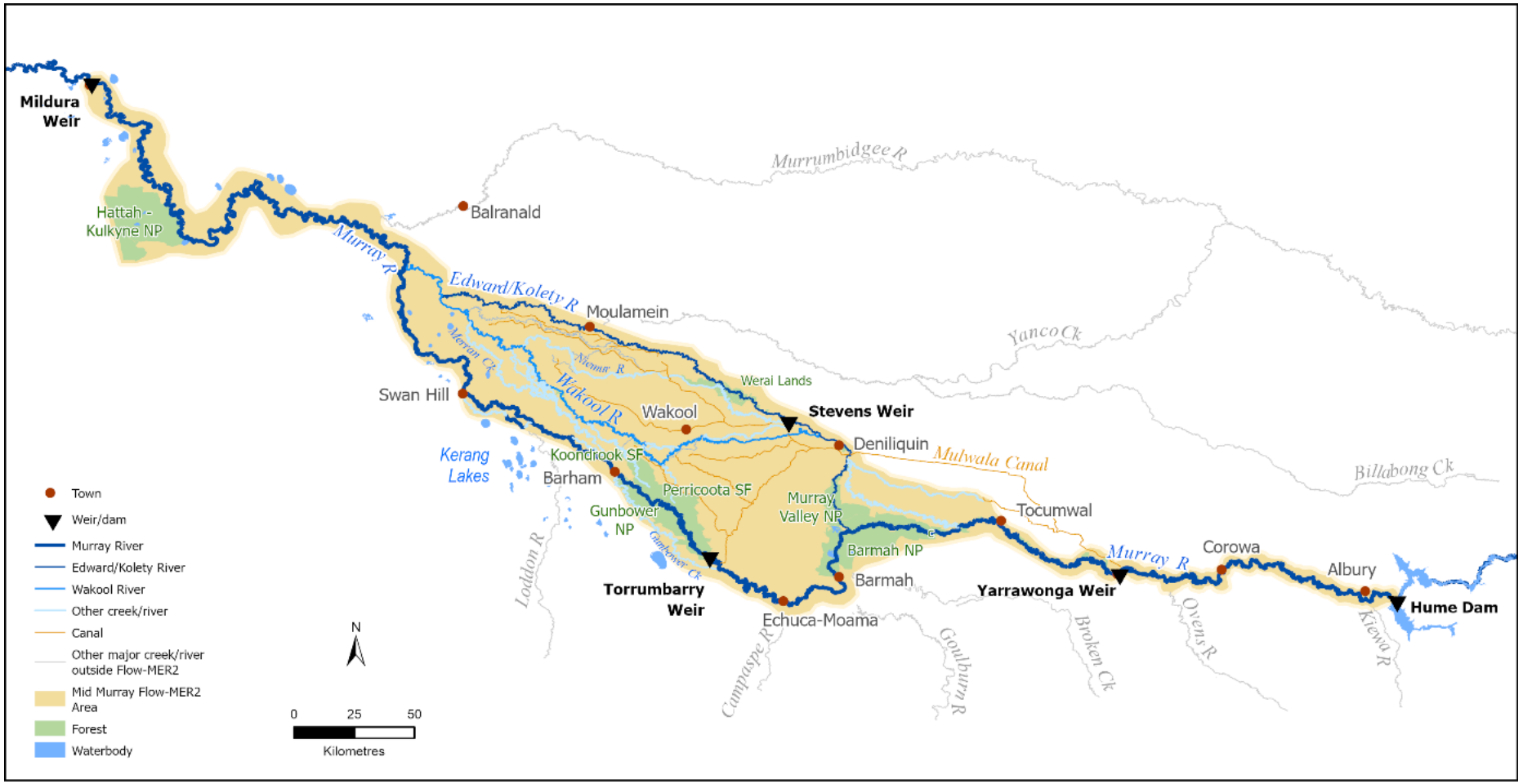

Figure 2.1 The Mid-Murray Flow-MER2.0 Area

The Mid-Murray Area features a major anabranch and floodplain system, the Edward Kolety-Wakool. The Edward/Kolety-Wakool River system plays a key role in the operations and ecosystem function of the Murray River and the southern MDB, connecting upstream and downstream ecosystems in the mid-Murray River. The multiple streams and creeks in this system provide important refuge and nursery areas for fish and other aquatic organisms, and adult fish regularly move between this system and the Murray River. As some of the rivers in the EKW system have low discharge (compared to the Murray River) there is a risk of poor water quality developing in this system, particularly during warm periods or from floodplain return flows. Maintaining good water quality is crucial for both the river ecosystem, the communities that rely on water from this system, and downstream communities along the Murray River that are influenced by the water quality in this system.

The Mid-Murray Area can be broadly divided into four aquatic ecosystem types:

1) the permanent and semi-permanent flowing rivers,

2) the floodplain forests and woodlands,

3) intermittent and ephemeral creeks, and

4) small wetlands, many of which are on private property.

Permanent and semi-permanent rivers and creeks

The permanent and seasonal rivers and creeks support high regional biodiversity and have significant value as drought refugia for native fish and other biota. The dominant vegetation is river red gum (*Eucalyptus camaldulensis*) with areas providing habitat for a number of threatened species. The permanent rivers in this area are the Murray River and Edward/Kolety River (Figure 2.1). The seasonal or semi-permanent rivers and creeks include the Wakool River, Yallakool Creek, Colligen-Niemur River and Merran Creek.

Floodplain forests and woodlands

Within the Mid-Murray River system there are floodplain forests and woodlands. Large forests include Barmah-Millewa Forest, Koondrook-Perricoota Forest, Gunbower Forest, Werai Lands and Niemur Forest and the red gum and black box woodlands surrounding Hattah Lakes. There are redgum riparian forests along the rivers and tributaries within the system and on higher land there are black box forests.

In 2003 Millewa Forest, Koondrook-Perricoota Forest and Werai Lands were listed as the NSW Central Murray Forests Ramsar site (NSW Office of Environment and Heritage 2018), being one of the matters of national environmental significance to which the EPBC Act applies. Other Ramsar sites in the Mid-Murray Area are Barmah Forest, Gunbower Forest, and Hattah-Kulkyne Lakes.

Werai Lands is proposed to be an Indigenous Protected Area (National Indigenous Australians Agency, 2023) owned by the Werai Land and Water Aboriginal Corporation. Werai Lands is recognised regionally, nationally, and internationally as an important forest and wetland. The higher floodplain areas in Werai are dominated by river red gum with lower lying areas typically dominated by giant rush. The low-lying areas, flood-runners and backwaters in Werai may be important habitat for larval and juvenile fish and is a potential source of carbon to feed the lower Edward/Kolety River and Niemur River systems. Werai Lands supports significant breeding colonies of several species of cormorants, whilst further downstream the Niemur Forest supports egrets and nankeen knight heron breeding colonies. Both forests support several listed species and migratory bird species.

Ephemeral and intermittent creeks

There are a large number of intermittent and ephemeral creeks and flood runners in the Mid-Murray River system including Cockrans-Jimaringle Creek, Gwynnes Creek, Tuppal Creek, Bullatale Creek, Thule Creek, Murrain-Yarrien Creek, Yarrien Creek, Whymoul Creek, and Buccaneit-Cunninyeuk Creek. These creeks provide refuge habitat and connect the larger permanent and semi-permanent rivers and creeks in the Mid-Murray Area and are considered biodiversity hotspots of significant regional value.

Small wetlands

There are numerous small wetlands throughout the Mid-Murray system. Many of these wetlands are located on private property. These wetlands create a landscape mosaic of aquatic habitats that provide refuge for many aquatic plants and animals the Mid-Murray Area.

2.2 Hydrological characteristics of the Mid-Murray

Like many rivers of the MDB, the flow regimes of rivers in the Mid-Murray River system have been significantly altered by river regulation (Green 2001; Hale and SKM 2011). Natural flows in this system are strongly seasonal, with high flows typically occurring from July to November. Analysis of long-term modelled flow data show that flow regulation has resulted in a marked reduction in winter high flows, including extreme high flow events and average daily flows during the winter period. There is also an elevated frequency of low to median flows and reduced frequency of moderate high flows. These flow changes reflect the typical effects of flow-regime reversal observed in systems used to deliver dry-season irrigation flows (Maheshwari et al. 1995).

Hydrological zones

At the commencement of the LTIM Program daily discharge data from 14 hydrological stations in the Edward/Kolety-Wakool River system were analysed along with information on geomorphology and location of major distributaries to classify the system into distinct hydrological zones (Watts et al. 2014). Fifteen distinct zones were identified and referred to in the LTIM and Flow-MER projects in the Edward/Kolety-Wakool River Selected Area (Watts et al. 2023).

With the expansion to the Mid-Murray Area in Flow-MER 2.0 Program, 35 distinct hydrological zones have been identified (Figure 2.2, Table 2.1). Transitions between these zones occur where there are major inflows or outflows to a river or at locations where there are significant changes in geomorphology. The zones range from ephemeral watercourses (e.g., Jimaringle, Cockran and Gwynne's Creeks), to smaller permanent and semi-permanent creeks and rivers (Wakool River, Yallakool Creek, Colligen-Niemur system, Merran Creek, Gunbower Creek and Gulpa Creek) to the larger Edward/Kolety River system and the Murray River.

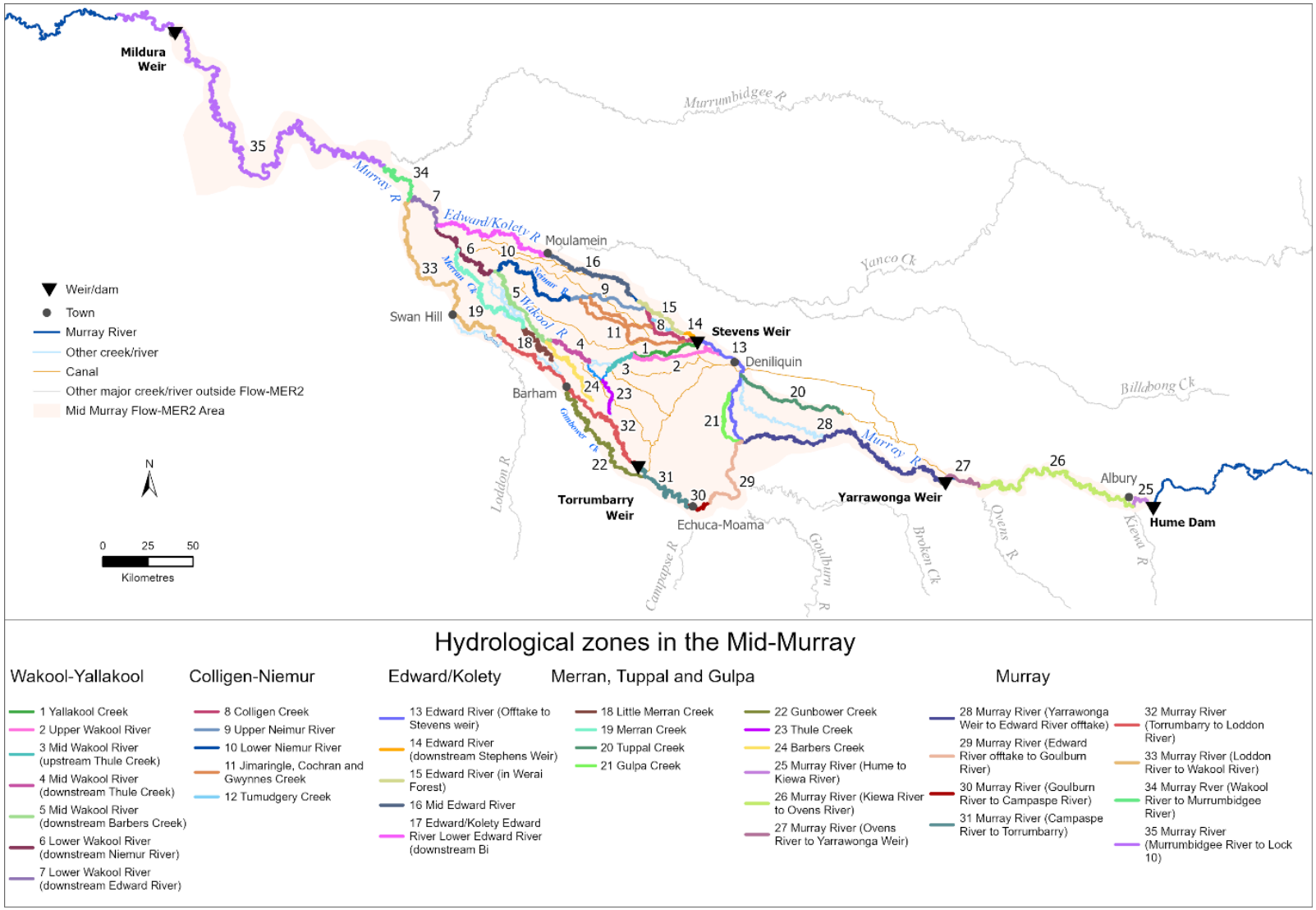

Figure 2.2 Map showing the 35 in-channel hydrological zones in the Mid-Murray Area. Flow-MER Basin and Area monitoring sites take place in a subset of these zones shown in Table 2.1

Table 2.1 List of the hydrological zones in the Mid-Murray River system Area

River system	Hydrological zone
Wakool-Yallakool	Yallakool Creek
	Upper Wakool River
	Mid Wakool River (upstream Thule Creek)
	Mid Wakool River (downstream Thule Creek)
	Mid Wakool River (downstream Barbers Creek)
	Lower Wakool River (downstream Niemur River)
	Lower Wakool River (downstream Edward River)
Colligen-Niemur	Colligen Creek
	Upper Niemur River
	Lower Niemur River
	Jimaringle, Cochran and Gwynnes Creek
	Tumudgery Creek
Edward/Kolety	Edward River (Offtake to Stevens weir)
	Edward River (downstream Stephens Weir)
	Edward River (in Werai Lands)
	Mid Edward River
	Lower Edward River (downstream Billabong Creek)
Merran	Little Merran Creek
	Merran Creek
Tuppal	Tuppal Creek
Gulpa	Gulpa Creek
Murray	Gunbower Creek
	Thule Creek
	Barbers Creek
	Murray River (Hume to Kiewa River)
	Murray River (Kiewa River to Ovens River)
	Murray River (Ovens River to Yarrawonga Weir)
	Murray River (Yarrawonga Weir to Edward River offtake)
	Murray River (Edward River offtake to Goulburn River)
	Murray River (Goulburn River to Campaspe River)
	Murray River (Campaspe River to Torrumbarry)
	Murray River (Torrumbarry to Loddon River)
	Murray River (Loddon River to Wakool River)
	Murray River (Wakool River to Murrumbidgee River)
	Murray River (Murrumbidgee River to Lock 10)

2.3 Flow management

The main source of Commonwealth environmental water for the Murray River watering actions is Hume Dam on the Murray River near Albury. Water is also delivered from Yarrawonga Weir and Torrumbarry Weir. Inflows of environmental water from the Goulburn River, Broken River, Campaspe River and Loddon River in Victoria and Murrumbidgee River in New South Wales also influence the flows in the Mid-Murray Area.

The main source of Commonwealth environmental water for the Edward/Kolety-Wakool River system is from the Murray River through the Edward/Kolety River and Gulpa Creek. The main flow regulating structures within the EKW River system are the Gulpa Creek Offtake, Edward/Kolety River Offtake (both located on the Murray River), and Stevens Weir, located on the Edward/Kolety River downstream of Colligen Creek (Figure 2.1). Stevens Weirpool allows Commonwealth environmental water to be delivered to Colligen Creek-Niemur River system, Yallakool Creek, the Wakool River, the Edward/Kolety River and Werai Lands.

Environmental watering actions delivered for the Murray River channel from Hume Dam to South Australia delivers water to Millewa Forest via Barmah-Millewa Forest regulators and some of this water exits via creeks and flood runners in Millewa Forest and influences the Edward/Kolety River hydrograph at the Toonalook gauge. However, environmental water also exits Millewa Forest via Tuppal Creek and Bullatale Creek, contributing to flows in the Edward/Kolety River downstream of the Toonalook hydrographic gauge. Watering actions from Hume Dam may also target Koondrook-Perricoota Forest via the inlet regulator connected to Torrumbarry Weir pool. Gunbower Creek and Gunbower Forest may also receive water via releases from Hume Dam.

Water diverted into the Mulwala Canal from Lake Mulwala can also be delivered into the EKW River system through irrigation 'escapes' or outfalls managed by the irrigator-owned company Murray Irrigation Limited (MIL). During a hypoxic water event in 2010, environmental water was released from the Mulwala Canal escapes to lessen the impact of hypoxia and create localised refugia with higher DO and lower DOC (Watts et al. 2017). Escapes were again used to deliver environmental water as refuge flows in response to the 2016 hypoxic water event (Watts et al. 2017, Liu et al. 2023). There are numerous smaller escapes throughout the MIL network that can also be used to deliver small flows to the river system, including ephemeral creeks, more permanent creeks and rivers and private wetlands.

2.4 Operational constraints

The ability to deliver environmental water to assets in the Mid-Murray system depends on water availability and circumstances in the river at any given time. Environmental water delivery in this system involves various considerations as outlined by Gawne et al. (2013), including:

- **The capacity of the off takes / regulators and irrigation escapes**. Environmental watering may be constrained due to limitations on how much water can be delivered under regulated conditions, particularly at times of high irrigation demand.
- **Channel constraints (e.g., to avoid third party impacts).** Delivery of Water for the environment to the Mid-Murray is limited by the operational constraints associated with the Barmah choke, and river operational rules relating to maintaining flows within channel and to limit third-party impacts. Delivery of instream flows are managed within regular operating ranges as advised by river operators to avoid third party impacts. For example, in the Wakool-Yallakool system the operational constraint is 600 ML/day at the confluence of the Wakool River and Yallakool Creek. The Water Sharing Plan for the Murray Lower Darling Item 33 (2) notes the following constraints: "The following capacities have been assessed: (a) Hume Dam and Lake Mulwala, 25,000 ML/day, (b) Tocumwal Choke, 10,600 ML/day, (c) Barmah Choke, 8,500 ML/day, (d) Edward River offtake, 1,600 ML/day, (e) Gulpa Creek, 350 ML/day." Thus, the types of flow components that can be achieved under current operating ranges are in-channel baseflows and freshes.
- **The availability of third-party infrastructure to assist in delivering water into the system.** Under some circumstances water for the environment in the Mid-Murray Area can be delivered via third-party infrastructure, such as via the Murray Irrigation Limited channel network. At times, the ability to deliver water for the environment via this network is limited as the channel network may be at full capacity due to the delivery needs of other water users.
- **Existing flows and other demands on the system.** If the system is receiving unregulated flows, there may not be enough capacity to deliver environmental water.

3 Commonwealth environmental watering

The Mid-Murray MER Plan aligns with the Basin-wide Environmental Watering Strategy outcomes (BWS) (Murray Darling Basin Authority 2019), Murray Lower-Darling Long Term Water Plan (LTWP) (NSW Department of Planning, Industry and Environment 2020). The Basin Plan currently lists four major flow types that have been used to develop the sustainable diversion limit: 1) Base flow, 2) Freshes, 3) Bank full, and 4) Overbank (Gawne et al. 2013b).

3.1 Overview of environmental watering options for the catchment

The Australian Government owns entitlements to water in the Murray–Darling Basin and this water is used to keep rivers healthy, so they continue to support communities for future generations (CEWO 2020). The CEWH manages this water for the environment. The amount of available water changes from year to year and plans are adjusted accordingly. The CEWH follow an annual cycle of 'plan, deliver, measure and review' to manage water for the environment (Figure 3.1).

Figure 3.1 Annual cycle of 'plan, deliver, measure and review' (Source CEWO 2020)

Each year the CEWH publishes a Water Management Plan which considers how much water is expected to be available, the seasonal rainfall outlook, and current ecosystem health (e.g., Commonwealth of Australia 2022). The annual Water Management Plan scopes options for a range of weather scenarios (from dry to wet) so the watering actions can adapt to the seasonal conditions. The CEWH also consider the needs of communities and irrigators, physical limitations of the river, lessons learned from monitoring the response of plants and animals to previous environmental flows, and the Basin Plan annual and long-term objectives (CEWO 2020). Annual Water Management Plans outline how the CEWH plan to use water for the environment across the Basin's rivers and wetlands under a range of different weather and water availability conditions at both the valley and Basin-scale. Every year is different. The plan describes: how much water is expected to be available, the seasonal rainfall outlook, and plant, animal, river and wetland health.

Commonwealth environmental water use is planned, delivered and managed in partnership with a number of individuals and organisations in the Mid-Murray, including:

- Edward Kolety–Wakool Environmental Water Reference Group

- NSW Department of Climate Change, Energy, the Environment and Water
- NSW Department of Primary Industries – Fisheries
- Murray Irrigation Limited
- NSW Local Land Services
- Victorian Environmental Water Holder
- Victorian Catchment Management Authorities
- Goulburn-Murray Water
- Murray-Darling Wetlands Working Group Ltd
- Murray-Lower Darling Environmental Water Advisory Group
- Local landholders and community members
- Murray-Darling Basin Authority
- Southern Connected Basin Environmental Watering Committee.

The first delivery of environmental water occurred in 2008-09. The history of environmental watering actions in the Mid-Murray catchment is described here.

The Commonwealth holds the following entitlement types in the Mid-Murray region:

- NSW Murray High Security
- NSW Murray General Security
- NSW Murray Conveyance
- NSW Murray Supplementary
- NSW Murray Groundwater
- NSW Murray Unregulated
- Victorian Murray High Reliability
- Victorian Murray Low Reliability.

For more information about current Commonwealth environmental water holdings in the Mid-Murray Region, please refer to Water Holdings by Catchment. For more information regarding the characteristics of entitlements and the water resource plan held in the Murray catchment please refer to Victoria's Department of Environment, Land, Water and Planning, South Australia's Department for Environment and Water and New South Wales Department of Planning and Environment.

3.2 Environmental watering options

The Mid-Murray Area is a highly integrated and connected system. There are a diverse range of sources of Commonwealth environmental water and types of watering actions that can occur in the Mid-Murray Area in any year (Table 3.1). The decision making around watering actions for any given year depends on water availability, current condition and history of watering of environmental assets, environmental priorities, and other operational and unregulated flow events occurring in the system in that year.

Both the Southern and Central Delivery teams in the office of CEWH manage environmental watering actions in the Mid-Murray Area.

Table 3.1 Source of Commonwealth environmental water and types of watering actions in the Mid-Murray Area

#	Point of delivery	Source	CEWH delivery section responsible	Target reaches or wetlands
1	Hume Dam	Hume	Southern	Murray River from Hume to Mildura, upper/mid/lower Edward/Kolety River, Wakool, Yallakool, Colligen Creeks. Also targets Barmah Millewa, Werai, Koondrook-Perricoota forests, and Gunbower system. The Living Murray (TLM) may also provide environmental water to these sites.
2	Goulburn from Eildon	Eildon (primary) Waranga Basin (occasional use)	Southern	Goulburn River contributes flow to Murray River outcomes d/s Goulburn, possibly mid/lower Wakool River and Merran Creek, *Potentially Koondrook-Perricoota Forest and Gunbower Creek. Potentially Eagle, Bullockhide, Waddy, Speewa Creeks, Lake Wollare/Tooleybuc Lakes*
3	Other Victorian Rivers (Campaspe / Loddon (including Kerang) / Broken / Ovens)	Loddon: Lake Eppalock Campaspe: Cairn Curran, Tullaroop, and Laanecoorie Reservoirs	Southern	Assets in Loddon and Campaspe Rivers Contribution flow to achieving Murray River outcomes d/s Loddon and Campaspe River confluences
4	Barmah-Millewa regulators	Hume (Yarrawonga is the order point)	Southern	Barmah-Millewa Forest
5	Gunbower Creek, Gunbower Forest	Murray River	Southern	Gunbower Creek and Gunbower Forest *Also return flows to Murray River*
6	Private wetlands	Various sources	Central and Southern	Individual wetlands
7	Koondrook Perricoota regulators	Mainly Hume via Torrumbarry, K-P Inlet Regulator	Central	Koondrook Perricoota including Pollack Swamp (pumped), Thule Creek, Barbers Creek *Also could impact Mid/Lower Wakool*
8	Merran Creek	Murray	Central	Merran Creek *Also could impact Barbers Ck, Little Merran Ck, St Helena, Lake Tooim, and Mid/Lower Wakool River*
9	Murrumbidgee	Burrinjuck and Blowering Dams	Central	Murray River DS Murrumbidgee confluence
10	Yanco Creek-> Billabong Creek	Yanco Weir on Murrumbidgee	Central	Lower Edward/Kolety River DS Moulamein
11	Wakool, Colligen Yallakool regulators	Stevens Weir	Central	Wakool, Yallakool, Colligen Creeks
12	Edward Escape	Mulwala channel -> Edward/Kolety	Central	Werai, Niemur River, mid/lower Edward/Kolety River, Murray DS Edward/Kolety confluence (flows to South Australia)
13	Other large MIL escapes	Mulwala channel, other MIL channels	Central	Wakool River, Niemur River, Local refuges in EKW system
14	Smaller MIL escapes and Regulators to ephemeral Creeks	Various sources	Central, except Bullatale Creek – can be watered via Hume.	Tuppal Creek, Murrain Yarrein Creek, Yarrein Creek, Cockrans Creek, Jimaringle Creek, Thule Creek. *Potentially return flows to tributaries. Potentially Bullatale Creek after regulator upgrade completed. Lake Agnus, Cunninyeuk Creek, Whymoul Creek.*
15	Werai Lands regulators (upgrades planned)	Edward/Kolety Stevens Weir, Edward Escape	Central	Werai Lands Colligen-Niemur system downstream of Werai Forest

16	Escapes to Billabong Creek	Finley (MIL) escape	Central	Billabong Creek, Lower Edward/Kolety DS Moulamein *Potentially also Murray River DS Wakool confluence and DS Murrumbidgee confluence.*
17	Hattah Lakes	Murray	Southern	Hattah Lakes *Return flows can be provided back to the Murray*
18	Lock 15 weir pool manipulation	Murray	Southern	Increased hydraulic complexity and flowing habitat, bank vegetation targeted by weir pool lowering. Connection with low lying wetlands and creeks and potentially Euston wetlands can be targeted by weir pool raising.

3.3 Expected outcomes for the Mid-Murray River system

Expected outcomes from the Basin-wide Environmental Watering Strategy that are relevant to the mid-Murray Region are listed below and in Table 3.2 and Table 3.3 (MDBA 2019).

River flows and connectivity

- Base flows are at least 60 per cent of the natural level
- A 30 per cent overall increase in flows in the River Murray
- A 30 to 60 per cent increase in the frequency of freshes, bankfull and lowland floodplain flows.

Vegetation

- Maintain the current extent of water-dependent vegetation near river channels and on low-lying areas of the floodplain
- Improve condition of black box, river red gum and lignum shrublands
- Improve recruitment of trees within black box and river red gum communities
- Increased periods of growth for non-woody vegetation communities that closely fringe or occur within the river and creek channels, and those that form extensive stands within wetlands and low-lying floodplains, including Moira grasslands in Barmah–Millewa Forest.

Fish

- No loss of native species
- Improved population structure of key species through regular recruitment, including:
    - Short-lived species: restored distribution and abundance to levels recorded pre-2007, requiring annual or biennial recruitment events depending on the species
    - Moderate to long-lived species: improved population structure, a 10-15 per cent increase of mature fish for recreational target species in key populations, and annual detection of species and life stages representative of the whole fish community through key fish passages.
- Increased movements of key species
- Improved community structure of key native fish species
- Significant increases in the distribution of key species in the southern basin.

Waterbirds

- Maintain current species diversity of all Basin waterbirds
- A 20-25% increase in waterbirds by 2024
- Up to 50% more breeding events for colonial nesting waterbird species, and 30-40% increase in nests and broods for other waterbirds.

Table 3.2 Important Basin environmental assets for native fish in the Mid-Murray (from MDBA 2019).

Environmental asset	Key movement corridors	High Biodiversity	Site of other Significance	Key site of hydrodynamic diversity	Threatened species	Dry period / drought refuge	In-scope for CEW
Murray main channel (from Hume Dam to Darling junction)	*	*	*	*	*	*	Yes
Hattah Lakes			*			*	Yes
Euston Lakes (including Washpen and Taila creeks)					*		Yes
Koondrook–Perricoota	*	*	*	*	*		Yes
Gunbower	*	*	*	*	*		Yes
Barmah–Millewa	*	*	*	*	*	*	Yes
Edward/Kolety–Wakool system	*		*	*	*	*	Yes
Werai Lands			*	*			Yes
Billabong–Yanco–Columbo Creeks		*	*	*	*	*	Yes
Lake Mulwala	*		*	*	*	*	Yes

Table 3.3 Key Basin-priority species for the Mid-Murray (MDBA 2019)

Species	Priorities for increasing distribution in the southern basin	In-scope for CEW in mid-Murray?
Flathead galaxias (*Galaxias rostratus*)	Expand the core range in the wetlands of the River Murray	Yes
Freshwater catfish (*Tandanus tandanus*)	Expand the core range of at least two current populations (candidate sites in the Mid-Murray include Columbo-Billabong Creek and Wakool system). Improve core range in at least three additional locations (candidate sites in the Mid-Murray include Merran Creek area in NSW).	Yes
Golden perch (*Macquaria ambigua*)	A 10–15% increase of mature fish (of legal take size) in key populations	Yes
Murray cod (*Maccullochella peelii peelii*)	A 10–15% increase of mature fish (of legal take size) in key populations	Yes
Murray hardyhead (*Craterocephalus fluviatilis*)	Expand the range of at least two current populations. Establish 3–4 additional populations, with at least one in the mid -Murray conservation unit.	Yes
Olive perchlet (*Ambassis agassizii*)	Olive perchlet are considered extinct in the southern Basin. Reintroduction using northern populations is the main option for recovery. Candidate sites may result from improved flow that reinstates suitable habitat in the River Murray.	Restoration of flow to Murray River could support future reintroduction of the species
River blackfish (*Gadopsis marmoratus*)	Expand the range of at least two current populations (candidate sites from the Mid-Murray include from the Mulwala canal).	Yes
Silver perch (*Bidyanus bidyanus*)	Expand the core range within the Murray River (Yarrawonga–Euston) and populations within the Edward-Wakool.	Yes

	Expand upstream of Lake Mulwala and into Ovens River. Improve core range in at least two additional locations (candidate sites in the Mid-Murray include Gunbower Creek)	
Southern pygmy perch (*Nannoperca australis*)	Expand the range of at least two current populations (candidate sites include Barmah-Millewa and other mid-Murray wetlands).	Yes
Trout cod (*Maccullochella macquariensis*)	Expand the range of trout cod up the Murray upstream of Lake Mulwala and into the Kiewa River. For the connected population of the Murrumbidgee–Murray–Edward: continue downstream expansion.	Yes

Water quality

Water quality targets for the Murray–Darling Basin are outlined in Chapter 9, Part 4, sub-section 9.14(5) of the Basin Plan (MDBA 2012). The target for DO is to maintain DO levels at a value of at least 50% saturation to be determined at 25°C and 1 atmosphere of pressure (sea level). This equates to a DO concentration of approximately 4 mg/L. In previous years the CEWH has used a trigger of 4.0 mg/L for the potential provision of refuge flows into catchments like the EKW River system.

The Guidelines for Managing Risks in Recreational Water (Australian Government 2008) also guide the green, amber and red alert levels issued by relevant state management agencies (e.g., in NSW – the Regional Algal Coordinating Committees) who are responsible for the catchment scale management of algal blooms. The CEWH has access to the alert advice issued by these state agencies and can adjust the use of Commonwealth environmental water accordingly.

Specific environmental outcomes that are targeted by Commonwealth environmental water delivery in the Mid-Murray River include:

1. Maintaining current species diversity, extending distributions and improving breeding success and numbers of short, moderate and long-lived native fish species by:
    - Providing in-stream habitat for fish and thereby supporting recruitment of fish, particularly by increasing the availability of food resources and habitat during periods where flows would be unnaturally low.
    - Promoting the recovery of Murray cod populations in the Mid-Murray that were affected by the 2022-23 hypoxic event.
    - Increasing the presence of fast flowing fish habitat along the Murray River and, where feasible, increased lateral connectivity with anabranches and low elevation floodplain wetlands.
    - Improving the body condition of mature fish during winter/spring ('pre-spawning conditioning') and providing opportunities for spawning during spring (subject to appropriate seasonal conditions).
    - Providing opportunities for native fish to move along the length of the Murray River and with its tributaries, including for juvenile golden perch to move from the Lower Murray to Mid-Murray to replenish ageing populations.
    - Contributing to the maintenance of critical habitat, water quality and the provision where possible of localised refuge sites as required. This could include nursery habitat sites for

juvenile native fish such as golden perch, or habitat for small-bodied threatened native fish species.

2. Maintaining the extent and condition of floodplain, riparian and in-channel vegetation by:
    - Increasing periods of growth for non-woody vegetation communities (including Moira grass and vegetation recolonising riverbanks) that closely fringe or occur within the Murray River channel, anabranches and low elevation floodplain wetlands.
    - Maintaining the extent and condition of inundation dependent river red gum, black box, lignum and non-woody vegetation within low-lying areas of floodplain, with scale of contribution subject to seasonal conditions.
3. Maintaining current species diversity, extending distributions and improving breeding success and numbers of water dependent bird species by:
    - Supporting suitable habitat conditions and food resources for waterbird growth and survival, maintenance of population condition and diversity along the Murray River valley.
4. Supporting waterbird breeding events if seasonally appropriate.
5. Supporting a range of other water dependent fauna such as invertebrates, crustaceans (shrimps and yabbies), turtles, rakali and platypus.
6. Contributing to riverine functioning by:
    - Supporting primary and secondary production along the Murray River through the mobilisation and transport of nutrients, carbon cycling and biotic dispersal.
    - Supporting riverbank stability and geomorphic processes such as scouring and deposition.
    - Supporting the managed export of salt and nutrients from the Murray River system.
    - Maintaining lateral and longitudinal flow integrity.
    - Reducing the impact of hypoxic events.

The in-channel flows will also contribute to the achievement of specific outcomes in the River Murray, Lower Lakes and Coorong. These are described in the Lower Murray, Coorong and Lower Lakes MER Plan (Ye et al. 2024).

4 Monitoring and Evaluation

4.1 Introduction

This section describes the Monitoring and Evaluation approaches and activities that will be undertaken in the Mid-Murray Area for the Flow-MER Project. Plan Evaluation activities and approaches planned for the Mid-Murray evaluation align with the Basin Evaluation approach (McInerney et al. 2024).

The design of Flow-MER2.0 monitoring in the Mid-Murray Area was guided by the following principles (https://www.dcceew.gov.au/water/cewo/monitoring/future-science-program):

- **Collaboration** – The Mid-Murray MER Plan has been developed in partnership with CEWH and with respect to and advice from a range of stakeholders including:
    - CEWH
    - Government agencies
    - Science providers
    - Independent Advisory Group
    - First Nations scientists
    - Local community representatives, including those that are members of the Edward/Kolety-Wakool Environmental Water Reference Group, and the Murray Lower-Darling Environmental Water Advisory Group
- **Build on success** – recognising the strengths and limitations of past programs as identified in the recent reviews of Flow-MER, LTIM and EWKR. The Mid-Murray MER Plan builds on monitoring and evaluation methods and project outcomes from the LTIM and Flow-MER Programs. Where possible a subset of monitoring locations from those programs were included in the study design to ensure a continuation of long-term data sets.
- **Program Purpose** – contributing to CEWH legislative reporting requirements and adaptive management of environmental water. The team has extensive experience working with environmental water managers and have developed indicators that will:
    - continue to support adaptive management of water during water actions,
    - clearly demonstrate outcomes from the use of environmental water,
    - contribute to improving our understanding of the role of environmental water in the Mid-Murray Area which in turn improves the planning for management of environmental water.
- **Complementary** – This project aligns with the Basin Environmental Watering Strategy, CEWH Flow-MER Areas, the River Murray Channel (RMC) Monitoring Plan (SCBEWC 2021), The Living Murray and other programs, including jurisdictional activities. We will ensure there is no duplication of other research programs.
- **Culturally inclusive** – including First Nations people and Indigenous science. The Mid-Murray Plan aligns with the First Nations People MER Strategy.
- **Data management and sharing** – enhancing the value and utility of monitoring and research data, through improved data governance, management and sharing. The Mid-Murray Plan will align with the Data Management Strategy and will endeavour to draw on

complementary data sets from other projects that are undertaken in the Mid-Murray Area.

- **Communication and engagement** – improving the effectiveness and impact of communication and engagement activities both internal and external to the Program. One of the key principles we have incorporated into the Mid-Murray Project is to integrate communications and engagement into many of the projects, to facilitate sharing of knowledge and create opportunities for local people to be involved in the project. The Mid-Murray Plan will align with the Knowledge Exchange Strategy.
- **Innovative and robust** – encouraging innovative approaches that are robust and underpinned by scientifically defensible research, monitoring and evaluation. New methods and technologies were considered when developing this Plan.
- **Impactful** – promoting a reporting structure which is impactful, efficient and focussed on clear communication of fit-for-purpose outcomes and guidance to inform legislative reporting and improve water management.

In the Mid-Murray Area three types of monitoring will be undertaken:

1. **Monitoring that contributes to Basin-scale evaluation**. These are needs as required for Basin-scale evaluation and reporting purposes as outlined in the Basin-scale Evaluation Approach.
2. **Monitoring that contributes to Area-scale evaluation**. These are needs as required by the Commonwealth and were determined in consultation between the Area Provider and the CEWH.
3. **Monitoring that contributes to the River Murray Channel Project**. These are needs as required by the Southern Connected Basin Environmental Watering Committee (SCBEWC) to assist environmental water holders to plan for and evaluate coordinated Murray River Channel system scale delivery. The design and monitoring requirements were designed by SCBEWC in collaboration with Project Lead provider CSIRO Land and Water. Monitoring for the RMC will be undertaken following the methods described in that RMC monitoring Plan.

4.2 Monitoring that contributes to Basin-scale evaluation

The monitoring undertaken in the Mid-Murray Area that will contribute to the Basin-scale evaluation will follow requirements outlined in the Basin-scale Evaluation Approach (McInerney et a. 2024).

The Mid-Murray is a large and hydrologically and geomorphologically complex Area. It incorporates four of the Icon Sites that are the focus of the Murray-Darling Basin Authority's The Living Murray Program (TLM) (MDBA 2024); Barmah-Millewa Forest, Koondrook-Perricoota Forest, Hattah Lakes, and The River Murray. One of the critical factors we considered when designing the monitoring program was to ensure we did not duplicate work being undertaken by other projects in the Area, and where possible we will collaborate to incorporate data from other programs into the evaluation for the Mid-Murray provided data sharing agreements and timelines for milestones align.

One of the critical factors in selecting monitoring locations was that the study design closely aligns with Commonwealth environmental watering actions and objectives, so that the outcomes of these watering actions can be evaluated against expected outcomes at both the Area-scale and Basin-scale.

Monitoring in the Mid-Murray Area will contribute to evaluation questions for four of the five Basin-scale themes, as listed below. A summary of the questions is in Table 4.1, and details of Basin-scale indicators are in Section 5.

- River Flows and Connectivity
- Native Vegetation
- Native Fish, and
- Cultural outcomes.

Waterbirds

In agreement with the CEWH, due to budget constraints the Mid-Murray MER Plan will not include the monitoring of waterbird outcomes at a Basin or Area-scale. Waterbirds in the Mid-Murray Area are monitored through other complementary programs such as The Living Murray Icon sites and NSW Waterbird surveys, and data from TLM waterbird programs will contribute directly to the Basin-scale waterbird evaluation.

A responsive monitoring component for monitoring waterbird breeding in response to environmental watering actions has been included (see section 7) and a research project focused on waterbirds has also been proposed (see section 6).

Table 4.1 Summary of Evaluation questions that will be monitored in the Mid-Murray Area to contribute to four Basin-scale themes: River flows and connectivity, Native Vegetation, Native Fish, and Cultural Outcomes

Basin-scale theme	Basin Question no.	Basin-scale Evaluation questions
River flows and connectivity	Flows-B1	What did CEW contribute to the regime of low flow conditions, freshes, and bank-full flows?
	Flows-B2	What did CEW contribute to connectivity, including overbank inundation?
Native vegetation	Vegetation-B1	What did CEW contribute to maintaining representative communities of native vegetation in the Basin?
	Vegetation-B2	What did CEW contribute to maintaining or improving the condition of forests and woodlands?
	Vegetation-B3	What did CEW contribute to maintaining or improving the condition of lignum shrublands?
	Vegetation-B4	What did CEW contribute to maintaining or improving representative populations and communities of non-woody vegetation?
Native Fish	Fish-B1	What did CEW contribute to native fish recruitment?
	Fish-B2	What did CEW contribute to native fish population structure?
	Fish-B3	What did CEW contribute to native fish abundance?
	Fish-B4	What did CEW contribute to native fish condition?
Cultural Outcomes	Cultural–B1	How has CEW contributed to Cultural Outcomes?

4.3 Monitoring that contributes to Area-scale evaluation

The monitoring and evaluation planned to contribute to the Mid-Murray Area-scale evaluation will follow the same principles as outlined in section 4.1. The Area-scale questions and activities were developed to:

- Be consistent with the Program Monitoring, Evaluation, Reporting and Improvement (MERI) Strategy, and Basin Evaluation Approach
- Focus on evaluation against the expected outcomes of watering actions in the Area
- Where possible, input to a whole of Basin evaluation of the contribution of Commonwealth environmental water to the objectives of the Basin Plan
- Input to adaptive management of Commonwealth environmental water within the Area.

A summary of the Area-scale evaluation questions are provided in Table 4.2 and details of indicators are in section 5.

Table 4.2 Summary of Mid-Murray Area-scale Evaluation questions

Area-scale theme	Area Question	Evaluation questions
River flows and connectivity	Flows-A1	Flows-A1a What low flow conditions and freshes occurred in the Mid-Murray Area? Flows-A1b What did water for the environment (and specifically CEW) contribute to low flows and freshes in the Mid-Murray Area?
	Flows-A2	Flows-A2a During winter shutdown conditions, was longitudinal connectivity maintained in Wakool River, Yallakool Creek and Colligen-Niemur river system? Flows-A2b What did water for the environment (and specifically CEW) contribute to maintaining longitudinal connectivity in Wakool River, Yallakool Creek and Colligen-Niemur river system during winter shutdown?
	Flows-A3	Flows-A3a What wetland and floodplain inundation occurred in the Mid-Murray Area, specifically Werai Lands and Niemur Forest? Flows-A3b What did water for the environment (and specifically CEW) contribute to wetland and floodplain forest inundation in these locations?
Native vegetation	Vegetation-A1	What did CEW contribute to maintaining representative communities of native vegetation in the Mid-Murray Area?
	Vegetation-A2	What did CEW contribute to maintaining or improving the condition of forests and woodlands in the Mid-Murray Area?
	Vegetation-A3	Vegetation-A3a Was the condition of lignum shrublands maintained or improved in selected locations in the Mid-Murray Area? Vegetation-A3b What did water for the environment (and specifically CEW) contribute to this outcome in these locations?
	Vegetation-A4	Vegetation-A4a Were populations and communities of non-woody vegetation in selected locations in the Mid Murray Area maintained or improved? Vegetation-A4b How was this influenced by flow? Vegetation-A4c What did water for the environment (and specifically CEW) contribute to this outcome?

Native Fish	Fish-A1	Fish-A1a Did native fish recruit in the Mid-Murray Area? Fish-A1b How was this influenced by flow? Fish-A1c What did water for the environment (and specifically CEW) contribute to this outcome? Years 1 to 5: Annual evaluation will focus on A1a, with qualitative interpretations for A1b and A1c. In Year 5 a quantitative model will be used to answer question A1b and A1c.
	Fish-A2	Fish-A2a Were native fish population structures maintained or improved in the Mid-Murray Area? Fish-A2b How was this influenced by flow? Fish-A2c What did water for the environment (and specifically CEW) contribute to this outcome? Years 1 to 5: Annual evaluation will focus on A2a, with qualitative interpretations for A2b and A2c. In Year 5 a quantitative model will be used to answer question A2b and A2c.
	Fish-A3	Fish-A3a Was native fish abundance maintained or improved in the Mid-Murray Area? Fish-A3b How was this influenced by flow? Fish-A3c What did water for the environment (and specifically CEW) contribute to this outcome? Years 1 to 5: Annual evaluation will focus on A3a, with qualitative interpretations for A3b and A3c. In Year 5 a quantitative model will be used to answer question A3b and A3c.
	Fish-A4	Fish-A4a Was native fish condition maintained or improved in the Mid-Murray Area? Fish-A4b How was this influenced by flow? Fish-A4c What did water for the environment (and specifically CEW) contribute to this outcome? Years 1 to 5: Annual evaluation will focus on A4a, with qualitative interpretations for A4b and A4c. In Year 5 a quantitative model will be used to answer question A4b and A4c.
	Fish-A5	What hydrological, temperature and other environmental conditions are associated with golden perch and silver perch spawning in the Edward/Kolety River?
Cultural Outcomes	Cultural-A1	How did the CEWH and the Mid-Murray Flow-MER Program support First Nations engagement and outcomes activities over the water year?
	Cultural-A2	How have the CEWH and the Mid-Murray Flow-MER Program planned, delivered and evaluated Commonwealth environmental watering actions with involvement of First Nations peoples?
Sentinel Surveillance of dissolved oxygen for early detection of hypoxia	Dissolved oxygen – A1	How effective was the sentinel surveillance monitoring of dissolved oxygen for early detection of hypoxia in enabling CEWH and other stakeholders to adaptively manage Commonwealth environmental water in the Mid-Murray Area?
	Dissolved oxygen – A2	How effective was the contribution of citizen science and First Nations science to the sentinel surveillance monitoring?
River Murray Channel Monitoring project	Not assessed	RMC questions not evaluated as part of Flow-MER Mid-Murray project.

It is not possible to undertake monitoring and evaluation in all thirty-five of the hydrological zones identified in the Mid-Murray River system (Figure 2.2). Prioritisation of hydrological zones and indicators was undertaken in consultation with our program partners, stakeholders and water delivery teams.

The following factors were considered when prioritising the zones to include in the MER Plan:

- Likelihood of hydrological zones receiving Commonwealth environmental water and aligning with CEW watering objectives in the Mid-Murray (see section 3)
- Location of hydrological gauging stations
- Availability of historical monitoring data in each zone and existing arrangements for access, including maintaining continuity of monitoring established during the LTIM and Flow-MER Programs
- Ease of access for undertaking fieldwork under a range of weather conditions
- Need for a number of zones that experience a range of flows to facilitate predictive ecosystem response modelling and Area gradient analysis
- Capacity to inform on specific objectives aligned with values and needs of local community, including First Nations peoples.

4.4 Monitoring that contributes to River Murray Channel Project

As part of the Area-scale evaluation, monitoring will be undertaken that will contribute data for the evaluation undertaken by CSIRO for the River Murray Channel project.

As environmental watering in the southern Murray–Darling Basin has evolved there is a growing need to better understand outcomes and learn from coordinated delivery at a system scale. Each year the SCBEWC develops a RMC delivery plan to assist environmental water holders to plan for coordinated system scale delivery. A five-year Monitoring and Evaluation Plan was developed for the RMC commencing in 2021 to evaluate outcomes in the RMC from Hume Dam to the Murray Mouth. The project is led by CSIRO Land and Water. Key objectives for ecosystem functions that are targeted in RMC monitoring include:

- To better understand how key ecological indicators respond to flow to inform improved decision making and adaptive management of water for the environment in the River Murray Channel.
- Supporting nutrient, carbon and sediment transport along channels, and between channels and floodplains/wetlands.
- Supporting instream and floodplain productivity.

A component of the on-ground monitoring of RMC sites in the Mid-Murray Flow-MER Area will be undertaken as part of the Mid-Murray Flow-MER Project following the design and requirements as outlined in the RMC Plan. Samples from the monitoring will be provided to CSIRO staff for laboratory processing. The RMC monitoring is expected to be undertaken during 2024-25 and 2025-26 to complete the RMC five-year plan, which will then be reviewed by the Southern Connected Basin Environmental Watering Committee to determine its future direction. Thus, monitoring to contribute to the RMC project has been incorporated into the Mid-Murray MER Plan for only the 2024-25 and 2025-26 water years.

5 Indicators

Indicators were selected to be consistent with the Program MERI Strategy, and Basin Evaluation Approach and to have input into a whole of Basin evaluation of the contribution of Commonwealth environmental water to the objectives of the Basin Plan. The selection of indicators and metrics as well as underlying predictor variables such as habitat type and hydrology have been established to evaluate a range of watering actions in the Mid-Murray (see Table 3.1, Section 3).

This section provides information on themes and Indicators for Basin-Scale, Area-Scale and River Murray Channel monitoring activities. Details of evaluation questions, methods, timing and monitoring locations for each indicator will be provided.

Indicators for the following Basin-scale and Area-scale themes are described in this section:

- River flows and connectivity (Basin-scale and Area-scale)
- Native vegetation (Basin-scale and Area-scale)
- Native fish (Basin-scale and Area-scale)
- Cultural outcomes (Basin-scale and Area-scale)
- Sentinel surveillance of dissolved oxygen for hypoxia detection (Area-scale)
- River Murray Channel Project monitoring (Area-scale)

5.1 River flows and connectivity (Basin-scale and Area-scale)

5.1.1 Background

Hydrology is one of the fundamental drivers of the structure and function of riverine and floodplain ecosystems (Bunn and Arthington 2002). River flows provide longitudinal and lateral connectivity, and create hydraulic conditions in the riverine environment. Altered flow regime is one of the key factors that have impacted the heath of rivers in the Murray–Darling Basin. The delivery of water for the environment is an important part of maintaining and restoring river health.

The river flows and connectivity theme in the Mid-Murray Area will focus on evaluation questions that quantify the contribution of Commonwealth environmental water to hydrological outcomes. Hydrological data are also essential to the evaluation questions in other themes.

The river flows and connectivity theme will describe the flow and inundation regime of rivers and wetlands in the Mid-Murray Area, which includes the Edward/Kolety-Wakool system as well as the Murray River from Hume Dam to Mildura, and includes inflows from several other waterways. The Mid-Murray Area is substantially larger and significantly more hydrologically integrated than the previous Edward/Kolety-Wakool Selected Area, that focused on the Edward/Kolety-Wakool system. Previous LTIM and Flow-MER monitoring and evaluation did not include the Niemur floodplain, Barmah Forest (Ramsar), Millewa forest (part of the NSW Central Murray Forests Ramsar site), Koondrook-Perricoota Forest (part of the NSW Central Murray Forests Ramsar site), Gunbower Forest (Ramsar), and Hattah-Kulkyne Lakes (Ramsar). The Werai Lands were included in the Flow-MER Program but excluded from the earlier LTIM Program.

5.1.2 Evaluation questions

Basin-scale questions

The overarching Flow-MER2.0 Basin-scale River Flows and Connectivity evaluation question is '*What did Commonwealth environmental water contribute towards the restoration of the hydrological flow regime*?' The specific evaluation questions are:

Basin-scale River flow and connectivity evaluation questions
Flows-B1. What did CEW contribute to the regime of low flow conditions, freshes, and bank-full flows?
Flows-B2. What did CEW contribute to connectivity, including overbank inundation?

Area-scale questions

The Flow-MER Mid-Murray Area-scale River Flows and Connectivity questions align with the Basin-scale River Flows and Connectivity evaluation questions, but with a Mid-Murray focus.

Area-scale River flow and connectivity evaluation questions
Flows-A1a What low flow conditions and freshes occurred in the Mid-Murray Area? Flows-A1b What did water for the environment (and specifically CEW) contribute to low flows and freshes in the Mid-Murray Area?
Flows-A2a During winter shutdown conditions, was longitudinal connectivity maintained in Wakool River, Yallakool Creek and Colligen-Niemur river system? Flows-A2b What did water for the environment (and specifically CEW) contribute to maintaining longitudinal connectivity in Wakool River, Yallakool Creek and Colligen-Niemur river system during winter shutdown?
Flows-A3a What wetland and floodplain inundation occurred in the Mid-Murray Area, specifically Werai Lands and Niemur Forest? Flows-A3b What did water for the environment (and specifically CEW) contribute to wetland and floodplain forest inundation in these locations?

5.1.3 Monitoring

Basin-scale

Data collection for the Basin-scale evaluation of River flows and connectivity theme follow the prescribed methods as outlined in Chapter 4 of the Flow-MER Basin-scale Evaluation Approach (McInerney et al. 2024). The Basin-scale River flows and connectivity theme will contribute to the development of foundational hydrology data sets and allow data to be used for both Basin-scale and Area-scale evaluation (McInerney et al. 2024). As such, data does not need to be collected by the Mid-Murray Area-scale Project team for Basin-scale evaluation.

The indicators, data requirements and source of the data used to address the Basin-scale evaluation questions are outlined in Table 5.1.

Area-scale

A summary of the indicators, data requirements and data sources for each Area-scale evaluation questions are outlined in Table 5.2, with data collection details described below.

Low flows, freshes and bank-full flows (Evaluation question A1)

Data collection

Daily flow data will be sourced from the existing network of gauges, and flow and water level data will be downloaded from the WaterNSW and Victorian water data websites for study sites that are relevant to the evaluation of river flows and connectivity as well as native fish, waterbirds, native vegetation and water quality outcomes. Hydrographs will be produced for these key gauges providing a comparison of flows with and without Commonwealth environmental water ('the counterfactual') based on release information provided by Commonwealth and state-based water agencies, the CEWH or other delivery partners such as Murray Irrigation Limited. Hydrological modelling provided by MDBA for nodes throughout the Mid-Murray is essential for this evaluation. Staff gauges have been installed at locations within the Edward/Kolety-Wakool River system as part of the LTIM and earlier Flow-MER programs and manual readings of river heights from these gauges may complement gauged flow data.

Site selection

Area-scale site establishment is linked to the evaluation methods for all themes with sites matched to the sampling locations. River gauges will be chosen to provide the most relevant flow data to describe responses to watering actions or objectives each year.

Timing of monitoring

The use of existing gauge data means that data are available throughout the year and records the passing of Commonwealth environmental water and other water. The event-based inundation depth and duration will be estimated and reported annually.

Longitudinal connectivity (Evaluation question A2)

Data collection

Imagery from the Planet satellite with 3.7 m spatial resolution and daily temporal resolution will be used to produce longitudinal connectivity and fragmentation maps during extreme (drought) events and/or the MIL winter maintenance period.

Site selection

While the occurrence of extreme events cannot be predicted, the MIL winter maintenance zones are defined in advance. Each year of the program will focus on the relevant maintenance zone for the analysis. Evaluation of connectivity during winter shutdown period will focus on the Wakool River, Yallakool Creek and the Colligen-Niemur River.

Analysis for the extreme (drought) events will be defined under responsive monitoring.

Image processing

Connectivity maps for single dates will be produced for cloud free days and low cloud cover days providing the relevant waterways are not obscured. If clouds are present in the mapped area, a mask layer is manually created to clearly identify them in the map. A final map will be produced with three classes: inundated, off-river storage and cloud to show area of water in channels across the area of interest.

Note: The image processing approach for this analysis will be developed in Year 1 and improvements in data accuracy are expected throughout Flow-MER2.0.

Event maps

To produce contiguous maps that cover each channel being monitored, data obtained on a single day are combined and clipped to the required extent. Using the three classes (inundated, off-river storage and cloud) a pixel wise summation of all maps will be performed for the period of the event (shut-down period / drought period). Pixels with a value greater than zero are reclassified to one, to produce a binary map that shows the length of channel where inundation has been detected and the number of days water is present. These maps will be provided in either a jpeg or png format and included in the annual report, quarterly outcomes newsletter and snapshot, and other communication paths when relevant.

A final connectivity map will be created with the number of days connected or disconnected for lengths of channel. These maps will be provided in either a jpeg or png format and included in the annual report, quarterly outcomes newsletter and snapshot, and other communication paths when relevant.

Floodplain wetland inundation (Evaluation question A3)

Data collection

Imagery from the Landsat and Sentinel-2 satellite with 30 m and 10 m spatial resolution and up to five-day temporal resolution will be used to produce inundation maps using the new approach outlined by Lymburner et al. (2024).

Site Selection

The target area for the assessment of extent and duration of CEW inundation will be the Werai Lands and Niemur Forest.

Image processing & event mapping

The new inundation methodology outlined by Lymburner et al. (2024) will be applied to available Landsat and Sentinel imagery to create a library of inundation extents for the target sites. Each

inundation extent can be linked to the closest flow gauge to create an area-inundation metric database. For each year, the extents will be mapped and compared to the library providing a comparison of flow events with and without Commonwealth environmental water.

Historic event inundation (within and without Commonwealth environmental water), and time-lapse camera imagery mapping from the previous Flow-MER Program will be used to verify the Year 1 inundation extents. Depth loggers and time-lapse imagery within the Werai Lands will be used for on-going verification of the inundation extents.

Event maps will be produced, which will include a progression map for each event displaying the expansion and contraction of an event and the duration of inundation in the wetlands for a given event. These maps will be provided in either a jpeg or png format and included in the annual report, quarterly outcomes newsletter and snapshot, and other communication paths when relevant.

Note: The image processing approach will be developed during Year 1 of the Program and improvements in data accuracy are expected throughout Flow-MER2.0 (see Research project section 6).

Depending on the outcomes, it may be possible to extrapolate this approach to other wetlands in the Area.

Table 5.1 Basin-scale evaluation question summary table for river flows and connectivity

Basin-scale evaluation questions	Indicators	Data requirements	Data sources
Flows-B1. What did CEW contribute to the regime of low flow conditions, freshes and bank-full flows?	Timing, duration and magnitude of flow events attributable to environmental water	No data required from Area-scale teams	Watering actions tables: CEWH Area-scale reports Daily flow and water level data at relevant gauging stations.
Flows-B2. What did CEW contribute to connectivity, including over-bank inundation?	Timing, duration and extent of inundation attributed to environmental water	No data required from Area-scale teams	-

Table 5.2. Area-scale evaluation question summary table for river flows and connectivity

Area-scale evaluation questions	Indicators	Data requirements	Data sources
Flows-A1a What low flow conditions and freshes occurred in the Mid-Murray Area? **Flows-A1b What did water for the environment (and specifically CEW) contribute to low flows and freshes in the Mid-Murray Area?**	Timing, duration and magnitude of flow events attributable to environmental water	Watering actions Gauged flow data Accounting data for watering actions	Watering actions: CEWH and NSW DCCEEW Daily flow and water level (stage) data for relevant gauging sites: WaterNSW Water accounting data: the CEWH and the NSW DCCEEW Counterfactual modelling (MDBA)
Flows-A2a During winter shutdown conditions, was longitudinal connectivity maintained in Wakool River, Yallakool Creek and Colligen-Niemur river system? **Flows-A2b What did water for the environment (and specifically CEW) contribute to maintaining longitudinal connectivity in Wakool River, Yallakool Creek and Colligen-Niemur river system during winter shutdown?**	River length connected / disconnected during extreme (drought) event or winter shut-down Duration of longitudinal connection / disconnection maintained Extent and location of individual pools which form	Watering actions Remotely sensed inundation Observations of inundation	Watering actions: CEWH and NSW DCCEEW Sentinel, Landsat and Planet Imagery Field observations
Flows-A3a What wetland and floodplain inundation occurred in the Mid-Murray Area, specifically Werai Lands and Niemur Forest? **Flows-A3b What did water for the environment (and specifically CEW) contribute to wetland and floodplain forest inundation in these locations?**	Timing, duration and extent of inundation attributed to environmental water	Watering actions Remotely sensed inundation Observations of inundation Water depth	Watering actions: CEWH and NSW DCCEEW Sentinel and Landsat Imagery Field observations Depth loggers

5.1.4 Evaluation

Basin-scale

The evaluation for Basin-scale River Flows and Connectivity theme is outlined in Chapter 4 of McInerney et al. 2024.

Area-scale

Within the Mid-Murray Area, the evaluation of River Flows and Connectivity in Flow-MER2.0 will align with the Basin-scale approach (Section 4 of McInerney et al. 2024), with a focus on the watering events which occurred within the Mid-Murray Area, including reporting outcomes against watering objectives. Changes in the duration, timing and magnitude of flow within-channel, connectivity (both longitudinal and lateral) caused by the management of environmental water will allow the assessment of the two broad Basin-scale evaluation questions (Flows-B1 and B2) and the Area-scale evaluation questions in the Mid-Murray Area (Flows-A1, A2 and A3). Hydrological modelling provided by MDBA for nodes throughout the Mid-Murray is essential for this evaluation.

Low flows, baseflows, cease to flows, freshes (Flows-A1)

The Area-scale team will conduct gauge-based (hydrograph) hydrologic analysis of environmental watering actions, which describe the Commonwealth environmental water contributions to the flow regime for each watering event at a series of nodes throughout the Mid-Murray Area where counterfactual modelling is available from the Murray-Darling Basin Authority.

The hydrographs will be interrogated to describe the range of effects on the different hydrological zones within the system, as for the previous Flow-MER Program, and expanded out in geographical area to include the broader Mid-Murray hydrologic zones. The hydrologic zones to be reported will be prioritized based on alignment with evaluation requirements of the other themes. The response to flows will be described in terms of change in volume by hydrologic zone/creek, hydrologic metrics (e.g. coefficient of variation). This flow information will be used as foundational information to provide context to the conditions that resulted in a response observed in the other Themes (such as in native fish).

Longitudinal Connectivity (Flows-A2)

Maps and metrics of waterway and/or pool longitudinal connectivity, and persistence within the maintenance zones will inform a descriptive assessment of how well connectivity is maintained over the winter shutdown period in the Wakool River, Yallakool Creek and the Colligen-Niemur River.

A similar approach will be adopted for extreme (drought) events.

These results will be contributing to evaluation in the other themes to inform the assessment of what the presence or absence of Commonwealth environmental water contributions means in terms of ecological outcomes and inform adaptive management actions.

Lateral Connectivity (Flows-A3)

The inundation mapping outputs will be evaluated to describe the Commonwealth environmental water contributions to the flow regime for each watering event for the Werai Lands and Niemur Forest where counterfactual modelling is available from the Murray-Darling Basin Authority.

This approach will provide an event-based evaluation of environmental water, allowing an accurate and repeatable way to report on the contribution of environmental water at improving over-bank

inundation and fundamental event-based flow information for the Area-scale evaluation of vegetation and waterbirds.

Contribution to other themes

Ecologically relevant flow or inundation metrics for CEW events will be extracted from the river flow and connectivity data to be used in the evaluation of responses observed in the other themes (e.g., native fish, native vegetation).

5.1.5 Data management

All data for the within-channel component of this indicator will be publicly available through the Flow-MER Monitoring Data Management System (MDMS) and uploaded annually. Uploading of data to the Flow-MER MDMS will be led by the Mid-Murray data theme lead, Dr Nicole Mccasker.

5.1.6 Risks and dependencies

- Hydrographs will be produced for key gauges, providing a comparison of flows with and without Commonwealth environmental water. This information is also being produced by the Basin-scale team for some of the flow gauges. However, due to the timing of the outputs and reporting, the likely reduced number of hydrograph sites in the Basin-scale evaluation compared to the Area-scale requirements, and the criticality of this information for the evaluation of other themes, the Area-scale team will undertake the analysis for the Area-scale reporting.
- The lack of gauging at key sites (e.g., Werai Lands) and upgrades to some regulating structures are proposed. The flow-inundation extent relationships will need to be checked following infrastructure upgrades to confirm their suitability for this analysis.
- The timely provision of daily data on CEW water/non-CEW water for selected flow gauges to be provided by the CEWH by 1 August every year is foundation to annual evaluation in order for the Mid-Murray team to meet our annual evaluation milestones.
- The timely provision of models from the Murray-Darling Basin Authority of Commonwealth environmental water delivered from Hume Dam to the Murray River and return flows from Millewa Forest to the Edward River and for other odes in the Mid-Murray Area is critical in order for the Mid-Murray team to meet our annual evaluation milestones.

5.1.7 Responsibilities

The evaluation of the contribution of CEW to off-channel sites will be undertaken by Streamology and CSU, led by Dr. Christine Lauchlan Arrowsmith. The interpretation of the data, presentation of the results and annual reporting will be led by river flows and connectivity theme lead Dr Christine Lauchlan Arrowsmith and with support from Professor Robyn Watts from the Mid-Murray Area team at CSU. Monitoring of water levels and ground-truthing of inundation on Werai Lands will be undertaken in collaboration with First Nations peoples.

5.2 Native vegetation (Basin-scale and Area-scale)

5.2.1 Background

Native vegetation plays an important role in the functioning of aquatic ecosystems, supporting riverine productivity and food webs and providing habitat for fish, frogs, birds and invertebrates. Flow management and the hydrological regimes of river systems can affect the condition, survival, growth and maintenance of adult plants and influence reproductive cycles, including flowering, dispersal, germination and recruitment.

The mid-Murray Area has high-value aquatic plant communities (see section 2) including the NSW Central Murray Forests Ramsar site (NSW Office of Environment and Heritage 2018), Barmah Ramsar site, Hattah-Kulkyne Lakes Ramsar Site, and Gunbower Ramsar site being matters of national environmental significance to which the EPBC Act applies.

Riparian areas of river channels and lower areas of the floodplain support river red gum forest (*Eucalyptus camaldulensis*) forest and woodland. The most frequently inundated channels; drainage depressions and oxbow lagoons support reed beds, sedgelands and wet grasslands. Areas of tangled lignum (*Duma florulenta*) are also located on the floodplain. Higher, less frequently flooded portions of the floodplain support black box (*Eucalyptus largiflorens*) woodland with an understorey of flood-tolerant grasses and saltbushes.

The Mid-Murray Area has had a history of river regulation. This, combined with other factors, such as the prolonged Millennium Drought (van Dijk 2013; Chiew et al. 2014), riparian land use, and introduced species (e.g., feral pigs) has had negative impacts on native vegetation in the Mid-Murray Area.

As part of the Flow-MER2.0 native vegetation evaluation, we will quantify and interpret the response of key plant species and communities in response to delivery of water for the environment, considering the effects of annual (12 months) and historical (>10 years) flow regimes.

5.2.2 Evaluation questions

The monitoring of Native Vegetation in the Mid-Murray Area will address both the Basin-scale requirements to meet the needs of Basin-scale evaluation, and the Area-scale evaluation questions to evaluate the contribution of CEW within the Mid-Murray Area and inform adaptive management.

Basin-scale questions

The Flow-MER Basin-scale Native Vegetation evaluation questions, as outlined in Chapter 5 of McInerney et al. (2024) are:

Basin-scale Native Vegetation evaluation questions
Vegetation-B1 What did CEW contribute to maintaining representative communities of native vegetation in the Basin?
Vegetation-B2 What did CEW contribute to maintaining or improving the condition of forests and woodlands?
Vegetation-B3 What did CEW contribute to maintaining or improving the condition of lignum shrublands?
Vegetation-B.4 What did CEW contribute to maintaining or improving representative populations and communities of non-woody vegetation?

Area-scale questions

Area-scale Native Vegetation evaluation questions
Vegetation-A1 What did CEW contribute to maintaining representative communities of native vegetation in the Mid-Murray Area?
Vegetation-A2 What did CEW contribute to maintaining or improving the condition of forests and woodlands in the Mid-Murray Area?
Vegetation-A3a Was the condition of lignum shrublands maintained or improved in selected locations in the Mid-Murray Area? Vegetation-A3b What did water for the environment (and specifically CEW) contribute to this outcome in these locations?
Vegetation-A4a Were populations and communities of non-woody vegetation in selected locations in the Mid Murray Area maintained or improved? Vegetation-A4b How was this influenced by flow? Vegetation-A4c What did water for the environment (and specifically CEW) contribute to this outcome?

5.2.3 Monitoring

Basin-scale

The indicators, data requirements and data sources for each Basin-scale Native Vegetation evaluation question, as outlined in Chapter 5 of McInerney et al. (2024), are listed below (Table 5.3). The evaluation of Native Vegetation outcomes will use a combination of spatial analysis, data collected using drones and field-based methods.

Table 5.3 Basin-scale evaluation question summary table for native vegetation

Basin-scale evaluation questions	Indicators	Data requirements	Data sources
Vegetation-B1. What did CEW contribute to maintaining representative communities of native vegetation in the Basin?	Extent and frequency of inundation of vegetation community types (ANAE classes)	Remotely sensed indicators of extent and frequency of inundation of vegetation communities (ANAE classes).	No Area-scale data required. In year 1 Area-scale team to undertake field validation of ANAE boundaries
Vegetation-B2. What did CEW contribute to maintaining or improving the condition of forests and woodlands?	Tree condition (satellite derived metrics e.g. fractional cover, greenness, evapotranspiration)	Basin-scale evaluation uses remotely sensed indicators of tree condition and does not rely on Area-scale data.	No Area-scale data required
Vegetation-B3. What did CEW contribute to maintaining or improving the condition of lignum shrublands?	Lignum condition (field and/or drone measures)	Annual surveys at a minimum of 3 lignum shrubland locations at 2 paired (50 x 50 m) treatment and control plots	Drone or field-based estimates
Vegetation-B4. What did CEW contribute to maintaining or improving representative populations and communities of non-woody vegetation?	Richness/ cover of water dependent groundcover species, including those known to be used by First Nations people. Community structure	Species richness and percent cover estimates within 20 x 20 m plots within key ANAE types.	Field-based surveys

Area-scale

The indicators, data requirements and data sources for evaluating the Mid-Murray Area-scale Native Vegetation questions are similar to Basin-scale native evaluation questions (Table 5.4).

Table 5.4 Mid-Murray Area-scale evaluation question summary table for native vegetation

Area-scale evaluation questions	Indicators	Data requirements	Data sources
Vegetation-A1 What did CEW contribute to maintaining representative communities of native vegetation within the Mid-Murray Area?	Extent and frequency of inundation of target vegetation community types (ANAE classes)	Accounting data for watering actions Sentinel and Landsat imagery ANAE Types and wetland locations	Watering actions: CEWH and NSW DCCEEW. Water accounting data: the CEWH and the NSW DCCEEW. Data from ANAE analysis of sentinel and Landsat imagery will be provided by the Basin-scale team
Vegetation-A2 What did CEW contribute to maintaining or improving the condition of forests and woodlands in the Mid-Murray Area?	Tree condition (satellite derived metrics e.g., fractional cover, greenness, evapotranspiration)	Basin-scale evaluation uses remotely sensed indicators of tree condition	No Area-scale data required. Data for the Mid-Murray Area will be provided by the Basin-scale team to be included in Mid-Murray Area reporting
Vegetation-A3a Was the condition of lignum shrublands maintained or improved in selected locations in the Mid-Murray Area? **Vegetation-A3b What did water for the environment (and specifically CEW) contribute to this outcome in these locations?**	Percent cover of lignum in two condition classes (high and low quality) Quality: based on viability and colour using methods in Campbell et al 2021	Annual surveys at a minimum of 3 lignum shrubland locations at 2 paired (50 x 50m) treatment and control plots	Drone imagery flown by Area-scale team, analysed by Basin-scale team. On-ground surveys of condition
Vegetation-A4a Were populations and communities of non-woody vegetation in selected locations in the Mid Murray Area maintained or improved? **Vegetation-A4b How was this influenced by flow?** **Vegetation-A4c What did water for the environment (and specifically CEW) contribute to this outcome?**	Composition, cover and species richness of water dependent groundcover species, including those known to be used by First Nations People. Community structure	Species richness and percent cover estimates within 20 x 20 m plots.	Field-based surveys in Spring and Autumn each year (groundcover diversity) in selected locations.

Considerations for selection of study locations

To address the needs of the Basin-scale and Area-scale evaluation questions, data will be collected from fixed locations across the Mid-Murray Area. The Mid-Murray Area contains several Ramsar sites and wetlands of national and regional significance as listed in the Directory of Important Wetlands (Environment Australia 2001) and these which will be the main focus of the Native Vegetation Theme monitoring and evaluation.

The vegetation response will be measured across the Area-scale and the evaluation stratified by Australian National Aquatic Ecosystem (ANAE) type (Brooks et al. 2021) and by the classification of Green (1997). The vegetation community in the Mid-Murray Area is dominated by woodland communities, with river red gum and river red gum communities prevalent in areas inundated by CEW. Tangled lignum occurs of floodplains and aquatic reeds, grasses and sedges are represented in some wetland locations.

Many of the wetlands are likely to be targeted with CEWH, MDBA, NSW DCCEEW or VEWH environmental flow deliveries over the next 5 years (2024–29). As part of Flow-MER2.0, the criteria used to select locations for inclusion in the Native Vegetation Theme monitoring and evaluation are:

1) Representative: Each location should be representative of the broader area and not a peculiarly unique to that location. In combination the locations should adequately represent the range of inundation dependent vegetation characteristic of the Mid-Murray Area.
2) Asset: The location must include a vegetation asset that is the target for CEW and/or for monitoring and evaluation for a given location (i.e. reedbeds in Werai Lands).
3) Continuity of long-term data sets: Groundcover survey locations will be selected to maintain some monitoring locations from LTIM/Flow-MER1.0 programs where possible, with the view to continue long-term data sets, which at some locations has now been maintained since 2014.
4) Likelihood of watering: Selected locations must be within scope to be likely to receive CEW at least once in the next five years.
5) Local importance: The location is of importance to local First Nations peoples or the local community, and they have shown commitment to being involved in the monitoring and evaluation.

Representative communities of ANAE vegetation types (Vegetation-B1, Vegetation-A1)

Field methods

Field work will be undertaken to complete a one-off validation of ANAE locations at target locations from which data will be collected, to improve/correct the ANAE base-map to ensure relevance at Area-scale. Updated ANAE layer for the Mid-Murray Area to be provided by CEWH.

Area Team aims to validate *a subset* of targeted locations identified in the ANAE layer. Potential locations include:

- Existing long term established vegetation transects (since 2014). Listed currently as Rt1.4: Temporary lowland stream (n=9) and F1.2: River red gum forest riparian zone or floodplain (n=11). These locations receive water via Wakool Offtake, Yallakool Offtake and the Colligen Creek regulator.
- Werai Lands and the Niemur Forest are poorly understood and are culturally significant areas that form part of the RAMSAR listed NSW Central Murray Forests Ramsar site. Werai Lands is proposed to be an Indigenous Protected Area (IPA) owned by Traditional Owners (Werai Land and Water Aboriginal Corporation). Validation of the ANAE dataset will help better understand

the area. These forests are planned to receive CEW in 2024-25 and subsequent years via Steven's Weir and the Tumudgery Creek.

- Several lignum shrubland (ANAE class F2.2) locations near Mildura, VIC (Figure 5.1) will contribute to Basin scale understanding of lignum condition. These locations typically receive environmental water via regulator and metered pumps. The CEWH Southern Delivery team has expressed an interest in providing water to these sites (NSW) as they are identified in NSW Long Term Watering Plans (LTWP) and opportunistically support waterbirds. Furthermore, these locations are rich in Cultural history and provide an opportunity for First Nations to work and learn On Country. This will facilitate two-way knowledge exchange.

The validation of ANAE target locations will be undertaken once in 2024-25. Suitably qualified staff will ground truth ANAE habitat types at targeted locations which currently include the Werai Lands and Niemur Forest and several lignum shrubland locations near Mildura, VIC. We will use GPS to mark locations and confirm data. Validation at Werai Lands provides an opportunity for First Nations and Traditional Owners to work and learn On Country. Wherever possible, we will engage First Nation Peoples to undertake work with qualified staff.

Remotely sensed estimates of CEW inundation (Vegetation-A1)

Indicators

- Extent and frequency of inundation of vegetation community types (ANAE classes)
- Richness/cover of water dependent groundcover species, including those known to be used by First Nations People
- Community structure

Evaluation

Evaluation question Vegetation-A1, which evaluates the contribution of CEW to maintaining native vegetation communities within the Mid-Murray Area, will draw on event-based remotely sensed estimate of inundation extent and duration (reported as part of the river flows and connectivity theme Flows-A3). The remotely sensed inundation extent and duration data will be intersected with the locations of vegetation communities (such as river red gum woodlands) or target assets (such as the reedbed of Werai Lands) to provide an evaluation of the role of CEW for vegetation communities or assets in a target area. Inundation duration and extent data for watering events which target floodplain and wetland vegetation communities will be provided by flows and connectivity Flows-A3 including figures showing inundation extent.

Condition of forests and woodlands (Vegetation-B2, Vegetation-A2)

This question will be evaluated at the Basin-scale by remote sensing. No data are required to be collected by the Mid-Murray Area team. If data are processed by the Basin-team in a timely way and available for Area-scale reporting the data for Mid-Murray may be included in the Annual evaluation report.

Condition of lignum shrublands (Vegetation-B3, Vegetation-A3)

Indicators

- Condition of lignum in lignum shrublands
- Cover and quality of lignum in lignum shrublands at locations managed with CEW.

Monitoring Locations

Three lignum shrubland (ANAE class F2.2) locations near Mildura (Figure 5.1, Table 5.5 and Table 5.6) were selected to contribute to Basin-scale and Area-scale understanding of lignum condition responses to environmental watering actions. These locations typically receive environmental water via regulator and metered pumps:

- Gol Gol Swamp
- Gol Gol Lake
- Gol Gol State Forest (Bottle Bend)

A additional location in Fletchers Creek and Reserve may be included in the study. Although this location is just downstream of lock 10, it is of interest because there are prior lignum survey data available for this location, it is of interest to local First Nations peoples, and it is likely to receive environmental water during the timeframe of Flow-MER 2.0. Other possible locations include Bullock Swamp in Victoria which is also of interest for local engagement.

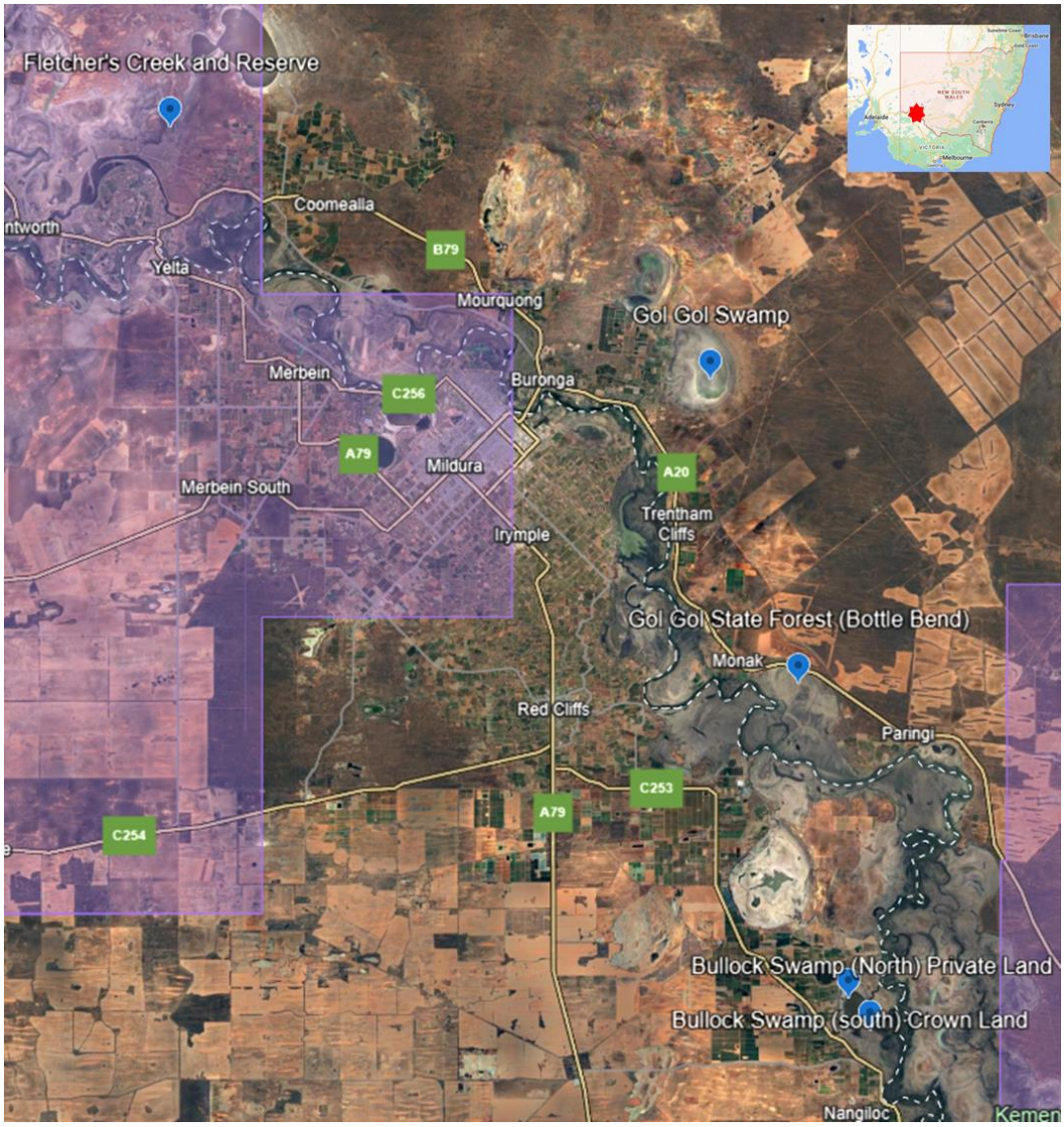

Figure 5.1 Monitoring locations for Lignum monitoring Flow-MER 2.0 near Mildura, VIC (https://earth.google.com/earth/d/1mhuDnW6OPm3VcfvCtjJOz06Rhh5RiXfm?usp=sharing)

Methods

Drone Surveys – We will apply Machine Learning using the methods developed by Higgisson et al. (2023) and summarised in Table 5.5. A minimum of two paired 50 m by 50 m (two treatment; two control) plots will be established at lignum shrublands (ANAE class F2.2) at each location (n=3). At each location surveys will occur annually at two plots that receive CEW (treatment) and two plots that do not receive CEW (control). The four 50 X 50m plots will be established at each of the selected wetland location based on these criteria:

- Two 50 X 50 m plots will be established within the maximum environmental watering zone.
- Two 50 X 50 m plots will be established outside the maximum environmental watering zone.
- Each plot should have ideally >20% and <70% cover of lignum to provide opportunity to increase or decrease in lignum cover in response to environmental watering.
- The approximate area will be flown, and imagery captured using a drone, the first time and the plot boundary will be established in the office using the imagery.
- No markers or pegs are required, as plots will be established using coordinate data and polygons of the imagery.

Data collection

The data will be collected using a drone and analysed using deep-machine learning.

1. Standard red, green and blue (RGB) imagery will be collected using a drone.
2. All flights will comply with Commonwealth regulations and will be conducted by a licensed pilot.
3. The flight missions will be set in a normal grid, with an overlap along and across-track of 80% at an altitude of 30 metres, which provides a resolution of 0.9 pixels per centimetre by using the minimum UAV speed possible at 2.0 m/s.
4. Flights will be conducted in clear conditions in the middle of the day (10.00 am – 3.00 pm) to reduce shading in the images.
5. Survey locations are located on Crown land and private property and flights will occur with the landholder's knowledge and approval to fly.

Data analysis

Drone data will be analysed by Basin-scale team and provided for Area-scale evaluation.

Following the flights, the RGB images will be aligned and processed - after a dense point cloud generation - into a single high-resolution true ortho-mosaic image for each plot. After building the ortho-images and DEM as GeoTIFF (Tagged Image File Format storing georeference and geocoding information), the ortho-mosaic images will be clipped via an overlay around the 50 x 50 m plot borders positioned with GPS coordinates.

The stitched ortho-mosaic images of each plot are then sliced into 128 X 128-mm image slices which are supplied to a built-for-purpose deep-machine learning model which has been developed to estimate cover for seven wetland attributes; two condition classes of tangled lignum (*Duma florulenta*) (high quality green and low quality brown/grey) along with other wetland attributes (e.g. water, bare ground and leaf litter, groundcover vegetation, nitre goosefoot and trees).

Further information on the development, accuracy and outputs for each of these machine learning models can be found at Higgisson et al. (2021a) for the common reed model and Higgisson et al. (2023) for the lignum model.

Field surveys

To measure lignum condition, a minimum of four 20 m x 20 m quadrats will be established at lignum shrublands (ANAE type F2.2) where possible. The condition of every lignum plant will be assessed on ground using two rating scales, namely, viability and colour based on methods outlined in Campbell et al. (2021). Ground surveys will be nested within Drone survey quadrats to validate drone data. This will be undertaken annually and concurrently with drone photogrammetric surveys. LCI monitoring has the potential to increase survey effort following CEW delivery if required.

Annual ANAE groundcover community surveys: Within established lignum shrublands (ANAE type F2.2), a minimum of three 20 m x 20 m quadrats to measure percent cover of plant taxa (to species wherever possible) bare ground and litter.

Table 5.5 Summarised methods, timing and frequency of proposed Lignum monitoring (Vegetation evaluation question A3)

Location	Drone surveys	Lignum condition index	Annual ANAE groundcover surveys	Timing/frequency	Sub-annual
Minimum of 3 locations in the Mid-Murray Area	Four 50 m x 50m plots Ranks lignum as low quality or high quality % cover estimate	Four 20 m x 20m quadrats Rates colour and viability of each plant % cover estimate	Three 20 m x 20 m quadrats (% cover of plant taxa (to species), bare ground and litter in accordance with McInerney *et al* 2024	All surveys concurrent annually, if possible, in ~February unless otherwise advised in accordance with McInerney *et al* 2024	Additional surveys may be undertaken before/after CEW delivered

Annual ANAE groundcover community surveys of non-woody vegetation (Vegetation -B4, Vegetation-A4)

Field methods

A suite of non-woody groundcover locations will be chosen to reflect the ANAE types within the Mid-Murray Area (Table 5.6). Where possible we will select locations that are likely to receive CEW and comparable locations which are unlikely to receive CEW as paired controls.

Within validated ANAE types with sufficient replication, a minimum of three 20 m x 20 m quadrats will be established to measure percent cover of plant taxa (to species where possible) bare ground and litter in line with the Basin-scale Native Vegetation methods outlined in Section 5 of McInerney et al (2024). Groundcover species composition and diversity will be assessed on-ground through surveys conducted Spring and Autumn each watering year. This is expected to, where possible, correspond with before and after watering, with the fixed timing accounting for seasonal variation in species present. The lignum and reed bed sampling (described in the previous section) will occur in February each year to coincide with the maximum yearly growth for each species, to represent the annual response to watering in growth and condition.

Table 5.6 Summary of potential survey locations and methods to measure non woody vegetation within ANAE types (Vegetation evaluation question Vegetation-B4, Vegetation-A4)

Survey location	ANAE Type	Target asset	Survey Method	Basin- and Area- Scale
Edward/Kolety-Wakool River System				
Colligen Creek	Rt 1.4: Temporary lowland stream	groundcover	Field-surveys, 20 X 20 m plots	Y
Upper Wakool River	F1.2: River red gum forest riparian zone or floodplain	groundcover	Field-surveys, 20 X 20 m plots	Y
Mid Wakool River	F1.2: River red gum forest riparian zone or floodplain	groundcover	Field-surveys, 20 X 20 m plots	Y
Lower Wakool River	F1.2: River red gum forest riparian zone or floodplain	groundcover	Field-surveys, 20 X 20 m plots	Y
Yallakool Creek	F1.2: River red gum forest riparian zone or floodplain	groundcover	Field-surveys, 20 X 20 m plots	Y
Werai Lands				
Niemur River	F1.2: River red gum forest riparian zone or floodplain	groundcover	Field-surveys, 20 X 20 m plots	Y
	F1.8: Black box woodland riparian zone or floodplain	groundcover	Field-surveys, 20 X 20 m plots	Y
Tumudgery Creek	F1.2: River red gum forest riparian zone or floodplain	groundcover	Field-surveys, 20 X 20 m plots	Y
Werai Forest	Pp 2.1.2: Tall Emergent Marsh	common reed	Field-surveys, 20 X 20 m plots	Y
	F1.8: Black box woodland riparian zone or floodplain	groundcover	Field-surveys, 20 X 20 m plots	Y
Wetlands downstream Euston/Robinvale				
Gol Gol Swamp	F2.2: Lignum shrubland riparian zone or floodplain	lignum	Drone surveys, 50 X 50m plots and Field-surveys in 20 X 20m plots	Y
Gol Gol Lake	F2.2: Lignum shrubland riparian zone or floodplain	lignum	Drone surveys, 50 X 50m plots and Field-surveys in 20 X 20m plots	Y
Gol Gol State Forest	F2.2: Lignum shrubland riparian zone or floodplain	lignum	Drone surveys, 50 X 50m plots and Field-surveys in 20 X 20m plots	Y
	F1.8: Black box woodland riparian zone or floodplain	groundcover	Field-surveys, 20 X 20m plots	Y
Fletcher's Creek and Lake	F2.2: Lignum shrubland riparian zone or floodplain	lignum	Drone surveys, 50 X 50m plots and Field-surveys in 20 X 20m plots	Y
Bullock Swamp (North)	F2.2: Lignum shrubland riparian zone or floodplain	lignum	Drone surveys, 50 X 50m plots and Field-surveys in 20 X 20m plots	Y
Bullock Swamp (South)	F2.2: Lignum shrubland riparian zone or floodplain	lignum	Drone surveys, 50 X 50m plots and Field-surveys in 20 X 20m plots	Y

5.2.4 Evaluation

Basin-scale

The evaluation for Basin-scale Native Vegetation theme is outlined in Section 5 of McInerney et al. (2024) and is the responsibility of the Basin-scale Native Vegetation team.

Area-scale

To address the Mid-Murray Area-scale Native Vegetation 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 plot.

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

The recruitment of key riparian species will be analysed with respect to the duration of watering using univariate and graphical methods to determine the contribution of CEW to the recruitment of long-lived organisms.

5.2.5 Data management

Following identification of the species, data will be transferred from field data sheets to an Excel data file. Hard copies of Field data sheets will be stored by Sascha Healy, scanned and electronic copies stored. Data will be verified by the theme lead and uploaded into MDMS after the data has gone through QA/QC. All vegetation data will be formatted as outlined in the Flow-MER data standards and uploaded into Flow-MER Monitoring Data Management System (MDMS) according to the protocols established by the CEWH to be provided to the Basin-scale Native Vegetation Theme team. The lignum drone imagery will be stitched and analysed the Basin-scale team. Uploading of data to the Flow-MER MDMS will be led by the Mid-Murray Data Theme lead, Dr Nicole McCasker.

5.2.6 Risks and dependencies

- Timely access to drone data analysed by Basin-scale team to be able to meet Area-scale evaluation requirements for Vegetation-B3 and Vegetation-A2
- Evaluation of Vegtation-A1 is dependent of having event-based remotely sensed estimate of inundation extent and duration (reported as part of the river flows and connectivity theme Flows-A3)
- The field team require ongoing site access for field surveys when sites are on private property.

5.2.7 Responsibilities

The planning and evaluation will be undertaken by Native Vegetation Theme Co-leaders Prof Robyn Watts (CSU) and Ms Sascha Healy (Murray-Darling Wetlands Working Group). The monitoring of native vegetation to CEW will be led by Sascha Healy. First Nations peoples will collaborate on vegetation monitoring, depending on the location. Organisations involved in lignum monitoring near

Mildura will include Barkindji Mauraura Elder Environment Team (for locations near Gol Gol) and First People of the Millewa-Mallee Aboriginal Corporation (if locations in Bullock Swamp, Vic, are included). First Nations peoples from Werai Traditional Owners and Yarkuwa Indigenous Knowledge Centre will be involved in monitoring of ANAE vegetation on Werai Lands and in other locations near Deniliquin. Over the duration of the Mid-Murray Flow-MER2.0 project other organisations may also be involved in the monitoring of native vegetation.

5.3 Native Fish (Basin-scale and Area-scale)

5.3.1 Background

The Mid-Murray Area is recognized as a priority area for fish diversity in the Murray–Darling Basin and is part of the threatened 'aquatic ecological community in the natural drainage system of the lower Murray River catchment' in New South Wales (*NSW Fisheries Management Act 1994*). Outcomes for fish have been a target for the delivery of environmental water. Historically, the Mid-Murray Area had diverse fish communities and supported extensive commercial and recreational fisheries (Rowland 2004). Twenty-two native freshwater fish species are thought to have historically occupied the lowland region of the central Murray valley. Fish are a key environmental asset valued by the Mid-Murray community.

The MER Plan has a strong emphasis on the response of fish populations to Commonwealth environmental watering. In addition, other indicators evaluated in this Plan (such as River flows and connectivity (section 5.1), and native vegetation (section 5.2) are likely to have indirect influence on fish population dynamics, and thus a key goal is to improve our understanding and interpretation of these interdependences.

Key processes that ultimately shape adult fish populations (spawning, recruitment and growth) have been monitored and evaluated in response to the contribution of Commonwealth environmental water as part of LTIM/ Flow-MER programs.

These standard methods describe the monitoring required for the Basin-scale Native Fish evaluation for the Flow-MER2.0 Program, as set out in Chapter 7 of Flow-MER Basin-scale Evaluation Approach (McInerney et al. 2024) and the Mid-Murray Area-scale fish evaluation.

5.3.2 Evaluation questions

Basin-scale questions

The overarching Flow-MER Basin-scale Native Fish evaluation question, as outlined in Chapter 7 of McInerney et al. (2024) is '*What did CEW contribute to native fish populations*?' The specific evaluation questions are:

Basin-scale Native Fish evaluation questions
Fish-B1. What did CEW contribute to native fish recruitment?
Fish-B2. What did CEW contribute to native fish population structure?
Fish-B3. What did CEW contribute to native fish abundance?
Fish-B4. What did CEW contribute to native fish condition?
Fish-B5. What did CEW contribute to native fish movement?

Area-scale questions

The Flow-MER Mid-Murray Area-scale fish population questions align with the Basin-scale Native Fish evaluation questions, but with a Mid-Murray focus. The Area-scale evaluation will not be limited to Basin-scale Priority Species required by Basin-scale evaluation, but instead report on the wider assemblage of fish populations in the Mid-Murray Area, including small and large bodied fish, and introduced and native fish.

Area-scale Fish evaluation questions
Fish-A1a Did native fish recruit in the Mid-Murray Area? Fish-A1b How was this influenced by flow? Fish-A1c What did water for the environment (and specifically CEW) contribute to this outcome? Years 1 to 5: Annual evaluation will focus on A1a, with qualitative interpretations for A1b and A1c. In Year 5 a quantitative model will be used to answer question A1b and A1c.
Fish-A2a Were native fish population structures maintained or improved in the Mid-Murray Area? Fish-A2b How was this influenced by flow? Fish-A2c What did water for the environment (and specifically CEW) contribute to this outcome? Years 1 to 5: Annual evaluation will focus on A2a, with qualitative interpretations for A2b and A2c. In Year 5 a quantitative model will be used to answer question A2b and A2c.
Fish-A3a Was native fish abundance maintained or improved in the Mid-Murray Area? Fish-A3b How was this influenced by flow? Fish-A3c What did water for the environment (and specifically CEW) contribute to this outcome? Years 1 to 5: Annual evaluation will focus on A3a, with qualitative interpretations for A3b and A3c. In Year 5 a quantitative model will be used to answer question A3b and A3c.
Fish-A4a Was native fish condition maintained or improved in the Mid-Murray Area? Fish-A4b How was this influenced by flow? Fish-A4c What did water for the environment (and specifically CEW) contribute to this outcome? Years 1 to 5: Annual evaluation will focus on A4a, with qualitative interpretations for A4b and A4c. In Year 5 a quantitative model will be used to answer question A4b and A4c.
Fish-A5. What hydrological, temperature and other environmental conditions are associated with golden perch and silver perch spawning in the Edward/Kolety River?

5.3.3 Monitoring

Indicators

Basin-scale

The indicators for each Basin-scale Native Fish evaluation question, as outlined in Chapter 7 from McInerney et al. (2024), are listed below (Table 5.6). Data will be collected in the Mid-Murray Area for all evaluation questions except for 'What did CEW contribute to native fish movement'. Basin-scale evaluation of fish populations will target Basin-scale Priority species, including Murray cod, silver perch, golden perch, trout cod and freshwater catfish (McInerney et al. 2024).

Table 5.6 Basin-scale native fish evaluation questions and indicators. *denotes questions that the Mid-Murray Area are not required to collect data for the Basin-scale evaluation.

Basin-scale Native fish evaluation questions	Indicators (for priority species)
Fish-B1. What did CEW contribute to native fish recruitment?	• Year class strength (e.g., young-of-year (YOY) class strength for medium-long lived species or small bodied fish abundance for annual recruiters.
Fish-B2. What did CEW contribute to native fish population structure?	• For medium-long lived species only – proportion of juveniles, adults and number of year classes in a population: with detailed metrics to undergo further refinement by working group.
Fish-B3. What did CEW contribute to native fish abundance?	• Common species – catch per unit effort (detection) • Rarer species – reporting rates (frequency of occurrence).
Fish-B4. What did CEW contribute to native fish condition?	• Body condition of medium-long lived priority species
Fish-B5. What did CEW contribute to native fish movement?*	• **Movement data will not be collected from the Mid-Murray for the Basin-scale evaluation*

Area-scale

The indicators for evaluating the Mid-Murray Area-scale questions for fish populations are similar to Basin-scale Native Fish evaluation questions, but with three key differences i) where possible all fish species, not just Basin-scale priority species will be included for evaluation, : ii) there is no fish movement evaluation question for Mid-Murray Area, and iii) fish spawning of golden perch and silver perch will also be monitored (Table 5.7).

Recruitment, population structure, abundance and condition

As per the Basin-scale evaluation questions, Mid-Murray Area evaluation questions will investigate to what extent CEW contributes to native fish recruitment, population, abundance and condition, but in the Mid-Murray Area. The CEWH southern basin delivery team has identified recovery of Murray cod populations in the Mid-Murray River following the 2022-23 floods as a priority objective for CEWH delivery, and the Area-scale evaluation questions will enable the Project team to track and Murray cod recovery and evaluate the contribution of CEW.

Spawning

The delivery of environmental water is seen as a fundamental way of enhancing the spawning and recruitment of native fish species (MDBC 2004). The environmental and hydraulic conditions under which the spawning and recruitment of Murray–Darling fish occurs varies across species (Humphries et al. 1999, Lyon et al. 2021). For example, for flow-dependent spawning species such as golden and silver perch, high spring flows and/or critical velocity thresholds are considered to be important for spawning (Tonkin et al. 2019). The Murray River in the Mid-Murray Area is known to support the spawning golden perch and silver perch, but the flow-spawning dynamics of these two species is not yet understood in the Edward/Kolety River, the second largest river in the Mid-Murray Area. Monitoring of golden and silver perch spawning in the Edward/Kolety River will address a knowledge gap in the spawning and recruitment of two Basin Priority species in the southern Basin.

Table 5.7 Mid-Murray Area-scale native fish evaluation questions and indicators.

Area-scale Fish evaluation questions	Indicators
Fish-A1a Did native fish recruit in the Mid-Murray Area? Fish-A1b How was this influenced by flow? Fish-A1c What did water for the environment (and specifically CEW) contribute to this outcome? Years 1 to 5: Annual evaluation will focus on A1a, with qualitative interpretations for A1b and A1c. In Year 5 a quantitative model will be used to answer question A1b and A1c.	• All species: Year class strength (e.g., young-of-year (YOY) class strength for medium-long lived species or small bodied fish abundance for annual recruiters.
Fish-A2a Were native fish population structures maintained or improved in the Mid-Murray Area? Fish-A2b How was this influenced by flow? Fish-A2c What did water for the environment (and specifically CEW) contribute to this outcome? Years 1 to 5: Annual evaluation will focus on A2a, with qualitative interpretations for A2b and A2c. In Year 5 a quantitative model will be used to answer question A2b and A2c.	• For medium-long lived species only – proportion of juveniles, adults and number of year classes in a population
Fish-A3a Was native fish abundance maintained or improved in the Mid-Murray Area? Fish-A3b How was this influenced by flow? Fish-A3c What did water for the environment (and specifically CEW) contribute to this outcome? Years 1 to 5: Annual evaluation will focus on A3a, with qualitative interpretations for A3b and A3c. In Year 5 a quantitative model will be used to answer question A3b and A3c.	• Common species – catch per unit effort (detection) • Rarer species – reporting rates (frequency of occurrence).
Fish-A4a Was native fish condition maintained or improved in the Mid-Murray Area? Fish-A4b How was this influenced by flow? Fish-A4c What did water for the environment (and specifically CEW) contribute to this outcome? Years 1 to 5: Annual evaluation will focus on A4a, with qualitative interpretations for A4b and A4c. In Year 5 a quantitative model will be used to answer question A4b and A4c.	• Body condition (for Basin priority species only: golden perch, silver perch, Murray cod, trout cod and freshwater catfish)
Fish A5 What hydrological, temperature and other environmental conditions are associated with golden perch and silver perch spawning in the Edward/Kolety River?	• Abundance (and CPUE) of golden perch and silver perch eggs and/or larvae.

Minimum data requirements for Basin-scale Evaluation

The following section outlines the minimum data requirements required by the Basin-scale to address the Native Fish key evaluation questions, as summarised from McInerney et al. (2024).

Considerations for site selection

- Sites are to be representative of fish habitat and flow conditions experienced by priority species.
- Annual monitoring should include a minimum of 20 sites within the river channel.
- Sites should span a minimum linear river length of 500 km (not necessarily continuous), with a target of 3-4 sites per 100 km.
- Site selection should:
    - maintain continuity with prior LTIM and Flow-MER monitoring.
    - retain at least 50% of existing sites and add additional sites to represent the range of habitat and flow conditions within an Area (with increase site numbers balanced by reductions in sampling effort).

    - Prioritise representativeness of sampling across the Area-scale, with a secondary focus on maintaining continuity of long-term data sets from other fish surveys (beyond LTIM and Flow-MER).
- The replacement of existing LTIM/Flow-MER sites should be justified based on representativeness (e.g., sampling previously unsampled habitat types) or practical considerations (e.g., changes to site access).
- The final number of sites and their arrangement may differ from the above requirements depending on local habitat conditions and hydrological heterogeneity, assuming an equivalent sampling effort is maintained and consistent with the overarching goal of representatively sampling priority fish species.
- Sampling data may be supported by complementary data sets.

Considerations for sampling effort within sites

- Addressing the evaluation questions requires data on total catch, and individual lengths and weights for all priority species that occur in an Area, as well as a measure of sampling effort.
- It would also be valuable to collect abundance and length data (not weight) for all species sampled, including common carp which may be used as a co-variate in Basin-scale response models.
- All values must be recorded at the individual sample level (e.g., per electrofishing “shot” or per fyke net/hr soak time).
- Genetic samples (fin clips) of golden perch, silver perch and Murray cod to be collected.
- In the first and last year of the Program, otoliths from a sample of 30-50 golden perch proportionally representing the length frequency of sampled fish to be collected.
- Area-scale teams should use the sampling method and replication that best captures the minimum required data for the priority species at each site and Area as a whole (catch, length, weight, and a measure of sampling effort), noting that measures of the entire fish community as per standardised sampling protocols are still a requirement.
- Preference should be given to either of the two methods used in previous LTIM/Flow-MER sampling (electrofishing and fyke nets), potentially with reduced effort to accommodate the increased number of sites.
- At a minimum, any electrofishing should follow the SRA/MDBFS protocol (12 shots per site, 90 sec per shot) and an appropriate number of replicate fykes should be used per site.
- Preferably, a single sampling method should be used within each Area, assuming this method reliably detects all priority species. Nevertheless, where justifiable, alternate sampling methods may be proposed between species.
- Other existing monitoring protocols that deviate from the above and have been in place as part of complementary data collections can still be considered if those protocols are appropriate for the priority species.

Complementary data

- Across the Area-scale, complementary data may play an essential role in meeting the minimum viable data requirements for Basin-scale fish evaluation. Areas may be able to reduce sampling effort by incorporating complementary data.

Process for Basin-scale site selection

This section provides an overview of the site selection process and methods protocol for the native fish monitoring in the Mid-Murray Area that will be used for the Flow-MER 2.0 Basin-scale Native Fish Evaluation.

These minimum data requirements as stated above have been used to guide sites selection within the Mid-Murray Area. Site selection for the Basin-scale native fish theme in the Mid-Murray were determined by the following considerations:

1. *Which rivers and creeks in the Mid-Murray Area receive CEW*

   We reviewed the Commonwealth of Australia's CEWH Water Management Plans for the Murray River Valley (2022,23), to identify the rivers and creeks identified as environmental assets for the potential use of CEW. For Basin-scale native fish evaluation, we considered only perennial rivers and creeks. The perennial rivers and creeks that receive CEW in the mid-Murray are:
   - Murray River (from Hume to Mildura)
   - Gunbower Creek
   - Edward/Kolety River
   - Wakool River
   - Yallakool Creek
   - Colligen-Niemur Rivers
   - Merran Creek.

2. *Distributions of priority species in the Mid-Murray Area*

   The priority fish species as defined in Section 7 of McInerney et al. (2024) for the Basin-scale fish evaluation, their occurrence and relative abundance in the Mid-Murray are summarised in Table 5.8. Of the six priority species listed in McInerney et al. (2024), five are found in the Mid-Murray Area. These are golden perch, silver perch, Murray cod, trout cod and freshwater catfish.

Table 5.8 Occurrence of Basin-scale priority fish species in the Mid-Murray Area. Fish highlighted in grey occur in the Mid-Murray Area.

Basin-scale priority fish species	Occur in the Mid-Murray Area	Relative abundance in river habitats
golden perch (*Macquaria ambigua*)	Yes	Common
silver perch (*Bidyanus bidyanus*)	Yes	Common
Murray cod (*Maccullochella peelii*)	Yes	Common
trout cod (*Maccullochella macquariensis)*	Yes	Moderate
freshwater catfish (*Tandanus tandanus*)	Yes	Rare
Hyrtl's tandan (*Neosilurus hyrtilii*)	No	Outside range

We reviewed the NSW Fisheries database of recorded fish captures for the five priority fish species that occur in the Mid-Murray Area to assist with the selecting the location of Basin-scale fish sampling sites.

Basin-scale fish site selection justifications

The Mid-Murray Area has expanded significantly from its predecessor, the Edward/Kolety-Wakool Selected Area (LTIM, Flow-ME). In accordance with the guidelines of site selection outlined in Chapter 7 of McInerney et al. (2024), the following trade-off with supporting justification has been made for choosing Basin-scale sites representative of habitat and flow variability across the Area.

- *Retain at least 50% (5 out of 10) of existing Basin-scale sites (McInerney et al. 2024):* **Justification**: We have retained 40% (4 of the 10) existing Basin-scale sites from the Edward/Kolety-Wakool Selected Area, rather than the recommended 50% (5 sites). Reducing the number of sites in the Wakool River upstream of Thule Creek reach allows us to sample a broader number of reaches with different habitat and flow conditions. This is particularly important in the Mid-Murray Area which encompasses a broad range of river and creek habitats and flow conditions. For example, the Edward/Kolety River can now be incorporated into the Basin-scale Fish evaluation for the first time, while also enabling other key Wakool River sites to also be retained.

Basin-scale monitoring locations

After reviewing:

i) the rivers in the Mid-Murray that receive CEW
ii) the occurrence and distribution of the five Basin-scale priority fish species
iii) the range of fish habitats and flow conditions by the priority fish species within the rivers that receive CEW;

Eight distinct hydrological reaches have been chosen for Basin-scale Fish monitoring (Table 5.9, Figure 5.2). The reaches represent a range of flow conditions and habitats throughout the Mid-Murray Area, including in the Murray River, the Edward/Kolety River, the Wakool River as well as smaller distributary and anabranching creeks such as Gunbower Creek. Each reach will contain four survey sites, located within 100 km of each other (McInerney et al. 2024). These sites will also be used for Area-scale evaluations.

Table 5.9 Monitoring reaches for Basin-scale fish monitoring, with summary of which Basin-scale priority fish species recorded have been recorded in them (NSW Fisheries Database 2024), and if complementary data exists within these reaches. **Denotes the existing LTIM/FLOW-MER - reach where sites will continue to be surveyed for Flow-MER2.0.

Monitoring reach	Basin Priority species recorded (NSW fisheries database)					Complementary data
	Murray cod	trout cod	golden perch	silver perch	fresh-water catfish	
Murray River @ Barmah	Y	Y	Y	Y		TLM
Murray River @ Gunbower-KP	Y	Y	Y	Y	Y	TLM, RMC
Murray River ds Wakool River	Y		Y	Y	Y	RMC
Gunbower Creek	Y		Y	Y		TLM
Edward/Kolety River ds Offtake	Y	Y	Y	Y		TLM
Edward/Kolety River ds Moulamein	Y		Y	Y		
Wakool River us Thule Creek**	Y		Y	Y		
Wakool River ds Barbers Creek	Y		Y	Y	Y	

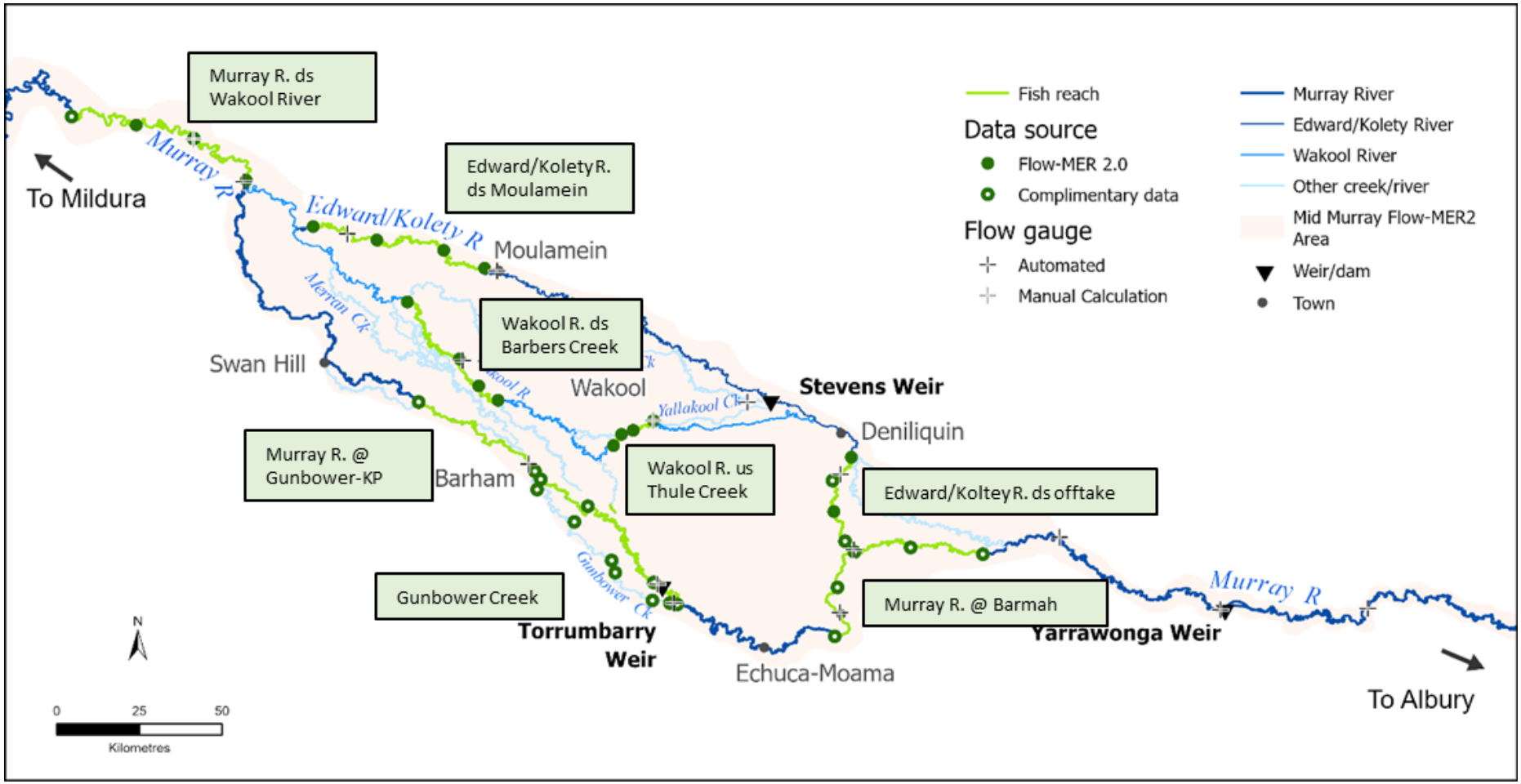

Figure 5.2 Location of the eight reaches that will be monitored in the Mid-Murray Area for Basin-scale evaluation and Area-scale evaluation. Sites to be sampled as part of the Mid-Murray Flow-MER monitoring are shown as closed circles, and sites where data will be sourced as complementary data from other research programs (TLM, RMC) are shown as open circles.

Complementary data

Data from the reaches and survey sites listed in Table 5.9 and Figure 5.2 will come from a combination of Mid-Murray Area Flow-MER surveys, and complementary data. Complementary data exists in the Mid-Murray from two relevant programs:

- The Living Murray Program (TLM, funded by Murray Darling Basin Authority), and
- The River Murray Channel Program (RMC, funded by Southern Connected Environmental Water Basin Committee).

A summary of where complementary data exists for the Basin-scale sites is provided in Table 5.10. Combining complementary data from TLM and RMC with Basin-scale reaches enables the Mid-Murray Area to exceed the Basin-scale minimum data requirements (from 20 to 32 sites) and cover a greater variety flow conditions that represent the diversity of fish and flow habitats in the Mid-Murray Area.

Table 5.10 Study reaches and survey effort for Flow-MER Fish Basin-Scale Monitoring, drawing on complementary data sets from The Living Murray (TLM) and River Murray Channel (RMC) programs. **Denotes the LTIM/FLow-MER Cat 1 reach, in which sites (n=4) will be retained for the Mid-Murray Area Flow-MER2.0 project to continue the long-term data set for the Area.

River	Reach Name	No. of survey sites			
		Total avail	Flow - MER (Basin & Area)	TLM	RMC
Murray River	Murray River @ Barmah	4	0	4	0
	Murray River @ Gunbower	4	0	2	2
	Murray River ds Wakool River	4	2	0	2
Edward/Kolety River	Edward/Kolety River ds Offtake	4	2	2	0
	Edward/Kolety River ds Moulamein	4	4	0	0
Wakool River	Wakool River us Thule Creek**	4	4	0	0
	Wakool River ds Barbers Creek	4	4	0	0
Gunbower Creek	Gunbower Creek	4	0	4	0
Total		**32**	**16**	**12**	**4**

Area-scale monitoring locations

Fish recruitment, population structure, abundance and condition

Mid-Murray Area-scale monitoring and evaluation of fish recruitment, population structure, abundance and condition will occur at the same reaches and sites used for the Basin-scale evaluation.

Fish spawning

Monitoring of golden perch and silver perch eggs and larvae will be undertaken at four sites in the Edward/Kolety River downstream of the Edward offtake (Figure 5.2). This reach is a hydrologically complex and structure-rich reach, has velocities most likely suited for golden and silver perch spawning, receives water for the environment via Hume releases. The reach aligns with the Basin-scale and Area-scale adult fish reach downstream of the Edward offtake.

Sampling methodology

Basin-scale

Annual sampling for Basin-scale Native Fish will follow the standard methods for in-channel habitats as specified by LTIM and Flow-MER Fish Sampling Protocols in Hale et al. (2014) but with the updates to methods outlined in Chapter 7 of McInerney et al. (2024). In Summary:

- In-channel habitats will be sampled annually, in Autumn.
- For the Mid-Murray Area, fish will be sampled with boat electrofishing. Sampling will follow the SRA/MDBFS protocol and Flow-MER 1.0 methods (12 shots per site, 90 sec per shot).
- Data on total catch (abundance), individual lengths and weights for all priority species will be recorded (Trout cod, Murray cod, golden perch, silver perch, freshwater catfish) that occur in an Area, as well as a measure of sampling effort.
- Abundance and length data (but not weight) will also be recorded for all other 'non-Basin priority' species sampled, including common carp which may be used as a co-variate in Basin-scale response models.
- All values will be recorded at the individual sample level (e.g., per electrofishing "shot").
- Genetic samples (fin clips) of golden perch, silver perch and Murray cod to be collected.
- In the first and last year of the program, otoliths from a sample of 30-50 golden perch proportionally representing the length frequency of sampled fish to be collected.

Area-scale

Fish recruitment, population structure, abundance and condition

- Annual sampling for the Area-scale fish population evaluation will follow the standard methods as described for the Basin-scale Native Fish monitoring, outlined in Chapter 7 of McInerney et al. (2024) and summarised in Chapter 5.5 of the Mid-Murray Area-scale MER Plan.

Fish spawning

- Sampling will occur in years 1 (2024), year 2 (2025) and year 3 (2026), fortnightly, from October-December (6 trips).
- Three drift nets (1.5 long, 0.5 m diameter opening) will be deployed overnight at each site on each sampling trip.
- Flow meters will be attached to the entrance of each drift net to record the amount of water filtered.
- In-channel flow velocity measurements (m/s) will be taken at each site on each sampling.
- All eggs/larvae collected in the drift nets will be identified to species and enumerated.
- Unidentified perch eggs and larvae, as well as a subsample of cod larvae will be sent to Australian Genomic Research Facility for species confirmation.

- Temperature and hydrological data will be obtained from nearby flow gauges to use as co-variates in models that explore flow-spawning relationships (discharge, temperature, velocity).

Timing and frequency

- Fish electrofishing surveys for Basin-scale and Area-scale monitoring and evaluation will take place in late Autumn (April-May), annually (2025, 2026, 2027, 2028 and 2029).
- Sampling of golden perch a silver perch and eggs and larvae in the Edward/Kolety Wakool River downstream of the offtake will occur:
    - Fortnightly, from October – December (6 trips)
    - In year 1 (2024), year 2 (2025), and year 3 (2026)

5.3.4 Evaluation

Basin-scale

As outlined in Chapter 7 of McInerney et al. (2004), the Basin-Scale Native Fish Team will answer the key evaluation questions through the use of counterfactual modelling to determine the contribution of Commonwealth Environmental water to fish populations at the Basin-scale. These models estimate fish responses to a range of flow predictors, which are then used to predict fish responses under a hydrological scenario without CEW (the 'counterfactual' scenario). This approach separates the effects of CEW from the effects of background hydrological variability and provides an estimate of possible fish population outcomes in the absence of CEW and has been used effectively for Flow-MER Basin-Scale Evaluation (20219-2024, Hladyz et al. 2024).

In-channel watering actions in the Mid-Murray Area that will be evaluated for the Basin-scale Native Fish theme are summarised in Table 5.11.

Table 5.12 is a summary table of Basin-scale native fish monitoring in the Mid-Murray Area, including indicators, scale, methods and timing.

Table 5.11 In-channel watering actions in the Mid-Murray that will be evaluated for the Basin-scale Native Fish theme. Watering action numbers refer to types of watering listed in Table 3.1. **Denotes the LTIM/FLow-MER Cat 1 reach that will be retained for the Mid-Murray Area Flow-MER2.0 project to continue the long-term data set for the Area.

Basin-scale evaluation question	Type of e-watering action to be evaluated																Rivers/ creeks monitored	Target issue/area/ species	Link to Basin-scale theme/ question	Dependencies (Timing, Data, etc)
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16				
Fish-B1 to B4 What did CEW contribute to native fish populations ?	✓			✓	✓						✓						Murray River Edward/ Kolety River Wakool River Gunbower Creek	Basin-scale priority species: Murray cod trout cod golden perch silver perch freshwater catfish	This is a basin-scale question, with links to: Area-scale fish populations Area-scale (fish spawning)	Complementary data sources: TLM (Gunbower) TLM (Barmah) River Murray Channel

Table 5.12 Summary of the Basin-scale native fish evaluation in the Mid-Murray Area, including indicators, scale, methods and timing

Basin-scale evaluation question	Scale	Method	Timing	Locations	Ecological relevance	Monitoring schedule	Evaluation approach
Fish-B1 to B4What did CEW contribute to native fish populations?	Basin	Boat electrofishing surveys	Annually Autumn/ winter	Murray River @ Barmah Murray River @ Gunbower Murray River ds Wakool junction Edward/Kolety River ds Offtake Edward/Kolety River ds Moulamein Wakool River us Thule Creek** Wakool River ds Barbers Creek Gunbower Creek	River flows can directly influence fish life histories and population dynamics through cues to migration and reproduction or indirectly through effects on water quality and habitat, and food availability, and biotic interactions such as competition and predation	Fish catch data collected annually and to be uploaded to the Flow-MER MDMS annually. Genetic samples (fin clips) collected annually. Otoliths of golden perch collected in years 1 and 5.	Annual counterfactual modelling

Area-scale

Fish recruitment, population structure, abundance and condition (Fish-A1 to Fish-A4)

Evaluation of the Area-scale fish population questions will be reported annually. We will use Basin-scale (Section 5.5), and Area-scale (this section) data to report on abundance, recruitment, population structure and condition in reaches receiving environmental water. This will provide an annual snapshot of fish populations throughout a diverse range of habitats and CEW deliveries throughout the Mid-Murray Area (Table 5.13).

Having a variety of reaches that capture the different hydrological variation in the system, from large rivers to smaller creeks means that:

- **In years of high-water availability:** we may be able to evaluate how water exiting floodplain forests affects adult fish populations (Barmah (Edward ds offtake & Murray @ Barmah reaches), Koondrook-Perricoota (Mid Wakool ds Thule reaches), and Gunbower (Murray River @ Gunbower reaches)
- **In years of low-water availability:** we may be able to evaluate how reduced longitudinal connectivity affects fish populations in different river systems (e.g. the Murray and Edward/Kolety vs smaller creek systems where flows are most impacted like the Wakool River).

In year 5, we plan to collaborate with Basin-scale Native Fish team to apply their counter-factual modelling to Mid-Murray fishes (beyond the Priority species) to quantify the role of environmental water on fish outcomes in the Mid-Murray.

Fish spawning (Fish-A5)

By monitoring the presence/absence of abundance of silver and golden perch eggs under a range of different hydraulic and flow conditions, we will evaluate if golden and silver perch use the Edward/Kolety River to spawn, and if they do, evaluate what environmental conditions are associated with their spawning. This work will address a key knowledge gap currently not covered by Living Murray Monitoring or the River Murray Channel Programs which only occur in the main channel of the Murray River. Eggs and larvae collected from drift nets will be calculated as 'catch-per-unit-effort' where units of units are density of eggs/larvae (number of individuals collected per drift net per volume of water passed through the net). Density data will be analysed at the site and reach level, meaning that data from the three drift nets per site will be pooled.

For the first two years of reporting, data will be reported as spatial and temporal trends in CPUE of golden and silver perch eggs and larvae. Associated hydrological and temperature metrics will be reported.

In the third year of reporting, logistic regression models will be used to establish what hydrological and temperature variables are associated with the probability of golden and silver perch spawning in the Edward/Kolety River. Covariates that will be used in the models include season/photoperiod, temperature, a suite of discharge metrics and water velocity. Water velocity will be measured in two ways: as spot-measurements during sampling, as well as derived from ratings tables from nearby hydrological gauges. These models will be important for understanding the mechanisms behind both the probability and magnitude of spawning in flow-dependent spawners like golden perch and silver perch and help to provide predictive capabilities of spawning for these species under different environmental watering actions in the Edward/Kolety River.

Comparisons of our findings with other golden and silver perch spawning monitoring studies in the main Murray River Channel (TLM Barmah, and River Murray Channel) will be made to help form a wholistic understanding of golden and silver perch spawning dynamics in the Mid-Murray Area.

Eggs and larvae of other fish species will also be reported on. For example, trout cod are known to be present in this reach, and our sampling will enable us to report on if trout cod are spawning in this reach. This information from this monitoring will support adaptive management of CEW, and indirectly links to the Basin-scale native fish evaluation question “What did CEWH water contribute to native fish recruitment" for these basin-priority species.

Table 5.13 summarises In-channel watering actions in the Mid-Murray Area that will be monitored for the Area-scale fish population indicators.

Table 5.14 is a summary table of Area-scale fish population monitoring in the Mid-Murray Area, including indicators, scale, methods and timing.

Table 5.13 In-channel watering actions in the Mid-Murray Area that will be monitored for the Area-scale fish population indicators. Watering action numbers refer to types of watering listed in Table 3.1. Full details of Area-scale questions are listed in Table 5.7.

Area-scale evaluation question	Type of e-watering action to be evaluated																		Rivers/ creeks monitored	Target issue/area/ species	Link to Basin-scale theme/ question	Dependencies (Timing, Data, etc)
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18				
To what extent did water for the environment (and specifically CEW) contribute to Mid-Murray fish recruitment (Fish-A1), population structure (Fish-A2), abundance (Fish-A3) and condition (Fish-A4)?	✓			✓	✓						✓								River reaches monitored for Basin-scale fish theme (Section 5.4)	All fish species (small and large bodied, native and introduced)	Data can be used for the Basin-scale Native Fish theme	This theme will also use data collected from the Mid-Murray for the Basin-scale Native Fish theme (see Section 5.5)
Fish-A5. What hydrological, temperature and other environmental conditions are associated with golden perch and silver perch spawning in the Edward/Kolety River?	✓											✓							Edward/Kolety River ds Offtake	Golden perch, silver perch. Other important species including Murray cod and Trout cod will also be reported on.	Links to the Basin-scale native fish KEQ sub question: What did CEWH water contribute to native fish recruitment.	Daily hydrological data with and without water for the environment - required by July 1 in 2025, 2026, and 2027.

Table 5.14 Summary table of Mid-Murray Area-scale fish population monitoring, including indicators, scale, methods and timing. Full details of Area-scale questions are listed in Table 5.7.

Area-scale evaluation question	Indicators	Method	Timing	Locations	Ecological relevance	Monitoring/evaluation schedule
To what extent did water for the environment (and specifically CEW) contribute to Mid-Murray fish recruitment (Fish-A1), population structure (Fish-A2), abundance (Fish-A3) and condition (Fish-A4)?	Length and age class structure, abundance, weight	Boat electrofishing surveys.	Annually, Autumn/ winter	River reaches monitored for Basin-scale fish theme.	River flows can directly influence fish life histories and population dynamics through cues to migration and reproduction or indirectly through effects on water quality and habitat, and food availability, and biotic interactions such as competition and predation.	**Monitoring schedule** Fish catch data collected annually and to be uploaded to Flow-MER MDMS annually. Genetic samples (fin clips) collected annually. Otoliths of golden perch collected in years 1 and 5. **Evaluation schedule** Indicators will be reported annually. Counterfactual analysis evaluated year 5.
Fish-A5. What hydrological, temperature and other environmental conditions are associated with golden perch and silver perch spawning in the Edward/Kolety River?	Occurrence and abundance of eggs/larvae.	Six fortnightly drift-net sampling surveys.	Oct-Dec, annually, for years 1-3.	Edward/Kolety River ds Offtake (4 sites).	Golden and silver perch have life histories whose spawning is cues to flow and hydraulic conditions. Understanding how Area-scale water delivery might promote the spawning of these two species in the Edward/Kolety will support adaptive management of CEW for golden perch and silver perch outcomes.	**Monitoring schedule** Monitoring in Years 1,2, 3. **Evaluation schedule** Year 1,2 3: Presence/absence of spawning Environmental-spawning relationships reported in Year 3
	In-channel velocity (co-variate)	In-channel measurements during field surveys Velocity estimates derived from nearby flow gauge rating curves.	Oct-Dec annually Cont. data (from 1 Jul to 1 Jan) each year.	Relevant flow gauges near the survey reach.	Minimum velocities may be limiting factor for spawning in golden and silver perch spawning.	**Monitoring schedule** Data collected and reported on annually. Calculated annually.
	Discharge (co-variate)	Flow gauges	Continuous data from 1 July to 1 Jan each year.	Relevant flow gauges near the two survey reaches.		**Monitoring schedule** Data downloaded 1 January each year.

5.3.5 Data management

All field sheets will be scanned and stored electronically. Data collected by Basin-scale and Area-scale Mid-Murray for the Native Fish indicator will conform to the data structure defined by the Flow-MER data standards (Brooks et al. 2024). Data uploads to the Flow-MER MDMS will be managed by the Mid-Murray Data Theme lead, Nicole Mccasker.

5.3.6 Risks and dependencies

- Access and data-sharing agreements for use of complementary data from The Living Murray Program (Gunbower and Barmah) and the River Murray Channel Program will need to be established. There is a risk that the Murray River would be under-represented for the Basin-scale evaluation if this data cannot be obtained.
- Timely access of complementary data to meet deadlines for Basin-scale evaluation requirements.
- Should access to complementary data not be available at the time required for Basin-scale evaluation, minimum data requirements will still be met through the provision of Area-scale fish population data to the Basin-scale native fish theme (see Chapter 5.7).
- Combining complementary data from TLM and RMC with Basin-scale and Area-scale reaches enables the Mid-Murray Area to exceed the minimum data requirements (from 20 to 38 sites) and cover a greater variety flow conditions that represent the diversity of fish and flow habitats in the Mid-Murray Area.

5.3.7 Responsibilities

- Electrofishing field surveys: led by NSW DPI Fisheries staff with CSU staff. Opportunities for First Nations peoples to participate in fish surveys.
- Fish spawning surveys: led by CSU staff, including Senior Technician John Trethewie, and the Mid-Murray Fish Theme Lead
- Data analysis and reporting: led by CSU Mid-Murray Fish Theme Lead, with contributions and input from the Mid-Murray Fish Team (Dr Jerom Stocks and John Trethewie)

5.4 Cultural Outcomes

5.4.1 Background

Indigenous perspectives and knowledges on land and water management are an important part of sustainable natural resource management. Indigenous knowledges represents observations and data collected over many millennia incorporating changes in climate and health of Country and is important to management of Country and water management. The CEWH recognises the important role of Indigenous perspectives, values and knowledges in the planning and management, monitoring and evaluation of CEW and has prioritised cultural outcomes as a (core) monitoring and evaluation theme as part of the Flow-MER2.0 Program.

5.4.2 Evaluation Questions

The proposed evaluation approach is based on the Chapter 8 of the Basin-scale Evaluation Approach , developed by the Cultural Outcomes Working Group. The Basin-scale Evaluation Approach acknowledges that as a new addition to the Program, the Cultural Outcomes Theme will mature with the life of the Program and supports a culturally safe and staged approach in its implementation. The evaluation is under review and evaluation questions are being refined.

The evaluation questions will be adapted by the Cultural Outcomes Working Group over time. The initial focus in the Mid-Murray Area will be consulting and getting to know the First Nations in the Mid-Murray Area. The Basin-scale Cultural Outcomes theme team recommends that for each Area, participating First Nations communities and representatives will identify the cultural values that could be impacted by Commonwealth environmental water. The Flow-MER2.0 Program will need to allow time for consultation, engagement and understanding to occur. Further, any activity where First Nations data maybe collected, it can only be undertaken once all appropriate human ethics approvals and any other agreements are established.

Another key focus will be collaborating with First Nations to support engagement activities and training opportunities that the different groups and organisations have identified as being priority for them (see section 8 First Nations Activities).

The Cultural Outcomes evaluation questions are expected to evolve over time following input from First Nations partners.

Basin-scale

The overarching Flow-MER Basin-scale Cultural Outcomes evaluation question, as outlined in Chapter 8 of McInerney et al. (2024) is '*How has CEW contributed to Cultural Outcomes*?' Where cultural outcomes are the things that need to be delivered to meet cultural obligations to care for Country, as defined by Indigenous communities. Cultural values can be broadly classified into Cultural indicators (Cultural indicators (i.e. living things that can be impacted by Commonwealth environmental water), Cultural places (i.e. locations that can be impacted by Commonwealth environmental water), and Cultural activities (i.e. things people do that can be impacted by Commonwealth environmental water)

Basin-scale Cultural Outcomes evaluation question
B1. How has Commonwealth environmental water contributed to Cultural Outcomes?

Area-scale

The Mid-Murray Area-scale Cultural outcome evaluation questions are:

Area-scale Cultural Outcomes evaluation questions
A.1 How did the CEWH and the Mid-Murray Flow-MER Program support First Nations engagement and outcomes activities over the water year?
A2. How have the CEWH and the Mid-Murray Flow-MER Program planned, delivered and evaluated Commonwealth environmental watering actions with involvement of First Nations peoples?

5.4.3 Mid-Murray Area First Nations Action Plan

This action Plan outlines ideas that were developed during discussions with First Nations in the Mid-Murray Area and align with the Flow-MER2.0 First Nations Strategy (DCCEEW 2024b).

Vision

Improve the outcomes for Country by implementing an integrated strategy that synergises knowledge with broader approaches, ensuring the protection and restoration of the MDB and its water-dependent ecosystems.

First Nation Cultural values and participation

Traditional values of inclusiveness and responsibility for Caring for Country - Living on Country. Traditional values encourage collaboration and commitment in developing relationships. This incorporates a moral obligation to care for land and a strong connection to country - *the wider community is invited to care for country with us.*

Action Plan Principles

- First Nation communities are an asset
- Recognising Cultural values and knowledge is critical to achieving positive outcomes
- Demonstrate best practice and ensure all actions are sustainable.

Table 5.15 Cultural Outcomes Action Plan Principles

Principles		
1. Empowerment and Self-Determination	Uphold the principle of empowerment and self-determination, recognising that communities are the experts in their own affairs	Design the project in a way that actively supports and enables communities to make decisions about the research and environmental water management initiatives that directly impact them.
2. Culturally Inclusive Communication	Prioritise culturally inclusive communication methods that resonate with the diversity of cultures and languages	Ensure that communication materials and platforms are culturally appropriate and accessible, facilitating effective dialogue and understanding.
3. Community-Led Consultations	Place an emphasis on community-led consultations that allow for open and honest conversations.	Actively seek input from community members, Elders, and knowledge holders in decision-making processes, considering diverse perspectives and ensuring that the community's concerns and aspirations are considered
4. Relationship Building and Trust	Recognise the importance of building and maintaining relationships based on trust and respect.	Invest time in building genuine relationships with communities, demonstrating commitment, reliability, and transparency throughout the project

5. Collaborative Goal Setting	Collaboratively set goals and objectives to ensure that project aims align with community priorities and values.	Engage in meaningful discussions to co-create project objectives, allowing communities to influence the research agenda and desired outcomes.
6. Inclusivity in Decision-Making Forums	Ensure that decision-making forums ar inclusive, allowing for diverse voices to be heard.	Create spaces for community members, especially women, youth, and Elders, to actively participate in decision-making processes, fostering a diversity of perspectives.
7. Responsive Adaptation to Feedback	Embrace a culture of responsiveness to community feedback and insights.	Actively listen and adapt project activities based on community feedback, demonstrating a commitment to incorporating community perspectives throughout the project's lifecycle
8. Transparent Information Sharing	Promote transparent and open information sharing throughout the project	Share project updates, findings, and decisions in a clear and accessible manner, ensuring that the community is well-informed and engaged in the ongoing process.
9. Cultural Safety and Respect	Prioritise cultural safety and respect for cultural protocols.	Establish clear protocols for engaging with Indigenous knowledge, respecting cultural practices, and fostering an environment where community members feel safe to express their perspectives.
10. Long-Term Relationship Building	Commit to long-term relationship building beyond the project's duration.	Develop strategies for ongoing engagement, recognising that relationships take time to build trust and understanding.

Table 5.16 Cultural Outcomes Evaluation template

Target	Action
Cultural Mapping and Traditional Land Use Studies	Conduct collaborative cultural mapping and traditional land management studies to comprehensively document their knowledge about the MDB. This will serve as a foundation for the programs management practices.
	Undertake mapping project to establish baseline data of Aboriginal community capital – Asset Based Community Development principles including human and organisational Assets on a geographic scale
Traditional Ecological Knowledge Sharing Programs	Establish programs that facilitate the sharing of knowledge. Encourage collaboration between Elders and scientists to enhance understanding of the river system's ecological dynamics.
	Develop communication protocols including interpretation and translation processes
	Undertake, and maintain, relationship activities that build awareness and trust
Community-Led Monitoring and Stewardship Initiatives	Empower communities to lead monitoring and stewardship initiatives, working with community members to observe and document changes in each study area. This knowledge will inform adaptive and sustainable management practices.
Foster Connection to Country and Cultural Practices	Integrate connection to Country and cultural practices into the management and restoration activities of the MDB. Recognise the cultural significance of the places within the MDB, fostering their connection to these ecosystems.
Collaborative Decision-Making Frameworks	Develop and implement collaborative decision-making frameworks in key decision points in the MDB. This strategy ensures that their perspectives are integral to policies and management plans, and where possible, restoration projects.
	Develop Annual reporting program including documenting proposed project activities, research questions and monitoring priorities.
	Develop a practical collaboration system include central information system (live map)

Cultural Outcomes

The Basin-scale evaluation approach considers measures of participation of water planning, water delivery, and monitoring evaluation and research in line with the First Nations Strategy. A key focus is that CEW contributes to ensuring that Country is healthy and that the cultural values of First Nations communities are sustained.

Table 5.17 Cultural Outcomes evaluation: How has Commonwealth environmental Water contributed to Cultural Outcomes?

Planning	
Cultural indicators	Living things impacted by CEW
	How many cultural indicators are identified in CEW action plans?
Cultural Places	Locations that can impacted by CEW
	How many cultural places are identified in CEW action plans?
Cultural Activities	Things people do that can be impacted by CEW
	How many cultural activities are identified in CEW action plans?
Community Education	Workshops, meetings, publications and other activities
	Have communities identified cultural values that can be influenced by CEW? Are communities influencing the design of CEW watering actions? Have existing CEW action plans been improved with additional cultural values?
Delivery	
Cultural indicators	Living things impacted by CEW
	How many cultural indicators were targeted in CEW watering action plans
Cultural Places	Locations that can impacted by CEW watering
	How many cultural places were targeted in CEW watering action plans?
Cultural Activities	Things people do that can be impacted by watering
	How many cultural activities were targeted in CEW watering action plans?
Community Education	Workshops, meetings, publications and other activities
	Are communities participating in the delivery of CEW for their cultural values? Were CEW watering actions communicated before/during/after events?
Evaluation	
Cultural indicators	Living things impacted by CEW
	How effectively did CEW assist in supporting cultural indicators?
Cultural Places	Locations that can be impacted by CEW
	Did CEW allow improved access to cultural places? Were cultural places effectively supported by CEW watering actions? Were negative impacts on cultural places protected by CEW watering actions?
Cultural Activities	Things people do that can be impacted by CEW
	Did CEW allow cultural activities to be undertaken?
Community Education	Workshops, meetings, publications and other activities
	Have CEW engagement activities been undertaken effectively? Have CEW engagement activities been in response to community requests? Are communities leading the CEW-related monitoring/evaluation activities? Do communities respond (e.g., cultural economy) to CEW watering actions?

Table 5.18 Preliminary Cultural Outcomes Evaluation Indicator methods

Method	Description
Area-scale MER - Knowledge Exchange	Via the Area-scale MER plans, work with Knowledge Exchange Working Group (KEWG) to support the recording and submission of an annual engagement activities log. The log should include date, engagement type, purpose and audience type.
Watering action plans	Via the Area-scale Cultural Advisors and CEWH Delivery and Local Engagement Officers, produce a summary of high-level cultural value categories for sharing
Water delivery plans	Via the Area-scale Cultural Advisors and CEWH Delivery and Local Engagement Officers, produce a summary of high-level cultural value categories for sharing
Area evaluations	Via co-design and co-implementation, areas will undertake monitoring and evaluation of watering actions. A reporting template will be provided for communities in areas to complete that characterises the results of their evaluation and is consistent with the Basin-scale evaluation framework. The approaches and evidence used will vary within each Area but may be guided by research or successful approaches in other areas. Specific details will remain within area-scale reporting.

Table 5.19 Preliminary Cultural Outcomes Evaluation Indicators

Indicator	Spatio-temporal scale	Method
Listing of community engagement activities	Annually	Area-scale MER – KECE activities
Number of cultural indicators identified	Annually	Watering action plans
Number of cultural places identified	Annually	Watering action plans
Number of cultural activities identified	Annually	Watering action plans
Number of cultural indicators targeted	Annually	Water delivery plans
Number of cultural places targeted	Annually	Water delivery plans
Number of cultural activities targeted	Annually	Water delivery plans
Assessment of CEW engagement survey results	Annually	Area evaluations
Impact of CEW watering action survey results	Per watering action in Area	Area evaluations

5.4.4 Evaluation

Basin-scale

Minimum viable data requirements have been described for Basin-scale reporting in Chapter 8 of McInerney et al. (20024). The evaluation approach has been designed to leverage off data that would already be recorded in each Area. The evaluation will be undertaken on an annual basis. An annual cultural outcomes and activities report will be prepared within the annual technical report that will detail all First Nations engagement and activities undertaken over the water year focusing on First Nations engagement and inclusion in the Flow-MER program and in CEW planning, delivery and evaluation. The evaluation will provide the following information to support Basin-scale evaluation of cultural outcomes:

- An annual engagement activities log
- Summary of high-level cultural value categories identified in watering action plans
- Summary of high-level cultural value categories targeted in water delivery plans
- Area-scale evaluation reporting via an agreed template (aligning with evaluation framework).

Area-scale

Story-telling or narratives are important to Aboriginal people in Australia as an approach for sharing of knowledge. First Nations people's involved in the Mid-Murray Flow-MER project will be invited to share stories relevant to environmental water management, monitoring, evaluation and research in the Mid-Murray Area. Through this approach we hope to understand and record First Nations narratives around water, the river, the people and their cultures. These may include:

- Description and outcomes from First Nations engagement sessions and activities
- First Nations groups and people engaged with regarding CEW
- Description of watering events planned and delivered with First Nations consultation and involvement.

Case studies will be central to the evaluation of the cultural outcomes and will demonstrate how high-level objectives are being met by the CEWH and the Flow-MER program.

As the Mid-Murray project develops, we may progress to evaluate the number CEW events which have been planned and implemented with First Nations involvement. This will be evaluated on how many of the watering actions were planned with First Nations involvement, how First Nations people, their views and cultural knowledge was used and integrated into water management. As the program matures, and as relationships and trust develop between the project team, the CEWH and First Nations groups and people in the Mid-Murray, cultural values (such as species and places) will be identified and documented. This may leverage of data collected as part of the other themes but specifically address the role of CEW in supporting cultural outcomes.

5.4.5 Data management

Data Management for the Flow-MER Mid-Murray Area Program will follow the guidelines outlined in the CEWH's Flow MER Data Management Strategy (Brooks et al. 2024). A Data management is described in section 10, describing approach to ensure Indigenous Data Sovereignty and Indigenous Cultural and Intellectual Property (ICIP) and Informed Consent (FPIC) throughout the project.

5.4.6 Risks and dependencies

As highlighted in the First Nations Peoples MER Strategy (DCCEEW 2023), consent may be withdrawn at any point of the project. If consent is initially granted but then withdrawn after material or knowledge has been published (e.g. scientific literature or social media) there are limitations around how much the Mid-Murray team can prevent further dissemination of this knowledge. The Mid-Murray team will work with First Nations groups and people to identify the cultural knowledge they would like to share and the way in which they would like to share it.

5.4.7 Responsibilities

Prof Robyn Watts from Charles Sturt University as leader of the Knowledge Exchange and Community Engagement theme will coordinate the evaluation and reporting of cultural outcomes with guidance and collaboration from the Mid-Murray Cultural Advisor Jeanette Crew, and with input from Local Cultural Advisors/Cultural Liaison Officers representing each of the First Nations organisations collaborating on the Mid-Murray project.

5.5 Sentinel surveillance of dissolved oxygen for early detection of hypoxia

5.5.1 Background

Since 2010 there have been several large unregulated flow events occurred in the Mid-Murray that have resulted in inundation of large areas of floodplain. Carbon and nutrient release following the inundation of agricultural and forested floodplain, can result in water with high organic loads (usually dark in colour) entering waterways from the floodplain. Water can become hypoxic (low dissolved oxygen concentration) when large amounts of organic material in rivers are broken down by bacteria, consuming dissolved oxygen in the water. Prolonged low oxygen concentrations can result in the interruption of flood-response movements, stress or death of native fish.

To mitigate some of the negative effects of the hypoxic water events, environmental water delivery has been delivered in the Mid-Murray Area (particularly the Edward/Kolety-Wakool River system) from irrigation escapes of Murray Irrigation Limited (MIL) network. Hypoxic water refuge flows via irrigation escapes provide refuge habitat for native fish before critical dissolved oxygen level drops to less than 6 mg/L (CEWO 2023). The history of using irrigation escapes for environmental water delivery in the Mid-Murray demonstrates that environmental watering can provide and maintain localise refuge habitat (favourable dissolved oxygen conditions) for fish populations in the system during hypoxic events.

Two recognised critical components that facilitate adaptive management during at risk periods of hypoxia is through collaboration and the timely provision of monitoring results and local knowledge (Liu et al. 2023).

The provision of timely warning system of dissolved oxygen levels across the Mid-Murray landscape is critical to inform the adaptive management of environmental water. However, there are limitations of the current available dissolved oxygen automated monitoring network and routine monitoring for detecting hypoxic risks and events in the Mid-Murray Area:

- **Limited spatial distribution of existing dissolved oxygen gauges in the Mid-Murray Area**. The existing automated hydrological gauges do not all include dissolved oxygen loggers. Thus there is no dissolved oxygen data available at several key river reaches where hypoxic water may either enter the Mid-Murray Area (e.g. Northern Victorian tributaries, Murray River upstream of Tocumwal) and/or exit points of floodplain forests where risk of the creation of hypoxic water may be of concern (e.g. Koondrook-Perricoota Forest), or anabranches that may face stress under low-water availability scenarios (e.g. Wakool River upstream of Yallakool Creek junction).
- **Lack of timely-detection of low dissolved oxygen concentrations in reaches monitored by ground surveys in the Mid-Murray Area.** Routine surveys of water quality were undertaken at a frequency of once per month as part of the LTIM and Flow-MER programs. Monthly monitoring frequency and end of the water year reporting is not frequent enough to serve as a robust early warning sentinel. There is the potential to miss the critical time at which dissolved oxygen concentrations start to change and CEWH staff may not have early enough warning to respond in a timely fashion to investigate environmental watering actions or establish responsive monitoring once an issue has been identified.
- **There is currently a lack of trained and engaged citizen scientists who are supplied with appropriate equipment to contribute to monitoring and timely reporting.** Relying on

monitoring to be undertaken on a monthly basis by scientists who do not live in the area is not the most effective approach to establish a sentinel monitoring. To ensure that a sentinel monitoring system is effective there is a need for a network of local people who have access to appropriate equipment and are trained to monitor and deliver data in a timely way to a central coordinator. Having a team of trained local citizen scientists will also improve responsive monitoring of environmental watering actions associated with hypoxic events.

This sentinel surveillance program is designed to address the current limitations to track hypoxia risk in the Mid-Murray and will provide an early-warning detection system for the CEWH. Early warning of these indicators has previously underpinned environmental water planning and active adaptive management of environmental water, including informing watering actions after they have commenced (Liu et al. 2023, Watts et al. 2013, 2017).

This sentinel surveillance is an 'Integrated Project' for the Mid-Murray Area, where we combine Area-scale monitoring with First Nations and community engagement and collaboration, and also can be used to underpin research/responsive monitoring. This project includes a range of approaches to increase the early detection of low dissolved oxygen events to inform management of environmental water and initiate responsive monitoring in a nimble way:

- Existing network of automated gauges that include dissolved oxygen loggers
- Deployment of additional dissolved oxygen loggers in locations known to be of high risk of low dissolved oxygen
- Deployment of additional dissolved oxygen sensors connecting with remote monitoring capability in location known to be of high risk of low dissolved oxygen but are sites that are difficult to access and/or do not have local citizen scientists nearby to undertake regular monitoring
- Dissolved oxygen measurements taken by local community and First Nations peoples at additional sites
- Dissolved oxygen monitoring undertaken by the Mid-Murray Flow-MER team.

5.5.2 Evaluation questions

The Flow-MER Mid-Murray Area-scale sentinel surveillance of dissolved oxygen evaluation questions are:

Area-scale evaluation questions
Dissolved oxygen-A1. How effective was the sentinel surveillance monitoring of dissolved oxygen for early detection of hypoxia in enabling CEWH and other stakeholders to adaptively manage Commonwealth environmental water in the Mid-Murray Area?
Dissolved oxygen-A2. How effective was the contribution of citizen science and First Nations science to the sentinel surveillance monitoring?

5.5.3 Monitoring

Indicators

- Dissolved oxygen concentrations (mg/L, critical threshold alerts)
- Co-variates: Water temperature (°C), discharge (ML/day)

Selection of sites

There are 15 automated continuous dissolved oxygen logging gauges within the Mid-Murray Area (Figure 5.3, Table 5.20). Four of these are located in the Murray River (between Tocumwal and Boundary Bend), two in the Edward/Kolety River, and the other nine are distributed across the Edward/Kolety River, Wakool River, Niemur River, Thule Creek, Barbers Creek and Little Merran Creek (Figure 5.3, Table 5.20). Dissolved oxygen gauges are also located at sites near to end of valley for incoming tributaries from Victoria including the Ovens River, Goulburn River and Broken Creek.

To fill in some of the critical gaps in the monitoring of DO, dissolved oxygen and water temperature loggers will be deployed and maintained where dissolved oxygen data is currently unavailable in the area. We will install DO sensor connecting remote monitoring capability to enable access to live data 24/7 from anywhere on any device. This will contribute to the availability of timely data from locations where there are not currently automated DO data.

The additional sites to install loggers are prioritised based on the following criteria:

i) reaches in the Mid-Murray Area that receive CEW but dissolved oxygen concentration is not measured

ii) reaches in the Mid-Murray Area where hypoxia has previously been a concern

iii) reaches where environmental watering actions can be targeted to create refuge during droughts and flooding events in the Mid-Murray Area

iv) align with other Mid-Murray Area monitoring so dissolved oxygen data could be used by other themes (such as fish)

v) major entry and exit reaches from floodplain forests (e.g. Thule Creek existing Gunbower Creek, Colligen-Niemur exiting Werai Lands, Barbers creek exiting Koondrook-Perricoota)

vi) accessible during high flows.

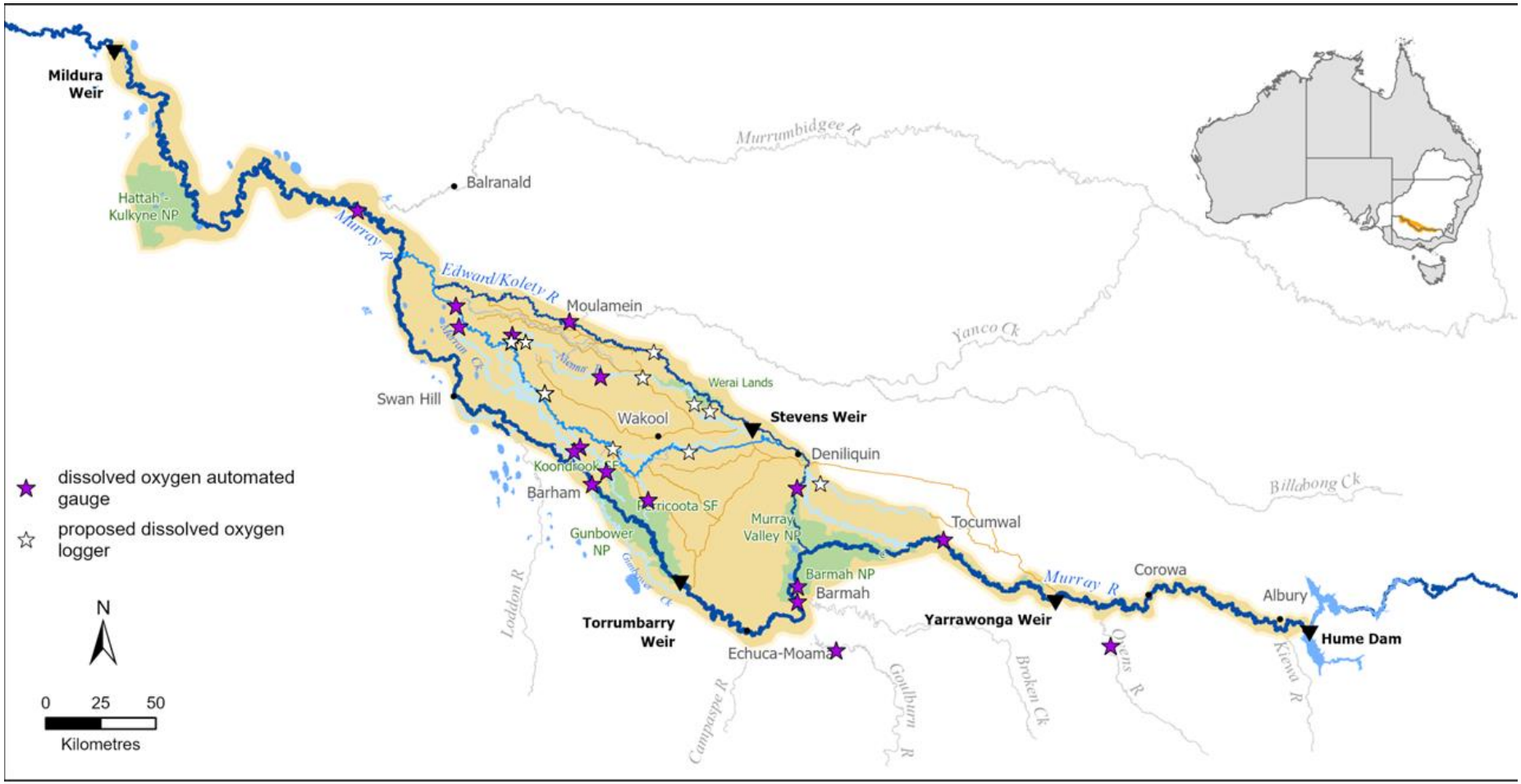

Figure 5.3 Automated gauges have dissolved oxygen measurements in Mid-Murray River Area are shown in purple stars and proposed additional sites to deploy dissolved oxygen loggers are in white stars.

Table 5.20 Summary of existing dissolved oxygen (DO) gauges in the Mid-Murray Area. These gauges also provide continuous data of Discharge (ML/day), water level (M), water temperature (°C) and electrical conductivity (µs/cm). *denotes gauges which log DO intermittently.

River	Gauge Location	Gauge Number	Lat/long
Within the Mid-Murray Area			
Murray River	Tocumwal	409202 (WaterVic)	-35.8135, 145.5560
	Barmah	409215 (WaterVic)	-36.0176, 144.9610
	Barham	409215 (WaterNSW))	-35.6298, 144.1245
	Boundary Bend	414201 (WaterVic)	-34.7196, 143.1698
Edward/Kolety River	Toonalook	409047 (WaterNSW)	-35.6428, 144.9596
	Moulamein	409014 (WaterNSW)	-35.0899, 144.0331
Niemur River	Barham-Moulamein Rd	409048 (WaterNSW)	-35.2739, 144.1595
	Mallan School	409086 (WaterNSW)	-35.1351, 143.8001
Wakool River	Gee Gee Bridge2	409062 (WaterNSW)	-35.3290, 143.9322
	Merran Creek upstream Wakool River	409036 (WaterNSW)	-35.1074, 143.5826
	Stoney Crossing	409013 (WaterNSW)	-35.0376, 143.5702
Thule Creek	Lower Thule Road	409109 (WaterNSW)	-35.6821, 144.3531
Barbers Creek	Sandy Bridge	409111 (WaterNSW)	-35.5066, 144.0761
	Pool *	409113 (WaterNSW)	-35.5883, 144.1830
Little Merran Creek	Franklings Bridge	409044 (WaterNSW)	-35.5214, 144.0517
Tributaries flowing into the Mid-Murray Area			
Ovens River	Peechelba	403241 (WaterVic)	-36.1629, 146.2363
Broken Creek	Rices Weir *	404210 (WaterVic)	-35.9677, 144.9619
Goulburn River	McCoy Bridge *	405232 (WaterVic)	-36.1777, 145.1190

Sentinel site locations

In addition to using the continuous logged dissolved oxygen data obtained from gauges (Table 5.20), additional surface dissolved oxygen loggers will be installed at key locations. Based on the criteria of site selection above, the site locations for the dissolved oxygen logger installation summarised in Table 5.21. The sentinel program will flexible and responsible, allowing for locations to change based on identified risks across the Mid-Murray in any given water year. The loggers which can be connected remotely will be installed at the sites at most risk of low dissolved oxygen.

Table 5.21 Additional Sentinel locations where dissolved oxygen loggers may be installed in the Mid-Murray Area

Area of interest	River	Additional sentinel DO logger site
Werai Lands	Tumudgery Creek	Upstream of Tumudgery Creek near confluence with Colligen Creek
	Colligen Creek	Downstream of Tumudgery Creek confluence
	Edward/Kolety River	Balpool Road
Niemur Forest	Niemur River	Upstream of Niemur Forest
	Niemur River	Downstream of Niemur Forest
Wakool River	Wakool River	Wakool River upstream Yallakool Creek Junction
Koondrook-Perricoota Forest	Wakool River	Upstream of Thule Creek confluence joining mid-Wakool
	Wakool River	Downstream of Thule Creek confluence Upstream of Barbers Creek confluence
	Wakool River	Gee Gee Bridge
Ephemeral creeks	Tuppal Creek	Aratula Road
Rivers and creeks receiving water from irrigation escapes	Flexible	Dependent on where CEW is delivered to create refuge during droughts and flooding events

Methods

The Sentinel surveillance of dissolved oxygen will gather real-time data at high-priority locations from i) existing dissolved oxygen loggers at automated hydrological gauges ii) new DO logger locations, iii) citizen scientist field monitoring of dissolved oxygen. Critical thresholds of concern that are of relevance to the CEWH will be defined in consultation with Mid-Murray Water Delivery Teams. Critical thresholds of concern will then be used to identify locations and times for when more intensive real-time feedback of DO conditions needs to be undertaken through collaboration with First Nations peoples and Citizen Scientists.

DO Logger data collection

Dissolved oxygen loggers data will be downloaded at each selected site and the loggers will be calibrated and maintained monthly. The data collected by the loggers will be used to calculate daily average temperature and dissolved oxygen.

In addition to conventional dissolved oxygen loggers, dissolved oxygen sensors connecting with remote monitoring kits (the 4G data logging system) that we can access real-time logging data remotely may be installed (if 4G and other conditions are suitable) in key locations where we cannot get to easily and do not have citizen scientists in that area.

The logger data will be complemented with spot water quality measurements of dissolved oxygen as well as temperature, pH, dissolved oxygen, turbidity, and electrical conductivity collected at each selected site.

Citizen scientist data collection - Engagement and collaboration

A critical part of the sentinel project is to integrate with KECE component of the Project (Section 9) to instigate a citizen science project to involve local people and First Nations peoples in the monitoring during at 'high-risk' periods in order to improve the frequency and spatial distribution of dissolved oxygen data for the sentinel surveillance.

Involvement of local communities in Flow-MER activities, facilitate ownership and empower champions. Local community members and First Nation peoples will collaborate with field monitoring. This will complement the data from the dissolved oxygen loggers and mean more frequent and cost-effective monitoring can be undertaken in collaboration with the community. Having a trained and engaged citizen science team means that responsive monitoring can be rapidly implemented to undertake responsive monitoring of environmental watering actions associated with hypoxic events.

Dissolved oxygen water sentinel monthly monitoring will summarise the latest water quality data collected from anabranches, tributaries and main river channels in Mid-Murray River Area and the collected data will be uploaded to Mid-Murray interactive website.

Informing Adaptive Management

This sentinel monitoring will inform water managers of how flows of various scales, particularly those delivered during the warmer part of the year, are contributing to healthy dissolved oxygen levels in a more detailed way. Critically, it will also inform managers of when dissolve oxygen concentrations are getting close to the trigger value to consider commencing environmental watering actions if the possibility of a hypoxic water condition is predicted. At present a trigger of 6 mg/L is used by water managers to commence the watering actions that can provide managers with time to consult with community, organise water orders and commence environmental watering actions before dissolved oxygen drops below the 4 mg/L threshold of concern for fish (CEWO 2017). It also enables CEWH decisions of timing at specific locations of environmental water delivery to create localised refuges for fish and mitigate the impact of hypoxic water events.

The sentinel program will report dissolved oxygen conditions in the Mid-Murray to the CEWH using a traffic light system dissolved oxygen levels are above the thresholds of critical concern (e.g >6 mg/L for more than 7 days; green), are near to reaching the thresholds of critical concern (e.g. < 6 mg/L for more than 4 days; orange), and when they have dropped below the threshold of concern (e.g <red <4 mg/L for more than 4 continuous days). Timing of reporting will be more regular reporting during spring and summer months. Data and traffic light summaries will also be uploaded to Mid-Murray interactive website for community to access.

Links to responsive monitoring/research components

The hypoxic water sentinel project will identify areas of concern, and this may inform responsive monitoring and research activities (see sections 6 and 7 of this Plan) that may involve more frequent monitoring in key locations such as Werai Lands (Ramsar site) or an increase in the spatial coverage of water quality monitoring.

Contribution to other themes

The sentinel surveillance of dissolved oxygen will also help provide context for interpreting the results from fish theme or other themes.

Timing and frequency

- Sentinel Surveillance Program will be implemented in year 1 and continued for years 2-5 of the Flow-MER Program (2024-2029)
- DO data from fixed gauges and additional logger locations will be downloaded and reviewed at a minimum monthly
- During warmer spring-summer periods, dissolved oxygen data will be observed more regularly and reports on sites reaching or staying above the threshold hold of concern reported to CEWH
- The citizen science and First Nations teams will be coordinated to ensure that monitoring of dissolved oxygen is undertaken in locations where there are no loggers, to ensure a broad spatial spread of sentinel surveillance
- If/when dissolved oxygen levels dip below the threshold of concern, citizen science and First Nations team will be activated across the Mid-Murray Area to provide more frequent on-ground real time observations of hypoxic conditions.

5.5.4 Evaluation

Evaluation question A1

The hypoxic water sentinel project will help to inform the adaptive management and ability of CEWH to respond to changing conditions of environmental water delivery, to assist decision making for responsive monitoring in the Mid-Murray Area. As such, while the key activity of the Program is to inform the CEW of hypoxic conditions in the Mid-Murray and provide an early warning system, the Evaluation of this program asks '*How effective was the sentinel surveillance monitoring of dissolved oxygen for early detection of hypoxia in enabling CEWH and other stakeholders to adaptively manage Commonwealth environmental water in the Mid-Murray Area*?'

Evaluation of this question will be achieved using a mix-methods approach (combination of qualitative and quantitative methods) including surveys of CEWH staff to see how the sentinel surveillance system influenced their decision making.

Evaluation question A2

A mixed method approach will be used to evaluate how the citizen science and First Nations science contributed to the sentinel monitoring, such as how many groups and/or how many people were involved, what sites/monitoring they did and what they gained from their involvement.

5.5.5 Data management

All field sheets will be scanned and stored electronically. Data collected by citizen science and First Nations teams will be sent to Dr Xiaoying (Sha sha) Liu (Charles Sturt University) for collation and synthesis. Dissolved oxygen data will conform to the data structure defined by the Flow-MER data standards (Brooks et al. 2024). Data will be uploaded to the Flow-MER MDMS annually and will be managed by the Mid-Murray Data Theme lead, Nicole Mccasker.

5.5.6 Risks and dependencies

- One of the key risks is access to loggers and monitoring sites during unregulated flows. To reduce this risk, sites will be selected to maximise access and sentinel monitoring can be undertaken by boat or via floating pontoons during overbank flows if road access cut off by water. Loggers will be installed on floating pontoons to avoid less reliable data collection from slower flowing backwaters. Some of the additional loggers will be automated so we can access real time data without the need to undertake field work.
- Gauging data from relevant hydrology gauges in Mid-Murray Area may be unavailable due to equipment failure (e.g., flooding events). If equipment failure occurs at at-risk locations, we will target key reaches for on-ground monitoring in collaboration with citizen scientists. The loggers installed at some reaches where automated stations are can also make up for the lack of dissolved oxygen data.

5.5.7 Responsibilities

The sentinel surveillance of dissolved oxygen activity will be led by Dr Xiaoying (Sha sha) Liu from Charles Sturt University, in collaboration with community citizen scientists and First Nations peoples. Dr Liu will be responsible for the planning and coordination of all fieldwork, collection and maintaining of the data, analysis, and reporting, with support from Professor Robyn Watts (Project Lead). Robyn Watts (leader of the KECE activities), First Nations peoples and citizen scientists will collaborate on this project.

5.6 River Murray Channel Monitoring

5.6.1 Background

The aim of the River Murray Channel (RMC) project is to determine the influence of flows on whole-of-river in-stream productivity. The evaluation questions of RMC project are outlined in Rees et al. (2020, 2021, 2023). The RMC project is led by CSIRO with consortia of researchers from CSIRO, Charles Sturt University, South Australian Research and Development Institute and University of Adelaide.

The Mid-Murray MER2.0 Project will contribute to part of the monitoring requirements for the RMC Project as described below. The evaluation of the RMC questions will be undertaken by CSIRO RMC team and no evaluation of RMC samples/data will be undertaken by the Mid-Murray MER2.0 Project.

5.6.2 Monitoring

RMC indicators

The monitoring for the RMC project undertaken as part of the Mid-Murray Flow-MER2.0 Project will undertake fieldwork at some of the RMC sites:

- Collection of water samples for analysis of dissolved organic carbon (DOC), nutrients (total phosphorus (TP), filtered reactive phosphorus (FRP), total nitrogen (TN), dissolved nitrate + nitrite (NOx) and ammonium (NH4+)), chlorophyll-*a*, phytoplankton concentrations
- Spot measurement of water quality (temperature, dissolved oxygen, electrical conductivity, pH, turbidity)
- Deployment and retrieval of light loggers
- Collection of zooplankton samples

RMC sites

There are eight monitoring sites for RMC Project that align with MI-Murray Area (Table 5.24, Figure 5.4). The fieldwork and sample collection at these 8 sites will be shared equally between Mid-Murray team and CSIRO led RMC team.

Table 5.24 River Murray Channel (RMC) Program study sites and indicators/analyses. Orange cells indicate data to be collected by the CSIRO RMC team and the Mid-Murray Flow-MER2.0 team. Green cells are complementary data

Reach name	Site name	Main Locations	Hydrology	DOC, nutrients etc	Metabolism	Phytoplankton	Zooplankton
Hume to Torrumbarry	Tocumwal	Upstream of BMF					
Hume to Torrumbarry	Barmah township	Downstream of BMF u/s Goulburn					
Hume to Torrumbarry	Toonalook/4Post	D/S Millewa on Edward/Kolety			WaterNSW		
Hume to Torrumbarry	u/s Echuca	D/S Goulburn, U/S Gunbower					
Torrumbarry to Lock 11	Torrumbarry						
Torrumbarry to Lock 11	Barham	D/S Gunbower			WaterNSW		
Torrumbarry to Lock 11	Swan Hill	Mid Murray channel process					
Torrumbarry to Lock 11	Boundary Bend	D/S Murrumbidgee			DEWLP		

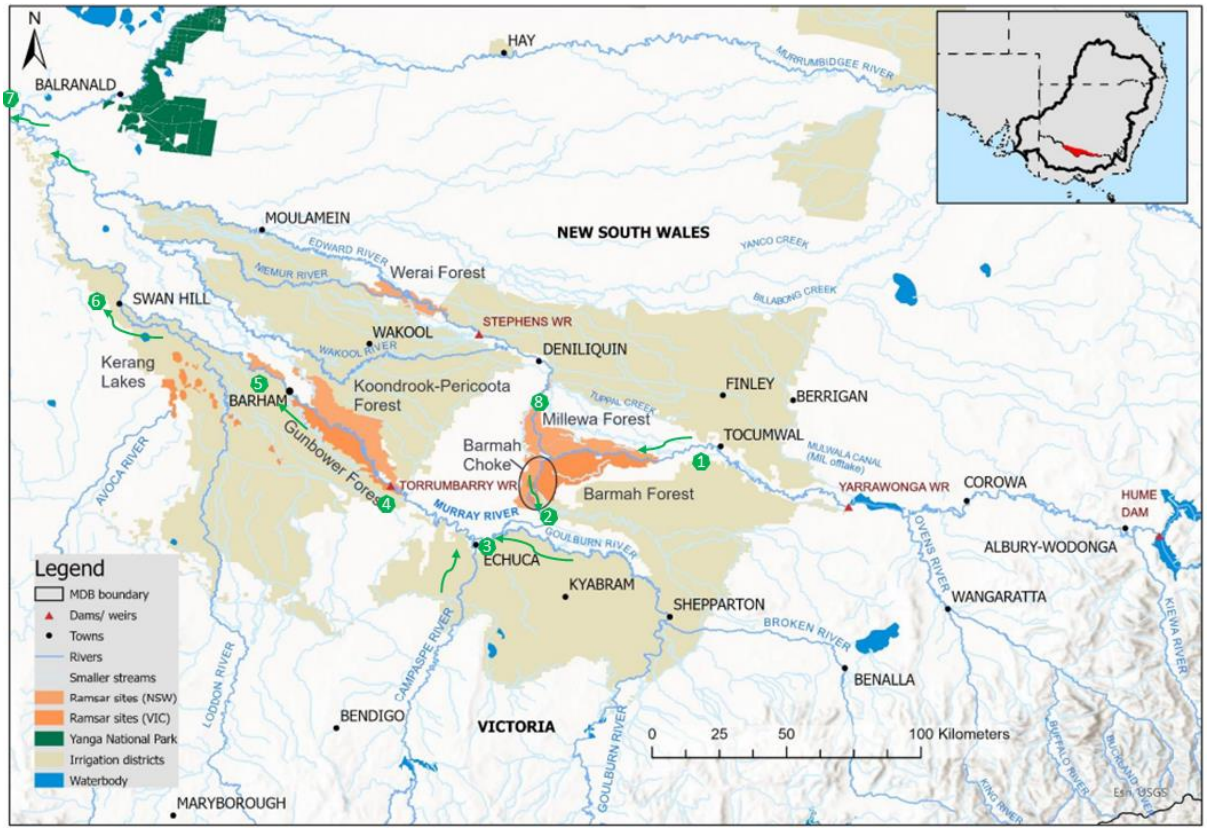

Figure 5.4 Map of the Mid-Murray Area showing existing River Murray Channel (highlighted in green) sites that will be monitored.

RMC methods

Water samples will be collected following methodology described in Rees et al. (2020, 2021, 2023). All water samples will be delivered to the National Association of Testing Authorities (NATA) accredited laboratory at CSIRO, Albury, for analysis, thereby ensuring the integrity of data and analysis procedures.

Light loggers will be delivered to CSIRO RMC team for downloading and analysis.

Zooplankton samples will be collected following methodology described in Rees et al. (2020, 2021, 2023). All Zooplankton samples will be delivered to CSIRO lab for processing.

Timing and frequency

The RMC field monitoring undertake as part of the Mid-Murray Flow-MER2.0 Project will be undertaken in 2024-25 and 2025-26.

The RMC project requires 12 fortnightly field trips (July/Aug – Dec/January) monitor before, during and after the coordinated spring pulse response at eight sites along Murray River system. The Mid-Murray Flow-MER2.0 Project team will undertake six of these RMC field trips in 2024-25 and 2025-26 and the other six will be undertaken by CSIRO RMC team.

Evaluation

Mid-Murray Flow-MER2.0 Project will not undertake analysis of data for RMC project. All evaluation for the RMC project will be undertaken by the CSIRO led RMC team following the RMC plan (Rees et al. 2020, 2021, 2023).

6 Research

6.1 Area-scale research objectives

This section describes the approach and activities that will be undertaken to develop research projects in the Mid-Murray Area for the Flow-MER Project.

The high-level objectives of Area-scale research in the Flow-MER Program are to:

- Improve understanding of the processes that drive ecological responses to flow and / or other drivers in the Area.
- Encourage research led by First Nations people (noting that this must align with the objectives of the Flow-MER Program).
- Provide recommendations for how Commonwealth environmental water can best be managed to influence these processes and encourage desired responses in the Area i.e. to directly inform adaptive management, and address critical knowledge gaps.

Research proposed here for the Mid-Murray align with the Flow-MER2.0 Research Strategy (King et al. 2023). The following principles will guide investment decisions in research projects including:

- First Nations people identify the cultural indicators that are important to them.
- Projects may extend directly from the monitoring activities and / or data of the Area teams by exploring the drivers of observed responses that are unexpected or poorly understood.
- Projects may relate to flow and / or other pressures and influences on the system.
- Findings from projects may have relevance more broadly across the Basin, but this is not a requirement.

The research questions listed in this MER Plan are a first step in identifying priority knowledge gaps (including Cultural knowledge). During the first year of the Project the Mid-Murray Team will spend additional time workshopping research ideas and will also engage with local stakeholders to listen to local people's ideas for research in the area. This process of identifying and prioritising research projects will continue throughout the project (2024-29).

The research projects listed in this MER Plan have been classified according to themes that align with the research objectives:

1. Projects that inform how water can be better managed to improve outcomes **- adaptive management of water for the environment** in the Mid-Murray Area
2. Projects that contribute to **understanding of the processes that drive ecological responses to flow** and/or **interactions with non-flow drivers** in the Mid-Murray Area
3. Projects that aim to **improve monitoring and evaluation methods**, including methods that may have applications across other areas in the Basin
4. Projects that improve our **understanding socio-ecological perspectives** in the Mid-Murray Area.
5. Projects that **promote First Nations people's science**

6.2 Summary of proposed Mid-Murray Area research projects developed to date – options for investment

The research questions included in this Plan are in two groups:

1. **Quick-start projects** that have already been developed and are able to be undertaken immediately in the first year of the Project whilst other research priorities and questions are being developed. Project 1 in table 6.1 is a quick-start project that can be undertaken in 2024-25 year 1 of the Mid-Murray Area Project.
2. **Other preliminary research ideas**, are included to provide some ideas for research investment in the Mid-Murray Area. These ideas are not yet fully developed, and we will be seeking opportunities to discuss and refine these ideas with stakeholders. We will also be seeking additional ideas during these discussions and applying a prioritisation process for research projects as outlined in King et al (2023). Project number 2 to 9 in Table 6.1 are preliminary research ideas for further discussion.

A summary of some preliminary research project ideas is presented in Table 6.1. Further details of each of these listed research projects are presented in section 6.3. This is a non-exhaustive list, as more options are likely to arise over the course of the Plan's implementation. Projects that improve our understanding of socio-ecological perspectives in the Mid-Murray Area, and projects that promote First Nations people's science will be developed as the program evolves.

Table 6.1 Summary of quick start research projects proposed for 2024-25 Mid-Murray Project, and preliminary research ideas for discussion for future research. This is not a comprehensive list of projects. During the five years of the Mid-Murray Flow-MER2.0 Project we will be seeking additional ideas during these discussions and applying a prioritisation process for research projects as outlined in King et al (2023).

Themes	#	Project type	Research question/Aim	Focus
River flows and connectivity	RP1	Quick-start project Included in budget for 2024-25.	Comparing inundation methods to evaluate the contribution of Commonwealth environmental water to wetland and floodplain forest inundation.	Improving monitoring and evaluation methods
Waterbirds	RP2	Preliminary research idea	Exploring existing datasets available for the Mid-Murray Area and drawing on complementary waterbird data as much as possible including existing NSW DCCEEW and TLM data	Understanding the processes that drive ecological responses to flow, support adaptive management
Native fish	RP3	Preliminary research idea	Native fish: Where are (and where were) the Mid-Murray nursery grounds for golden and silver perch?	Understanding the processes that drive ecological responses to flow
	RP4	Preliminary research idea	What is the status of wetland/population specialist fish species in the Mid-Murray wetlands?	Understanding the processes that drive ecological responses to flow
	RP5	Preliminary research idea	Long-term contribution of water for the environment to Mid-Murray fish outcomes	Understanding the processes that drive ecological responses to flow
	RP6	Preliminary research idea	What is the distribution of trout cod, river blackfish, and freshwater catfish in the Mid-Murray region? Implications for flow and future monitoring.	Understanding the processes that drive ecological responses to flow

Mussels	RP7	Preliminary research idea	Water requirements for freshwater mussels in the Mid-Murray River system	Understanding the processes that drive ecological responses to flow
Water quality	RP8	Preliminary research idea	Quantifying the contribution of CEW to salt mobilisation in the Mid-Murray	Support adaptive management
	RP9	Preliminary research idea	Modelling of water quality responses to environmental water using the data from 10 years of LTIM / Flow-MER	Understanding the processes that drive ecological responses to flow, support adaptive management

6.3 Overviews of quick start and preliminary ideas for Mid-Murray Area-scale research

6.3.1 Research topic RP1 - River flows and connectivity

Aim: Comparing inundation methods to evaluate the contribution of Commonwealth environmental water to wetland and floodplain forest inundation.

Research theme: Improving monitoring and evaluation methods

Project team: Dr Christine Lachlan-Arrowsmith (Streamology), Thom Gower (Streamology), Dr Sam Davidson (Streamology), Prof Robyn Watts (CSU), Jess Heath (DCCEEW), Leo Lymburner (GEOsciences), Cultural Advisor.

Project summary: As part of Area-scale monitoring question 3 (see section 5.2) there are three different approaches that could be used to undertake this monitoring and calculate the extent of inundation attributed to Commonwealth environmental water. The three methods include the method previously applied to inundation modelling in Werai Lands as described in Watts et al (2023), a method developed by Leo Lymburner (Geoscience Australia) aiming to map inundation and resolve the issues of overhanging trees, and a method currently used by NSW DCCEEW undertaken by Jess Heath. These three methods use different sources of remotely senses data and potentially have different sensitivities and accuracy.

This quick-start research project will undertake a comparison of these methods and evaluate which produced more accurate and results and can be readily applied to the types of inundation that occur in the Mid-Murray areas, such as Werai Lands. This work will be undertaken in the first two quarters of 2024-25, so that the most suitable approach for evaluating the inundation CEW/no-CEW can be selected and then applied monitoring planned for the proposed watering action in Werai Lands in the 2024-25 water year.

6.3.2 Research topic RP2 Water Birds

Aim: Exploring existing datasets available for the Mid-Murray Area and drawing on complementary waterbird data as much as possible including existing NSW DCCEEW and TLM data.

Research theme: Understanding the processes that drive ecological responses to flow

Project team: Dr Jen Spencer (NSW DCCEEW), Jess Heath (NSW DCCEEW), Cultural Advisor, opportunities for First Nations and community involvement.

Project summary: We will prioritise waterbird research activities that improve our understanding of waterbird responses to flow and other drivers, support adaptive management in the Mid-Murray Area and improve the evaluation of ecological responses to CEW, and provide opportunities for co-design and co-delivery with First Nations people.

Projects that can be undertaken in the Mid-Murray Area and adjacent Areas will also be prioritised. This approach would work particularly well for waterbirds as they are highly mobile species reliant on a network of wetlands for feeding and breeding habitat. The research priorities can follow a staggered approached with a number of quick-start desktop projects that can start almost immediately running for 1-2 years of the Poject and additional projects in later years of the Project (years 2-4) that can improve monitoring and evaluation of waterbird responses to flows and feed into priority knowledge gaps for the broader waterbird theme.

Potential projects include:

- Years 1-2: Assessing changes in breeding habitat condition in the Werai Lands and Gunbower-Koondrook-Perricoota Forests using remotely sensed vegetation and inundation data. This project would support the Basin-scale Waterbirds evaluation question “What did CEW contribute to providing waterbird habitats?”
- Years 2-4: Testing active and passive eDNA sampling techniques to assess threatened waterbird responses to flows in the Mid-Murray, Lachlan and Murrumbidgee Areas. This project would support the Basin-scale Waterbirds evaluation question “What did CEW contribute to the species diversity of waterbirds?”
- Years 2-4: Investigating the influence of flows (including timing and duration) on food availability for breeding waterbird species. This project would support the Basin-scale evaluation question “What did CEW contribute to waterbird breeding success?” and “What did CEW contribute to providing waterbird habitats?”

6.3.3 Research topic RP3 – Native fish

Aim: Where are (and where could be) the Mid-Murray nursery grounds for native fish including golden and silver perch, freshwater catfish and other floodplain specialist species?

Research theme: Understanding the processes that drive ecological responses to flow; adaptive management of water for the environment

Project team: Dr Nicole McCasker (CSU), Dr Jerom Stocks (DPI Fisheries), Dr Dylan Van der Meulen (DPI Fisheries), Mr John Trethewie (CSU),Paul Childs (DCCEEW BCS), Cultural Advisor.

Project summary:

- The Riverscape Recruitment Synthesis Model (Humphries et al. 2020) predicts that fish recruitment and growth is maximised when young fish have access to nursery areas characterised by high productivity, concentration and retention of prey items.
- This research would be in the form of hypothesis led field studies into productivity and growth differences in in-channel vs off-channel habitats.
- In-kind contribution likely to be available from DCCEEW BCS in the form of advice on potential nursery sites (including sites identified via the Reconnecting River Country golden perch population model as applied to different flow regimes) and field staff availability.
- For present or potential nursery grounds:
    - Which sites may be the priority for delivering water for native fish nursery outcomes?

- What is a suitable scenario-based approach to supporting these nurseries? For example, maintaining water levels during dry between periods to sustain the fish in the nursery, then seeking to provide connectivity with the river channel to enable dispersal in wetter times.
- How does i) productivity (zooplankton density), and ii) fish growth (otoliths) differ in off channel lentic habitats compared to in channel habitats?
- How can environmental water be used to help re-establish/foster connections between in-channel and nursery areas for fish recruitment and growth outcomes? What complementary measures are required? (e.g. works)

6.3.4 Research topic RP4 - Native fish

Question: What is the status of wetland/population specialist fish species in the Mid-Murray wetlands?

Research theme: Understanding the processes that drive ecological responses to flow

Project team: Dr Nicole McCasker (CSU), Dr Jerom Stocks (DPI Fisheries), Dr Dylan Van der Meulen (DPI Fisheries), Mr John Trethewie (CSU), Cultural Advisor, opportunity for First Nations and local community involvement.

Project summary:

- Small-bodied floodplain/wetland specialist species are some of the most threatened fish species in the Murray–Darling Basin. In the Mid-Murray CEW is increasingly being used to deliver water to off-channel wetlands. This project would identify where/what wetland specialist species are in the mid-Murray wetland and provide recommendations on how environmental wetland watering can support these species.
- Combination of eDNA and conventional sampling
- e-DNA would be used to detect distribution rare species, create current list of distribution and detection of small-bodied floodplain species in the Mid-Murray wetlands. The e-DNA surveys would enable diversity of other taxa to be reported in addition to fish
- Conventional sampling to assess population structure and recruitment of small-bodied floodplain species.
- Opportunities for First Nations and community participation

6.3.5 Research topic RP5 - Native fish

Aim: Long-term contribution of water for the environment to Mid-Murray fish outcomes

Research theme: Understanding the processes that drive ecological responses to flow

Project team: Dr Nicole McCasker (CSU), Dr Jerom Stocks (DPI Fisheries), Dr Dylan Van der Meulen (DPI Fisheries), Mr John Trethewie (CSU), Cultural Advisor.

Research theme: Understanding the processes that drive ecological responses to flow

Project summary

- Prior to Flow-MER 2.0 annual adult fish sampling has taken place in the Mid-Murray through a variety of long-term programs (2014-2024), including TLM at Barmah and Gunbower in Murray

River, and LTIM, Flow-MER that have focussed Edward/Kolety Wakool River system. To our knowledge data from across these programs has never been brought together, to look at long-term trends in fish populations within the Mid-Murray region, and the influences of environmental water over the past decade.

- This research project would combine past long-term fish data sets from the Murray (TLM - Gunbower, Barmah) and Edward/Kolety River system (LTIM, Flow-MER) to investigate patterns in fish metrics (age structure, biomass, abundance) to see how much spatial differences there are within and between years, and investigate contribution of ewater to fish outcomes (effectively running Basin-scale analytical approach, but for Area-scale from 2014 to 2024).
- This project would be an opportunity for research collaboration with Basin-scale team, the Mid-Murray Area-scale native fish theme team and TLM researchers and project managers (e.g NCCMA, ARI, GBCMA).

6.3.6 Research topic RP6 - Native fish

Question: What is the distribution of trout cod, river blackfish, and freshwater catfish in the Mid-Murray region? Implications for flow and future monitoring.

Research theme: Understanding the processes that drive ecological responses to flow

- **Project team:** Dr Nicole McCasker (CSU), Dr Jerom Stocks (DPI Fisheries), Dr Dylan Van der Meulen (DPI Fisheries), Mr John Trethewie (CSU), Cultural Advisor, opportunities for First Nations and community involvement.

Project summary

- Trout cod, river black fish and freshwater catfish are species found in the Mid-Murray, but considered to have restricted distributions, though recent reports of range expansion (trout cod, river blackfish) have been documented.
- This research project apply eDNA sampling throughout the Mid-Murray to create a current distribution map of each of these key species.
- The findings of this work would allowing future targeted monitoring and research to take place,
- broadscale eDNA survey
- Opportunity for First Nations and community Involvement
- Open opportunity for project to be expanded to other water dependent animals (e.g. Murray crayfish, Rakali, turtles, platypus)

6.3.7 Research topic RP6 - Native fish movement

Question: How is golden perch and/or silver perch movement linked to flow in the Mid Murray? How can environmental water be delivered to improve dispersal of juvenile perch and assist with the recovery of perch, in a part of the basin where populations are depleted?

Research theme: Adaptive management of water for the environment

Project team: TBC; Dr James Dyer (DCCEEW BCS), Cultural Advisor

Project summary

- To increase our understanding of the influence of environmental variables, primarily river flow, on juvenile golden perch and/or silver perch dispersal into the Mid Murray and Edward/Kolety-Wakool river system.
- Would complement or extend existing 2023 to 2025 golden perch movement monitoring project being conducted by DCCEEW BCS and CSU (400 fish tagged in 2023-24, a further 100 will be tagged in spring 2024).
- Could involve further exploration of golden perch movement, or expand to focus on lesser-known movement patterns of silver perch in the Mid Murray.
- In-kind contribution likely to be available from DCCEEW BCS in the form of maintenance of the existing acoustic receiver array and field staff availability. FlowMER research contribution would be required primarily for tagging surgeries in the field (as per ethics permit requirement) and technical evaluation.
- Likely to contribute to basin-scale fish evaluation of native fish movement.
- Opportunity for First Nations and community Involvement

6.3.8 Research project RP7 - Freshwater mussels

Aim: Water requirements for freshwater mussels in the Mid-Murray River system

Research theme: Understanding the processes that drive ecological responses to flow

- **Project team:** Dr Nicole McCasker (CSU), Cultural Advisor, opportunities for First Nations and community involvement.

Project summary

- Freshwater mussels where once abundant throughout the river and floodplain habitats of the Mid-Murray.
- Changes to flow and flooding regimes are thought to be a contributing factor to population declines for freshwater mussels, but little is known of their current distribution in the Mid-Murray Area,
- This research could address gaps in our knowledge of the flow and watering regimes of freshwater mussels by:
- Mapping the distribution and abundance of billabong/floodplain mussels and river mussels throughout a range of aquatic habitats present in the Mid-Murray Area.
- Identify spatially explicit watering priorities for CEW as relevant for freshwater mussel life histories.

6.3.9 Research project RP8 – Water quality

Aim: Quantifying the contribution of CEW to salt mobilisation in the Mid-Murray

- Explore the potential to use the MDBA River Murray salinity model to assess salinity impacts of an individual environmental watering actions from the tributary inflows to Mid-Murray River system?
- What did an individual environmental watering action contribute to salt mobilisation from the particular tributaries/river to Mid-Murray River system?

Project team: Dr Xiaoying (Shasha) Liu (CSU), MDBA modellers, Prof Robyn Watts (CSU), Cultural Advisor.

Research theme: Support adaptive management

Project summary

As stated in Basin Plan (2012), monitoring surface water salinity is a priority for long-term salinity planning and management for the Basin. The MDBA River Murray model is used to estimate salinity impacts from salt load, flow and salinity input data. However, River Murray model (SOURCE) assesses salt mobilisation from the aggregation of watering actions across the whole River Murray system and evaluate salinity impacts of environmental water actions cumulatively.

We would like to explore the potential of using MDBA River Murray model to evaluate salinity impacts of individual environmental watering actions from tributaries and to determine whether we are able to evaluate the salinity impacts of each environmental watering action at individual rivers within Mid-Murray River system.

The outcome of this research project would help to inform management of environmental water and improve understanding the effects of each environmental watering action on salt mobilisation in Mid-Murray River system to help long-term salinity planning and management for MDB.

This project would be undertaken in collaboration with modellers at MDBA, with the needs to have MDBA modellers provide salinity modelling of nodes coming into River Murray channel. This project would generate the salinity impacts at individual nodes within Mid-Murray River system over the period of a particular environmental watering action

This project could be undertaken in collaboration with Knowledge exchange and community engagement citizen science project to upload the photos and river heights from staff gauge readings in Mid-Murray River system.

This could also be integrated with a project to examine the distribution and potential risks of acid sulfate soils in the Edward/Kolety-Wakool River system.

This could also be integrated with an interdisciplinary project that includes social research on the community involvement and understanding of the Project.

6.3.10 Research topic RP9 Water quality

Aim: Modelling the contribution of CEW to water quality responses using data from LTIM and Flow-MER monitoring. Q: To what extent did environmental water contributed to the total river flow? To what extent did environmental watering actions influence water quality changes? Did environmental water have long-term trends in water quality changes?

Research theme: Understanding the processes that drive ecological responses to flow

Project team: Dr Xiaoying (Shasha) Liu (CSU), Dr Luke McPhan (CSIRO), Prof Robyn Watts (CSU), Cultural Advisor.

Project summary: Over the 10 years of LTIM and Flow-MER Program we have developed an extensive dataset of water quality data from sites throughout the Edward/Kolety-Wakool system under a wide range of flow conditions (including regulated and unregulated flows). Water quality parameters were selected and monitored at sites in the Wakool-Yallakool system for LTIM Project and expanded area was monitored in the Edward/Kolety-Wakool system during the period of Flow-MER1.0 Program to better capture the impact of environmental water in the broader system.

To date we have not had the resources to explore the relationships and model water quality responses to flow. In 2024-25 water year, we propose to conduct a research project to model water quality responses to flow using 10 years LTIM/ Flow-MER1.0 data. This research project will be in collaboration with scientists from La Trobe University. This quick-start project utilises this existing dataset and will result in a predictive model that inform future watering actions and assist planning of water actions that specifically target water quality issues.

7 Responsive Monitoring

7.1 Overview of proposed responsive monitoring in the Mid-Murray Area

Responsive Monitoring refers to monitoring that is responsive to:

- Emergent on-ground events such as adverse water quality events and waterbird breeding events
- Improved integration through a multi-disciplinary approach; or
- Improved approaches to evaluation.

A range of response monitoring projects could be undertaken in the Mid-Murray Area in response to ad hoc events, such as hypoxic water and waterbird breeding events. These would build on projects that have monitored responses to events in previous years, as well as new projects. The study design of these projects would be developed depending on the circumstances and geographic natures of the issue at the time.

The primary aim of responsive monitoring funding is for adaptive management purposes, particularly to inform real-time delivery of CEW where information is required at short notice and could not have been planned and confirmed in a detailed way during development of the MER Plan or Annual Implementation Plans.

When extreme events occur Area-scale Providers will work closely with CEWH and, where appropriate, with other Area-scale Providers, the Basin-scale and Knowledge Exchange Provider, when developing responsive monitoring projects.

Some examples of responsive monitoring projects are described here. This is a non-exhaustive list, as more options are likely to arise over the course of the Plan's implementation.

7.1.1 Monitoring waterbird breeding in response to environmental watering actions

Aims:

- Identify gaps in waterbird breeding coverage
- Draw on complementary NSW DCCEEW and TLM data where possible
- Link to River Flows and Connectivity theme for water depth and inundation extent monitoring

Project team: Dr Jen Spencer (NSW DCCEEW), Jess Heath (NSW DCCEEW), Cultural Advisor, opportunities for First Nations and community involvement.

Approach:

- Annual planning to identify potential events and gaps in complementary monitoring programs
- Repeat on-ground surveys to document stage of nesting, breeding species, site conditions, evidence of mortality and predation.
- Drone surveys for large ibis colonies to document breeding site extent and total number of nests.

Project summary: Waterbird responsive monitoring may be needed to capture information on waterbird breeding events when they occur in the Mid-Murray Area. Group-nesting waterbird species, such as ibis, egrets and herons, breed in a relatively small number of wetlands in the Murray–Darling

Basin and it is critical to document information on the location and size of active breeding sites when they occur. Waterbird responsive monitoring is expected to contribute to the Basin-scale waterbird theme evaluation question: What did CEW contribute to waterbird breeding occurrence? Waterbird breeding events can be triggered following high river flows and CEW can be used for some sites to extend the duration of flows to support successful nesting.

Responsive waterbird breeding monitoring will be needed to supplement NSW DCCEEW and TLM complementary waterbird programs in the Mid-Murray Area. There are gaps in the coverage of these complementary programs in the Mid-Murray, particularly for the mid- Niemur wetlands and Werai Lands, where limited data has been collected to date. Widespread waterbird breeding events in the Mid-Murray Area and neighbouring catchments was recorded on three occasions (2016-17, 2021-22 and 2022-23) in the last decade and so there is likely to be at least two events in these wetlands where responsive waterbird breeding monitoring is required during the five-year project. Some key breeding sites such as Barmah-Millewa Forest support waterbird breeding events more regularly with TLM intervention monitoring supporting some data collection in most years but this is often restricted to the Reedbeds and Boals swamps only.

On-ground monitoring can provide vital real-time information on stage of nesting, water depth and evidence of disease and predation in breeding sites which can support the adaptive management of environmental water. In previous years UNSW have successfully monitored large ibis breeding sites in the Murray–Darling Basin with ground surveys to document number of nesting species, stage of nesting and overall reproductive success (Brandis et al. 2023a, 2023b). Multiple agencies have also undertaken monitoring of waterbird breeding sites in Barmah-Millewa Forest and Koondrook-Perricoota Forest supported through TLM funding to include sites that have supported nesting ibis, egrets, cormorants, spoonbills and herons.

Waterbird breeding responsive monitoring would follow the same methods used previously in other Areas (e.g. Wassens et al. 2017; 2023) to include: 1) repeat visits throughout the breeding period to collect information on breeding species, estimated numbers of nests and stage of nesting, 2) where needed, repeat drone surveys for ibis breeding sites to track changes in total number of nests and stage of nesting over the breeding event, and 3) where possible, continuous water depth monitoring using fixed data loggers. Water depth monitoring and evaluation will be done as part of the River Flows and Connectivity Theme.

Ground surveys

Initial breeding assessments will be carried out in October-November each year as part of NSW DCCEEW and TLM complementary spring ground surveys and UNSW aerial spring surveys. Subsequent follow up surveys will be undertaken monthly (Nov-Mar) at active sites to the end of the breeding period (see Wassens et al. 2019 for detailed methods). Briefly, ground surveys are conducted on foot or using a large canoe or small boat. During each survey detailed assessment of the breeding site will be made to include estimates of site boundary, total number of nests of each species and stage of nesting and water depths. This information will be used to inform the need for delivery of environmental water to maintain active sites. For most breeding sites, a complete assessment of total number of nests per species is possible by two observers systemically moving from one nesting tree/area to the next. An evaluation of breeding success for each site is based on observations made during the monthly surveys where the number of birds in each development stage is recorded. It is assessed at the end of the breeding events using a count of total number of fledged birds, number of predators (i.e., feral predators and raptors) observed and number of dead birds (if present) recorded in each breeding site. Observations of other waterbird species and their breeding activity will also be recorded.

Drone surveys

UNSW have used drone surveys effectively to document the extent and size of the ibis breeding sites in Barmah-Millewa Forest (e.g., Francis and Brandis 2023) and elsewhere in the MDB in the recent 2021-22 and 2022-23 breeding events. We recommend that drone imagery is collected at the start of the breeding event (when adults are sitting on eggs or young chicks) and later in the event (when chicks are mobile) to document any expansion of the site and any mortality. Two sets of imagery of the breeding site will allow us to assess any changes in the size and extent of each breeding site since nests were first established. Often rookeries increase in size and boundaries change as more birds set up nests, or different species join the site. UNSW has a semi-automated approach developed for counting nesting ibis which reduces the time and cost associated with manual counting of nests (Francis et al. 2020).

7.1.2 Monitoring water quality responses to poor water quality events

Aims: Monitoring water quality during;

- Hypoxic events
- Algal blooms

Project team: Dr Xiaoying (Shasha) Liu (CSU), Christine Lachlan-Arrowsmith (Streamology), Prof Robyn Watts (CSU), Mr John Trethewie (CSU), Dr Luke McPhan (CSIRO), Cultural Advisor, opportunities for First Nations and community involvement.

Project summary: Since 2010 there have been several large unregulated flow events in the Murray River that have resulted in inundation of large areas of floodplain. Carbon and nutrient release following the inundation of agricultural and forested floodplain, can result in water with high organic loads (usually dark/black in colour) entering waterways from the floodplain. Water can become hypoxic (low dissolved oxygen concentration) when large amounts of organic material in rivers are broken down by bacteria, consuming dissolved oxygen in the water. Prolonged low oxygen concentrations can result in the interruption of flood-response movements, stress or death of native fish.

Responsive monitoring can be undertaken to examine the role of CEW in the provision of temporary refuges within the river channel during severe hypoxic water and other poor water quality events, to help inform the adaptive management of environmental water delivery in the Area.

Should the responsive monitoring component be triggered due to hypoxic water or other adverse water quality in the system, sites may be selected to monitor the progress and severity of the hypoxic water or other adverse water quality. The specific sites will be determined on an event basis in collaboration with the CEWH and other stakeholders. The sampling design for responsive monitoring will be developed depending on the specific event.

Responsive monitoring of poor water quality events has been undertaken in the past as part of the LTIM and Flow-MER1.0 projects. It can provide rapid feedback to water managers during the watering action to assist water managers adaptively manage the environmental water and adjust the watering actions and increase knowledge about the effectiveness of using environmental water to create refuges.

There are also opportunities for community collaboration during these responsive monitoring activities. Community members have previously been involved in monitoring water quality.

7.1.3 Monitoring fish responses to refuge flows from Escapes

Aims: Monitoring the creation of fish refuge during hypoxic events

Project summary: Responsive monitoring can be undertaken in response to hypoxic events: Fish responses to refuge flows from Escapes. Various methods to evaluate refuges were undertaken in 2023 (Liu et al, 2023) that could be applied to future poor water quality events and watering actions.

There are opportunities for First Nations and community collaboration during these responsive monitoring. Community members have previously been involved in monitoring fish refuges.

Integration with water quality monitoring and hydrological data from the same reaches/sites will help provide context for interpreting the fish results.

7.1.4 Water quality responses to Werai Lands inundation

Aim: What is the impact of environmental watering of Werai Lands on the water quality (carbon, nutrients, dissolved oxygen) and productivity of Colligen Creek?

Project team: Dr Xiaoying (Shasha) Liu (CSU), Christine Lachlan-Arrowsmith (Streamology), Prof Robyn Watts (CSU), Dr Luke McPhan (CSIRO), Mr John Trethewie and Mr Chris Davey (CSU), Cultural Advisor, Traditional Owners of Werai Lands, opportunities for First Nations involvement.

Research theme: Adaptive management of environmental water

Project summary: A new type of environmental watering action is planned for Werai Lands (Ramsar site) in 2024-25, and this type of watering action is likely to be a priority for water managers in future years. The watering action to Werai Lands will flow via Tumudgery Creek to the Colligen- Niemur River system. However, the thresholds or likely water quality outcomes of this type of environmental watering actions through Werai Lands have been poorly studied. Water quality monitoring of environmental water delivered through Werai Lands can be integrated with inundation modelling of wetland and floodplain forest (evaluation question 2 in the river flows and connectivity theme) and can help create knowledge to inform adaptive management of changes in water quality conditions.

This project will monitor a small managed environmental water action where it is expected that water will return to Colligen Creek via Tumudgery Creek. In order to address this question, one monitoring site downstream of the Tumudgery Regulator (upstream of Werai Lands before water passing through Werai Lands), one site in Tumudgery Creek upstream of Tumudgery Creek in Werai Lands near confluence with Colligen Creek (environmental water end of forest), one site in the Colligen Creek upstream of Tumudgery Creek confluence (operational flow without environmental water) and one site in the Colligen Creek downstream of Tumudgery Creek confluence (environmental water plus operational flow after forest), can be selected to detect changes in water quality indicators.

This type of research design could be applied in future years to watering actions targeted to other forests, such as Niemur Forest or Koondrook-Perricoota Forest.

8 First Nations activities

8.1 Introduction

First Nations peoples have a holistic and integrated world views that encompass all aspects of their lives. Caring for Country is integral to their lives. Knowledges are culturally and spiritually embedded in communities and is passed down orally through generations. Indigenous knowledges and practices therefore differ among First Nations peoples and groups.

The Mid-Murray Area extends from the Hume dam through to Mildura on the Murray River and includes the Edward/Kolety-Wakool system and its tributaries. The Mid-Murray Flow-MER Area is Country to many First Nations including the Bangerang, Barapa Barapa (Perrepa Perrepa), Barkindji (Barkandji), Dadi Dadi, Kureinji, Latji Latji, Wadi Wadi, Wamba Wamba (Wemba Wemba), Wiradjuri, and Yorta Yorta First Nations peoples. These First Nations, groups and peoples have an intrinsic and deep connection to the rivers, wetlands and lands in the Mid-Murray Area, which has formed an important part of their cultures for millennia.

The Flow-MER2.0 Program has dedicated funding for activities with First Nations peoples. The dedicated funding provides an opportunity to continue to build on existing activities while supporting new opportunities. The Mid-Murray Area-scale team will be guided by the Flow-MER2.0 Program First Nations People MER Strategy (DCCEEW 2024b), and support First Nations led and delivered activities and actively involve First Nations peoples in the monitoring and research for the Flow-MER Project. The activities that we will support will aim to:

- Share skills, techniques and knowledges between First Nations peoples and Flow-MER practitioners
- Provide two-way learning opportunities
- Relationship and trust building
- Share knowledge and understanding on flora, fauna and ecological processes.

The Flow-MER2.0 First Nations People MER Strategy (DCCEEW 2024b) highlights how the Program can support capacity building, leadership opportunities, and connection to Country for First Nations people through investments in First Nations involvement in the Program. The aim of the First Nations People MER Strategy highlights a focus on First Nations determined and driven involvement through embedding cultural knowledges within the Program, see DCCEEW (2024b).

8.2 Previous First Nations activities

As part of the Edward/Kolety-Wakool Flow-MER1.0 (2019-2024) Project, the Edward/Kolety-Wakool team has collaborated with First Nations organisations and peoples on a range of activities. These activities include:

- Research project on turtle movement and condition https://flow-mer.org.au/tracking-turtles-in-the-edward-kolety-river-system/

- Vegetation surveys in Werai Lands https://www.dcceew.gov.au/water/cewo/publication/edward-kolety-wakool-mer-project-werai-forest-report-2022
- Monitoring inundation on Werai Lands using field cameras https://www.dcceew.gov.au/sites/default/files/documents/edward-kolety-wakool-newsletter-15-2023.pdf
- Fish surveys in ephemeral creeks https://flow-mer.org.au/learning-more-about-ephemeral-creeks/
- Community field days https://flow-mer.org.au/riverside-community-field-day-highlights-collaboration/
- Research project on fish spawning in the Edward/Kolety River
- Monitoring responses of native fish to environmental watering https://www.dcceew.gov.au/water/cewo/water-for-environment/local-stories/local-citizen-scientists-deniliquin-locals-monitoring-native-fish-responses-water-environment
- Providing opportunities for the Kolety Werkul River Rangers at Yarkuwa Indigenous Knowledge Centre and other First Nations peoples to participate in a range of Flow-MER monitoring and research activities (including some of the projects listed above), providing training and skills development and opportunities to access Country.

Through these activities the Edward/Kolety-Wakool Project team have developed relationships, shared knowledge and have developed a richer understanding of First Nations.

8.3 Appointment of Mid-Murray Project First Nations Cultural Advisor and Local Cultural Advisors/Liaison Officers

There are many First Nations and First Nations organisations in the Mid-Murray. After discussions with a number of different Nations, groups, organisations and individuals in the Mid-Murray Area it was evident that engagement with First Nations Groups would be best facilitated by working with established organisations and employing a Local Cultural Advisor/Liaison Officer from each of the organisations for the period of time that they plan, implement and report on Mid-Murray Flow-MER activities. A Mid-Murray Project Cultural Advisor will facilitate engagement with the many First Nations peoples and organisations in the Mid-Murray Area.

Individual Flow-MER activities may occur over short time frames or may extend across several years. Thus, over the course of the five-year Mid-Murray Project it is likely that there will be several local First Nations Advisors/Liaison Officers working with the Mid-Murray Flow-MER Project at any one time.

This approach of engaging a Mid-Murray Project First Nations Advisor and several local First Nations Advisors/Liaison Officers will facilitate:

- Local, on-ground First Nations peoples to work with the Mid-Murray team. The First Nations Advisors/Liaison Officer in each organisation will help coordinate Flow-MER on-ground activities of First Nations peoples in their area/organisation

- The establishment of a Cultural Network of First Nations Advisors/Liaison Officers in the Mid-Murray Area that will support knowledge exchange and cultural exchange among First Nations involved in the Mid-Murray Flow-MER Project. One representative from this group will serve as the Mid-Murray Project Cultural Advisor and participate in the Program-level Cultural Network meetings. Having multiple First Nations Advisors/Liaison Officers in the Mid-Murray will provide opportunities for different people to contribute to the Cultural Network in different years of the Program.
- Local people from different First Nations to contribute to reporting of First Nations Cultural Outcomes in the Mid-Murray.

The leader of the Knowledge Exchange, Communication and Engagement component of the Mid-Murray Project Professor Robyn Watts will be the point of contact between the First Nations Advisors/Liaison Officers and the Mid-Murray Project team.

8.4 Staged approach to engagement and collaboration with Mid-Murray First Nations

Developing relationships and collaborative activities takes time. The development of relationships, activities with First Nations peoples will be a staged approach. Relationships with some organisations will take longer to develop than others. Some activities will take longer to develop and commence than others, and thus different First Nations activities will commence at different times. The Mid-Murray team will work with many First Nations groups and strive to provide active involvement in the Mid-Murray Project and provide meaningful, paid opportunities to local First Nations peoples to care for the river and its people.

The Mid-Murray Flow-MER Team will:

1. Work closely with the Mid-Murray Project First Nations Cultural Advisor and Local First Nations Advisors/Liaison Officers on the Mid-Murray Project
2. Facilitate activities which are First Nations led, and facilitate co-design, co-development and co-delivery of projects with First Nations peoples and the Mid-Murray team
3. Support training and knowledge exchange opportunities that are sought by First Nations groups for their peoples
4. Establish regular and meaningful mechanisms for two-way sharing of knowledge among different First Nations peoples and organisations
5. Share First Nations stories or knowledge after seeking Free Prior and Informed Consent
6. Ensure any engagement, research or sharing of information is undertaken ethically, with consent, and in a culturally safe way with protection for ICIP
7. Ensure that First Nations peoples are remunerated for their knowledges, expertise, and time in a self-determined way
8. Provide regular updates to the First Nations MER Lead and attend Cultural Network meetings.

8.5 Initial steps to develop First Nations activities

As part of discussions with First Nations organisations and peoples in the Mid-Murray undertaken in Stage 1 planning phase of Flow-MER2.0, several potential project ideas were provided by First Nations peoples for consideration. These included:

1. Providing training and skills development opportunities for River Rangers and First Nations peoples through involvement in Mid-Murray Flow-MER monitoring and research activities. Provide training opportunities that can assist with the development of competencies that can contribute to completion of TAFE Certificate 3 in Conservation and Ecosystem Management
2. Collaborative development of knowledge and cultural exchange opportunities for River Rangers from different parts of the Mid-Murray Area to get together to share knowledge and experiences from their involvement in the Mid-Murray Flow-MER Project. Improve linkages between First Nations Rangers Groups in different NIAA regions
3. Investing in water quality equipment and training for local First Nations people as citizen scientists
4. Providing training in videography and use of drones and funding to enable First Nations peoples to document stories from their involvement in the Flow-MER Project using a range of media
5. Provide opportunities to be involved in the planning, delivery and monitoring of environmental watering actions
6. Developing seasonal calendars.

Further discussions will be undertaken with First Nations organisations and groups to develop these ideas. Several First Nations organisations have indicated that they will discuss within their organisations and develop ideas for First Nations led projects and ideas for collaboration and training.

8.6 Ensure Indigenous Cultural and Intellectual property (ICIP) and Free Prior and Informed Consent (FPIC) integration throughout the program

Indigenous Cultural and Intellectual Property (ICIP) refers to the rights of First Nations people to their tangible and intangible cultural heritage. As outlined in the AIATSIS 2020 guide to applying the Australian Institute of Aboriginal and Torres Strait Islander Studies (AIATSIS) Code of Ethics for Aboriginal and Torres Strait Islander Research, researchers have a responsibility to understand the interaction of knowledge systems and legal systems in research practice. Here ICIP refers to all aspects of Indigenous peoples' cultural heritage, including:

- laws, philosophical traditions and spiritual beliefs
- knowledge and knowledge systems (scientific, agricultural, technical, ecological and ritual knowledge)
- cultural expression (stories, designs and symbols, literature and language)
- performances (ceremonies, dance and song)

- cultural material (including, but not limited, to arts, crafts, ceramics, jewellery, weapons, tools, visual arts, photographs, textiles and contemporary art practices)
- human remains, human tissue, genetic information and material obtained or derived from human tissue (including plasma, proteins, DNA and RNA, for example), or processed forms of material of this kind
- knowledge about genetic resources
- secret and sacred material and information (including sacred and/or historically significant sites and burial grounds)
- the documentation of Indigenous peoples' heritage in all forms of media such as films, photographs
- artistic works, books, reports and records taken by others, sound recordings and digital databases
- connections to land, waters, natural resources and ecologies
- cultural places, sites and landscapes.

Indigenous Cultural and Intellectual Property Rights refer to the rights of First Nation people to:

- own, control and maintain their ICIP
- ensure that any means of protecting ICIP is based on the principle of self-determination
- be recognised as the primary guardians and interpreters of their cultures
- authorise or refuse the use of ICIP according to their own law
- maintain the secrecy of Indigenous knowledge and other cultural practices
- guard the cultural integrity of their ICIP
- be given full and proper attribution for sharing their cultural heritage
- control the recording of cultural customs, expressions and language that may be intrinsic to cultural identity, knowledge, skill and teaching of culture
- publish their research results.

The Mid-Murray team will work with Cultural Advisors/Liaison Officers from First Nations organisations in the Murray Area. Involvement with Cultural Advisors/Liaison Officers will be an ongoing process, and consent will be sought at each stage of any work or activity undertaken together.

Free Prior and Informed Consent (FPIC) is a specific right that applies to First Nations people under the United Nations Declaration on the Rights of Indigenous Peoples and is a critical part of First Nations self-determined involvement in any aspect of work that may affect First Nations people, including but not limited to First Nations data, cultural values and Country (DCCEEW 2023b).

Following the First Nations People MER Strategy, the Mid-Murray Team will ensure prior consent has been provided for any aspect of the Project that includes First Nations involvement. This includes aspects of planning and design, collecting and storages of data, and publishing of results.

As a starting point for this Project we will develop local cultural protocols that will then form part of Human Ethics applications and underpin our approach to engaging with First Nations. Prior to any formal activities where First Nations knowledge will be obtained, used, or documented in any form, a Human Ethics approval will be obtained through the Charles Sturt University Human Research Ethics

Committee (HREC), which is constituted in accordance with the National Statement on ethics conduct in human research. This will include providing an approved consent statement which is to be approved and signed by all First Nations people participating in any activity where ICIP is a factor. This process will commence early in the first year of the Program and FPIC will be sought for different activities.

As highlighted in the First Nations Peoples MER Strategy (DCCEEW 2024b), consent may be withdrawn at any point, however it is important that all parties understand that once material or knowledge has been published, such as in the scientific literature or on social media, there are limitations around how much the dissemination of this knowledge can be prevented. Thus, consent will govern the types of projects, scope, and expected output/s which will be planned. This is a potential limitation of the Program – as consent may limit the scope of projects or activities which may occur. The Mid-Murray Team will work with First Nations groups and people to identify the cultural knowledge which they would like to share and the way in which they would like to share it.

The withdrawal of consent also poses a potential project risk, as this may result in the return of data or information and removal of material or text from reports, Flow-MER website, or social media. This risk will be managed throughout the life of the Program as best as possible.

8.7 Cultural competency

The Mid-Murray Flow-MER2.0 team, have been working with First Nations peoples and groups across a range of projects and have developed respectful relationships with First Nations peoples and organisations. The Flow-MER team members have undertaken and will continue to undertake training workshops in cultural awareness and competency, including cultural awareness training and annual training modules through Charles Sturt University and other partner organisations. Charles Sturt University employed team members are also working under the principles outlined in the CSU First Nations Strategy (https://cdn.csu.edu.au/__data/assets/pdf_file/0008/4183748/First-Nations-3year-Strategy.pdf). The team will continue to seek opportunities to develop cultural competency.

9 Knowledge Exchange, Communication and Engagement

This plan will intersect closely with Section 8 (First Nations activities). Approaches to engage and work with First Nations peoples are outlined in Section 8.

9.1 Background

The long-term success of environmental watering programs requires strong relationships with stakeholders, including local communities, private landholders, and First Nations. The CEWH recognise the importance of effective communication and engagement in building relationships and achieving their goals for environmental watering across the Basin.

In the Flow-MER2.0 Program, Knowledge Exchange, Communication and Engagement (KECE) has replaced the Communication and Engagement activities that were an integral part of the previous LTIM and Flow-MER1.0 programs. The KECE approach for Flow-MER2.0 encompasses an additional focus on knowledge exchange. The Flow-MER2.0 Knowledge Exchange Strategy (DCCEEW 2024a) defines the following key terms as such:

- Knowledge exchange as two-way flow of ideas, evidence and expertise to enable information and knowledge to be shared and used.
- Engagement is a process of working with and sharing knowledge across organisations and communities to shape decisions or actions
- Communication is the provision and dissemination of information, data and knowledge to identified audiences via apprioriate channels to increase their understanding, and in some cases encourage them to take certain actions.

This Mid-Murray Area KECE approach describes a set of KECE approaches and activities and how they will align with and meet the seven objectives of the overarching Knowledge Exchange Strategy (DCCEEW 2024a).

The overarching aim of the Knowledge Exchange Strategy is "*Improved understanding, decision-making and outcomes for water for the environment through a knowledge generation and sharing network based on trust, collaboration and long-term relationship"* (DCCEEW 2024a). The key principles of the Knowledge Exchange Strategy are: to be relevant, empowered, accessible, timely, evidence based and cohesive.

The role of KECE in Flow-MER is to support the achievement of the Flow-MER vision by:

- Sharing and exchanging knowledge to inform adaptive management of environmental water use
- Embedding First Nations people's cultural knowledge into activities of the Program
- Building awareness of environmental watering outcomes detected through our monitoring, evaluation and research.
- Building connections, engaging, and coordinating locally to undertake monitoring
- Contribute to basin-wide understanding and transparency through communicating Flow-MER knowledge to the broader community
- Supporting internal collaboration and coordination to support the delivery of the Program.

The steps we have taken in developing KECE approaches and activities for the Mid-Murray Area are:

- Consider the context
- Understand the role of the team and relevant groups
- Consider participation goals
- Identify a diversity of approaches
- Describe and prioritise activities
- Identify risks and mitigation strategies.

The Mid-Murray KECE approach and activities will align with the following:

- Knowledge Exchange Strategy
- First Nations People MER Strategy
- Branding and Acknowledgement Guide
- MER Plan requirements for the Knowledge exchange, communication and engagement approach set out in the Statement of Work in the contract.

Our method for developing this Mid-Murray KECE approach includes the following principles:

- Consider Communities of Place as a key part of the engagement strategy. Involve local people in monitoring, research and KECE activities in their local area.
- Aim to ensure KECE activities are undertaken across the Mid-Murray Area, targeting activities to be associated with environmental watering actions if possible. This will be challenging as the Mid-Murray Area cover a large landscape. KECE activities may not be equally spread across the Area if there is an uneven distribution of environmental watering actions in different parts of the Area.
- Seek opportunities to link KECE activities with monitoring and research activities as much as possible.
- Leverage KECE activities of other opportunities in the area e.g. linkages with One Basin CRC activities, local NRM activities etc
- Understand the bounds of this project at the same time as seeking opportunities to take up opportunities and link with other activities.

9.2 Relevant individuals, communities and organisations in the Mid-Murray Area

9.2.1 Stakeholders for the Mid-Murray Flow-MER2.0 project

A range of stakeholder groups were the target of communications and engagement for the Edward/Kolety-Wakool LTIM project (2014-2019) and Flow-MER (2019-2024) projects. For Flow-MER 2.0 the boundary of the Area has been expanded and a broader range of stakeholders will be the target audiences for KECE in the Mid-Murray Area. Relevant groups broadly include Flow-MER practitioners, water managers, First Nations peoples, broader science community, local community, broader community, and CEWH. Descriptions of these groups are provided in the Knowledge Exchange Strategy (DCCEEW 2024a).

The concept of 'Community' is central to the Knowledge Exchange Strategy, implied in statements about communication and engagement. In the Mid-Murray Area we consider the larger community of interest in relation to the typology proposed by Harrington et al. (2008) and widely used in natural

resource management (NRM) projects in Australia. This has five, not mutually exclusive, categories for consideration (Table 9.1).

There are a wide range of stakeholders in the Mid-Murray Area (Table 9.2). The Mid-Murray Area has a rich and diverse Indigenous history and many First Nations people maintain strong connections to Country. The Area also supports a productive agricultural community and communities that live in small towns through to large regional centres. In the Mid-Murray Area, there are a range of Federal, State and local government agencies, corporations, non-government organisations, community groups and individuals involved in water management or with a strong interest in water management.

Table 9.1 Classification of Communities of Interest (after Harrington et al 2008)

Broad community type		Description
Communities of place	Community of locality	Communities of place within defined boundaries; e.g., towns, regions, or project areas
	Affected community	A space outside of the community of locality -but impacted by decisions, e.g., communities downstream of a project area
Communities of interest	Special interest groups General interest groups	Collectives or groups with some stake in an issue or site, not necessarily in one place, bound by shared interests values and concerns. e.g., NFF, Landcare groups
Communities of practice		Groups organised around an activity or common practice, e.g., irrigation communities, fishing groups
Communities of identity		Structures around aspects of culture, class, age, e.g. First Nations people, farmers, environmentalists

Table 9.2 Core stakeholders for the Mid-Murray Area Flow-MER2.0 Program

Stakeholder Groups	
Area-scale team	Mid-Murray Area Flow-MER2.0 team
Flow-MER Program teams	Basin-scale Flow-MER team Other Area-scale Flow-MER teams Flow-MER Knowledge Exchange team CEWH Flow-MER Program Teams
Operational Stakeholders	CEWH – Central Delivery team, Southern Delivery Team DCCEEW NSW environmental water managers Murray-Darling Basin Authority WaterNSW Murray Irrigation Limited Key members of other state agencies including NSW DPI, Murray CMA
Advisory Groups	Edward/Kolety-Wakool Operations Advisory Group Edward/Kolety-Wakool Environmental Water Reference Group Murray Lower Darling Environmental Water Advisory Group
Other stakeholders	First Nations organisations Local government Catchment Community groups (e.g. Fishing associations, irrigation groups etc) Non-government organisations Individual landholders who provide access to monitoring sites

Different stakeholders have different KECE needs in relation to the Flow-MER Program. The Mid-Murray Project will use a range of strategies across the International Association of Public Participation (IAP2) spectrum of inform, consult, involve, collaborate and empower. The level of participation will depend on the specific KECE activity undertaken. A given stakeholder group may be targeted at the IAP2 level of inform for one KECE activity, but the same group for another activity may be collaborators on another activity.

The Mid-Murray team will undertake KECE across three broad areas:

- *Operational (internal) project communication and engagement*, relating to activities associated with the delivery of the monitoring, evaluation and research components of the Flow-MER Program. This includes subcontracted partner organisations, participating First Nations Groups involved in the monitoring, evaluation and research, and the CEWH.
- *External KECE*, with stakeholder groups outside of the delivery of the Flow-MER Project and includes landholders, affected communities, First Nations peoples not directly involved in the Project, and the broader public.
- *Whole of Program KECE activities*, that contribute to the Program-level activities, the wider Flow-MER community and the CEWH.

9.2.2 Previous social research in Mid-Murray Area

As part of the Edward/Kolety-Wakool Flow-MER1.0 Project, social research was undertaken by Allan and Minato (2021) to better understand the knowledge, values and opinions of people with some form of 'stake' in the Edward/Kolety-Wakool in relation to environmental water and its use in that river system. The method involved completion of an online survey, and the respondent population was predominantly of local people over 40 years old. There was poor representation of people under 24 years old and no respondents who chose to identify as Indigenous. Nonetheless, the survey provides some indications of how some members of the communities of locality and communities of practice respond to water for the environment as enacted at the time.

All of the respondents agreed that healthy rivers are necessary for healthy societies. The respondents generally supported using water to improve the health of the river system, especially in relation to supporting native fish and water birds and improving water quality. Most respondents were aware of, and generally support, scientific monitoring in relation to water for the environment in the Edward/Kolety-Wakool River System. Some of their reflections on the value of monitoring and research in relation to water for the environment are presented in Figure 9.1.

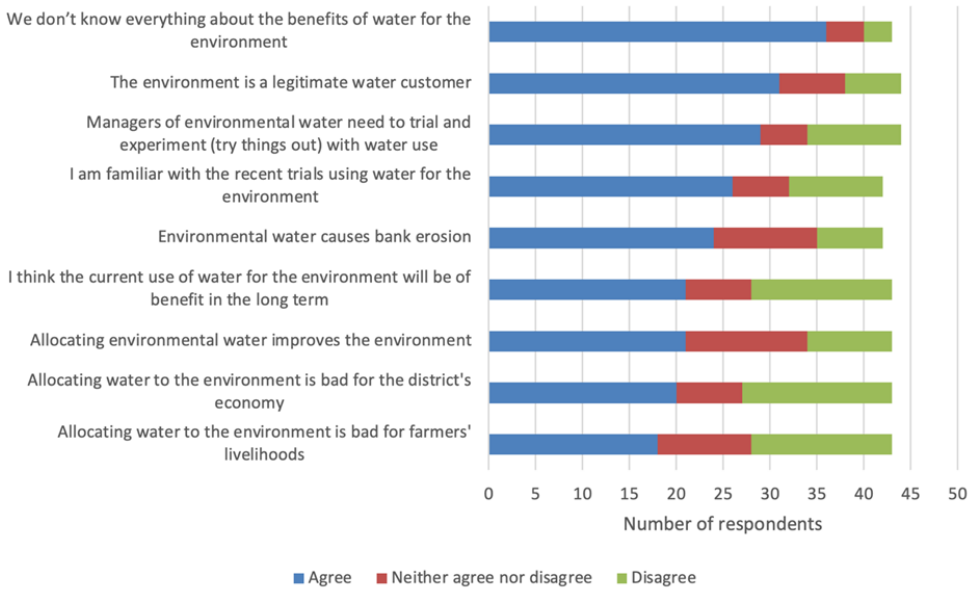

Figure 9.1 Reflections on the use of water for the environment in the Edward/Kolety-Wakool River system. (Source: Allan and Minato 2021)

We understand that different groups have different preferences for how they like to be engaged, receive information and exchange knowledge. Previous social research undertaken with Edward/Kolety-Wakool River system with stakeholders as part of Flow-MER in 2020/2021 (Allan and Minato 2021) sought information on desired information and communication preferences. Respondents noted a number of river system aspects about which they thought there should be more publicly available information. Of these water quality, fish and crayfish were a high priority, with social aspects and plants ahead of birds, turtles, frogs and cultural aspects. Respondent preferences for sources of information are presented in figure 9.2, with preference for local and in person communication evident. We will endeavour to find out the preferences of groups that we work closely with in the Flow-MER2.0 Project.

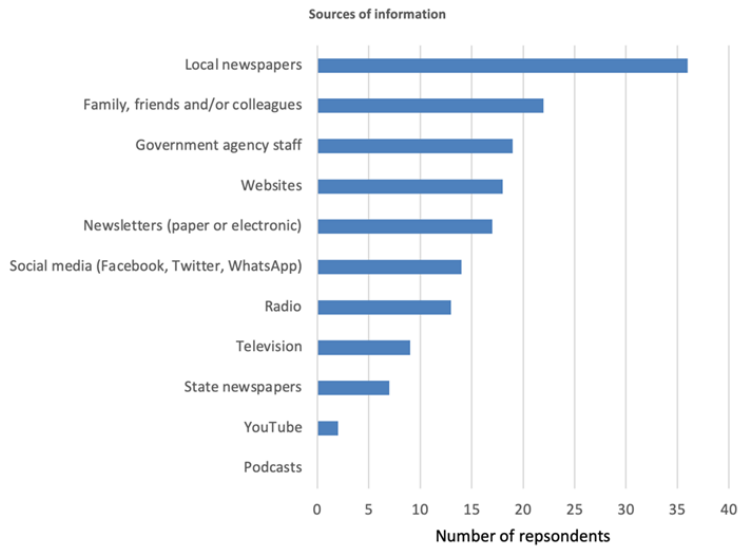

Figure 9.2 Responses from social survey where community members who completed the survey indicated where they sourced their information about water for the environment.

9.3 Roles and Responsibilities

In the Flow-MER2.0 Program there are four key groups contributing to the implementation of the Knowledge Exchange Strategy:

- Knowledge Exchange Working Group
- Basin-scale and Area-scale Providers
- Knowledge Exchange Provider
- the CEWH.

The key KECE roles that the Mid-Murray Area team will lead are described in Table 9.3, specifically:

- to write the Area MER Plan and Annual Implementation Plan
- to deliver activities as outlined in the MER Plan and Annual Implementation Plans for the Area
- to apply best practice approaches
- to collect data and assess performance of activities and Plans
- Incorporate improvements into plans and implement those improvements.

Each of these groups have different key roles and responsibilities (Table 9.3). The Mid-Murray Area team will also apply and support the Knowledge Exchange Provider, the CEWH and contribute to the Knowledge Exchange Working Group as described in Table 9.3.

Table 9.3. Overview of roles and responsibilities for KECE in the Flow-MER2.0 Program as identified in the Knowledge Exchange Strategy (DCCEEW 2024a)

		Knowledge Exchange Working Group	Basin-scale and Area-scale Providers	Knowledge Exchange Provider	CEWH
PLANNING	Area-scale MER plans and Basin-scale ER Plan and Annual Implementation Plans	Inform	Lead	Support and Advice	Approve
	Knowledge exchange plan and Annual Implementation Plans	Inform	(Inform through Working Group)	Lead	Approve
IMPLEMENTATION	Deliver activities in Area-scale MER Plans and Basin-scale ER Plan	Support	Lead	Support	Approve
	Deliver activities in Knowledge Exchange plan	Support	(Support through Working Group)	Lead	Approve
	Consistent branding and messaging	Support	Apply	Support Apply	Lead
	Integration with CEWH communication and engagement.	Support	Apply	Support Apply	Lead
	Coordination and best practice approaches	Support	Apply	Lead	Support
REVIEW	Collect data and assess performance of activities and plans	Support	Lead	Lead	Support
	Identify improvements	Lead	Support	Support	Support
	Incorporate improvements into plans and implement	Support	Lead	Lead	Support

9.4 Categorisation and approaches/activities

Four categorisation approaches will be employed to evaluate how the KECE activities we undertake in the Mid-Murray Area are meeting KECE Strategy objectives:

1. *Contractual (contractually required activities or additional KECE activities)*

KECE activities undertaken in the Mid-Murray Flow-MER2.0 Area will be classified as contractual requirements ('required activities' see 9.5.1) and 'additional' activities that have been designed and prioritised by stakeholders from the Mid-Murray Area (see 9.5.2). These additional activities can include Area-scale activities that apply across projects and those that are specific to a single activity.

2. *Content pillars*

KECE activities that are undertaken in the Mid-Murray Area will be described in detail in the Mid - Murray Annual Implementation Plans (AIP). Activities will be categorised across four content pillars to describe what types of information we are exchanging knowledge, engaging and communicating on (Table 9.4).

Table 9.4 Content pillars as described in the Knowledge Exchange Strategy (DCCEEW 2024a)

Content pillars	Why we do monitoring, evaluation and research	How we are doing it	What the outcomes are	What we are learning
What does this include?	Messaging that explains why the program is needed, and what it sets out to achieve	Information about the methods and approaches used for monitoring, evaluation and research, including who we are partnering with.	Stories that demonstrate the results and outcomes of environmental watering.	Stories that share what we are learning through MER (expected and unexpected), and how that is changing our research and informing the delivery of environmental water.

3. *Participation - International Association of Public Participation (IAP2) spectrum*

KECE activity approaches and participation undertaken in the Mid-Murray Area will be categorised according to the Knowledge Exchange Strategy, which aligns with the International Association of Public Participation (IAP2) spectrum (Table 9.5).

4. *Target Groups.*

Relevant groups for KECE activities that are undertaken each year in the Mid-Murray Area will also be identified: Flow-MER practitioners, water managers, First Nations peoples, broader science community, local community, broader community, and CEWH.

Table 9.5 Toolbox of approaches grouped into three main categories of participation approaches as described in the Knowledge Exchange Strategy (DCCEEW 2024a)

Approaches that help to Inform	Approaches that help to Consult - Involve	Approaches that help to Collaborate - Empower
Scientific publications	Meetings & seminars	Personal relationships
Outreach publications	Workshops & forums	Partnership arrangements
News	Field days & events	Mentoring
Case studies & storytelling	Surveys, questionnaires & interviews	Training
Graphical & artistic modes		Citizen science
Websites & social media		Communities of practice

9.5 Range of activities undertaken to meet the KECE Strategy objectives

9.5.1 Required activities

The KECE required activities (Table 9.6) have been classified according to the three main categories of approaches described in the Strategy (Table 9.7).

Table 9.6 Contractually required KECE activities for the Flow-MER2.0 Project

Required KECE Activity	Description
Attend Annual Forum	Members of Mid-Murray team will attend the Annual Forum in Canberra
Quarterly snapshot	Approximately two-page document produced quarterly for online publication
Attend and give presentations at Learning by Doing workshops	An example of this type of workshop is Flow-MER Fridays webinar series (online)
Content for Flow-MER website	Stories and outcomes of monitoring and evaluation, research and communications and engagement activities
Attend KE Working Group meetings	Internal communication and sharing among KECE representatives from each Flow-MER2.0 Area
Provide information to KE Provider to include in monthly communique	Brief stories and outcomes of monitoring and evaluation, research and communications and engagement activities to include in monthly communique

Table 9.7 Classification of contractually required KECE activities

Required KECE Activity	Approaches		
	Inform	Consult/Involve	Collaborate/empower
Attend Annual Forum	✓	✓	✓
Quarterly snapshot	✓		
Attend webinars/workshops	✓		
Content for Flow-MER website	✓		
Attend KECE Working Group meetings	✓	✓	✓
Provide information to KE Provider to include in monthly communique	✓		

9.5.2 Additional activities

In addition to the required activities, a range of additional activities will be developed to align with target group participation goal and objectives. The Flow-MER2.0 Project will continue to build on approaches developed under the Edward/Kolety-Wakool Flow-MER Project, with specific Mid-Murray content, community field days, and engagement activities integrated into research projects.

Over the five years of the Mid-Murray Flow-MER2.0 Project a range of different approaches will be undertaken including;

- Community events workshops and field days, including school activities and Cultural knowledge exchange events,
- Articles in local newspapers
- Radio and television interviews
- While the CEWH and Flow-MER websites are the primary sources of information for the Flow-MER2.0 project, the Mid-Murray Flows website provides a location where other sources of information can be made available for local community and other interested user. The Mid Murray Flows website currently hosts an interactive map where local people can access data and information about the local area https://midmurrayflows.com.au/ The Mid Murray website will provide a comprehensive repository where different types of information about the Mid Murray can be housed. For example, it currently hosts factsheets, photos, journal articles, as well as outputs of non-CEWH funded projects that have been undertaken in the Mid Murray Area, as well as reports produced from the Edward/Kolety-Wakool LTIM component of work, related Short Term Intervention Monitoring and research projects. The Edward/Kolety-Wakool interactive map has been well received by the members of the Edward/Kolety-Wakool Environmental Water Reference Group.
- Citizen science projects, where local people can contribute to monitoring and data collection
- Digital story telling, through videos, podcasts or interactive content to be shared through the CEWH and Flow-MER websites and social media
- Social media content

Details of specific activities planned for each year of the Project will be outlined in the Mid-Murray Annual Implementation Plans.

9.6 Reporting and evaluation of KECE outcomes

The Mid-Murray Area team will adhere to the Branding and Acknowledgment Guide and associated protocols and processes, in the implementation of all specified KECE approaches and activities.

Details of all KECE activities will be summarised for annual reporting. Evaluation will consider both activity (what is done) and the impact of that activity.

In relation to activities, the following statistics will be summarised in the Mid-Murray Annual Report and data shared with the KE Provider:

- Numbers of people attending all events, with attendees classified by target groups where appropriate. This information will be collated by asking participants to complete an event response form, or from the attendance register

- Flow-MER website statistics for content related to the Mid-Murray Flow-MER Project, and Mid-Murray website usage statistics, with breakdown of numbers according to the target webpage (e.g., interactive map, stories, other content)
- Numbers of Mid-Murray team members attending the Annual Forum and Learning by Doing workshop. Number and details of presentation given at these events each year
- Number and details of other presentations given by the Mid-Murray team given each year
- Number of Mid-Murray team members attending contractual Area-scale Mid-Murray team meetings each year
- Number of stories written for local newspapers, online content.

Impact is best measured through qualitative or mixed methods:

- Participant feedback from events will also be sought via a range of mixed methods appropriate to the event
- Mid-Murray team members will collect brief 'stories of change' from participants throughout the Project at events and activities. The methodology to undertake and record these 'stories of change' has been developed and applied in other NRM projects. The methodology involves talking with people about what they are learning or what is changing and recording that in a database. Over time a solid data set can be created, and analyses undertaken.

The survey instrument (questionnaire) developed for the Edward/Kolety-Wakool River System in Flow-MER (Allan and Minato 2021) is effective, robust and available to be used in further research related to exploration of the social acceptability of the use of water for the environment. This could be used multiple times to provide longitudinal data.

10 Data management

10.1 Overview

Data Management for the Flow-MER Mid-Murray Area Program will follow the guidelines outlined in the Data Management Strategy (Brooks et al. 2024). Accordingly, we will:

- Manage Flow-MER data with an Open Data policy in accordance with FAIR principles (Findable, Accessible, Interoperable, Reusable) and the *Data Availability and Transparency Act 2022*
- Ensure data management is robust with transparent processes that are pragmatic and appropriate and don't unnecessarily burden participating organisations, managers or researchers
- Facilitate data sharing among all aspects of the program and to and from external industry partners and stakeholders,
- Support the embedding of First Nations knowledge and science in the Flow-MER Program
- Build data management capacity and improve data literacy within the Flow-MER Program.

Indigenous Data Sovereignty and Indigenous Cultural and Intellectual Property (ICIP)

The Mid-Murray Project team will work with the Basin-scale Data Manager, First Nations MER Lead, and First National Cultural Network to ensure that ownership and intellectual property is appropriately managed for all monitoring and research data including respecting Indigenous data sovereignty and indigenous Cultural Intellectual Property (ICIP).

In consultation with the Mid-Murray Cultural Advisors, the Project Leader and Data manager will ensure the Project team adopts the CARE Principles for Indigenous Data Governance (Collective Benefit, Authority to Control, responsibility, Ethics), and in accordance with:

- CEWH's Indigenous Data Sovereignty guidance (CEWH 2023)
- Data Management Strategy Indigenous Cultural and Intellectual Property (ICIP) guidance (Brooks et al. 2024)
- Charles Sturt University's Intellectual Property Policy (Section 2.36-2.40, Respecting Indigenous cultural and intellectual property).

10.2 Data collection, management and storage

Data collection

Data to be collected in the Mid-Murray Flow-MER Project includes:

- Basin-scale data for Hydrology, Native Fish and Cultural Outcomes themes
- Area-scale monitoring data for Hydrology, Native Fish, Vegetation and Water Quality
- Area-scale responsive monitoring data during opportunistic events (e.g., Hypoxic conditions, water bird breeding events)
- Area-scale research data
- First Nation's led research data
- KECE products.

The types of data and information that the Mid-Murray Area will collect is outlined in Chapter 2 of the Data Management Strategy (p. 4, Brooks et al. 2024).

Data management and storage

Raw data

Field and laboratory primary data sheets will be scanned and stored within the CSU data management system as image files using tagged image file format at a minimum 300 dpi resolution. This will include trip reports, audit reports and any relevant data documents.

Final data

All data collected as part of this project will conform to the data structures and standards as defined by the Flow-MER Basin-scale Data Working Theme. The data standards provide a means of collating consisting data that can be managed within the Flow-MER 2.0 MDMS.

All derived data that supports shared evaluation will adhere to the Flow-MER Program data standards and be traceable to primary data sets held on the CSU Sharepoint. The Mid-Murray Project team will submit data that supports shared evaluation into the Flow-MER Program's Monitoring Data Management System (MDMS) according to protocols established by CEWH and as outlined in the Data Management Strategy (Brooks et al. 2024).

The Mid-Murray Project team anticipates that the MDMS may not provide all the needs for storing final data products derived from the Mid-Murray Area. In addition to the MDMS, we will use a CSU online Sharepoint data storage as a repository for both raw and final data products, and active and archived datafiles, and will facilitates the sharing of data among the project team. A register of all data products derived from monitoring (Basin, Area, and Responsive monitoring) and research activities will be maintained, with a current copy uploaded to the MDMS.

The Mid-Murray Project team will store and manage access to primary data for the duration of the Flow-MER Project. The Mid-Murray Project Leader and Data Manager will be responsible for ensuring all team members comply with the management and storage of all primary data.

Project management documents

Charles Sturt University has a well-established document management system 'Total Records and Information Management' (TRIM). TRIM is an Electronic Document and Records Management System software solution for managing records of all formats. All controlled copies of accepted documents and reports will be recorded in TRIM. In addition, such documents and reports will also be recorded in Research Master. Financial data is recorded on Banner Finance, which in turn feeds financial information into Research Master. Data stored on Banner Finance is used to generate the relevant financial reports and acquittal for both internal and external purposes.

QAQC

Quality assurance and Quality Control of data procedures are outlined in Table 10.1

Table 10.1 QA/QC processes for the Mid-Murray Area

Data type	Protocols for QAQC
Raw data	• Copies of field sheets will be scanned and uploaded to the CSU Sharepoint. • Hard copies of data will be retained by relevant organisation leading the surveys.
Transcribed data	• Data entered electronically from field sheets will be checked for consistency and accuracy by appropriately trained staff. • Prior to conducting any analyses or synthesis, Theme Leads will undertake a second QAQC check of the data, checking for outliers, inconsistencies, and/or missing data.
Final data	• Data will be summarised to meet the requirements of the Flow-MER Program data standards as required for submission to the Flow-MER MDMS. The Mid-Murray data manage will be responsible for ensure the derived data sets are traceable to the raw/transcribed data set through a library of R scripts. • Once uploaded to the Flow-MER MDMS, the Mid-Murray data manager will work with the Basin-scale Data Broker to run and approval a final check for outliers, inconsistence and/or missing data.

10.3 Complementary data

The Mid-Murray Area aims to make use of complementary data sources, where methodology and timing for data collection align with the Area- and Basin-scale evaluations (Table 10.2). The Basin-scale Data Broker will assist the Mid-Murray Data manager by facilitating user access to complementary data, including understanding and communicating technical requirements, usage restriction and assisting the CEWH Data Manager and Mid-Murray Data Manager to develop data sharing agreements (Brooks et al. 2024). The Mid-Murray Data Manager will work with the Basin-scale Data Broker to verify complementary data are fit-for-purpose in times of completeness, quality, timeliness of availability and adequacy of metadata and resolve, where possible, any issues with the data custodians. The Basin-scale Data Broker will provide the Flow-MER Program a single point of contact to avoid redundant data requests and transactions from Areas and Basin-scale Project Teams (Brooks et al. 2024).

Complementary data shared with the Flow-MER Program remains the property of the respective data owners. Derived data based on or incorporating complementary data will acknowledge data sources and ensure that any licensing constraints extending from the source data are respected and upheld.

Table 10.2 Critical timing for access to complementary data that is needed to support Mid-Murray Flow-MER evaluation, research and knowledge exchange

Theme	Data type	Required for	Data source/owner	Who's responsible for co-ordinating data	Date required
Flows and connectivity	Daily hydrology data for i) non-CEW water, ii) CEW- Water and other iii) environmental water for water year	Area-scale Annual reporting and evaluation for Hydrology, Cultural Outcomes, Vegetation, Native Fish and Water Quality Themes.	CEWH (data modelling MOU between CEWH and MDBA) Murray Irrigation Limited data (escapes use) NSW Water data (regulator use) MDBA model (Hume releases)	CEWH to provide Mid-Murray Project team	1 August for State data sources. 1 September for MDBA model outputs.
Fish	Annual survey adult electrofishing survey data from: The Living Murray (Gunbower and Barmah Programs)	Area-scale and Basin-scale fish evaluation	MDBA	Mid-Murray Data Manager in collaboration with Basin-scale Data Broker and the Flow-MER Data Working Group	1 September each year
Fish	Annual survey adult electrofishing survey data from The River Murray Channel Project	Area-scale and Basin-scale fish evaluation	SCEWBC (CSIRO/ARI)	Mid-Murray Data Manager in collaboration with Basin-scale Data Broker and the Flow-MER Data Working Group.	1 September each year

10.4 Data availability

Data collected in the Mid-Murray that is required for Basin-scale evaluation will be made available as outlined in Table 10.3. The contracted date for data uploads is 30 November each year. Wherever possible we will work with the Basin-Scale Data Broker to uploaded data earlier than this.

Table 10.3 Timing that data derived from Mid-Murray Area-scale monitoring required for Basin-scale evaluation will be made available.

Theme	Contracted date for Data uploads to MDMS	Data to be uploaded by
Flows and connectivity	30 November each year	Mid-Murray Data Manager
Native vegetation	30 November each year	Mid-Murray Data Manager
Fish	30 November each year	Mid-Murray Data Manager
Cultural outcomes	30 November each year	Mid-Murray Data Manager

10.5 Data management roles

- **Mid-Murray Project Leader (Robyn Watts)**

  As per the Data Management Strategy (Brooks et al. 2024), the Mid-Murray Project Leader will be:

  - Responsible for coordinating MER activities and providing an environment that supports Area-scale Data Managers to perform their role.

- **Mid-Murray Data Manager (Nicole McCasker)**

  As per the Data Management Strategy (Brooks et al. 2024), the Mid-Murray Data Manager will be:

  - Resourced to work with the Basin-scale project data management team to arrange data supply, review and pass quality control checks and facilitate data sharing
  - Responsible for collating Mid-Murray Flow-MER 2.0 monitoring data, uploading the data to the MDMS in accordance with project data standards
  - Participate in quality control procedures, including coordinating with Area-Scale project team members to correct any data issues
  - Facilitate publication of Area-scale research data produced including production of metadata for publication on data.gov.au
  - Will collaborate with the Basin-scale Data Broker and through existing relationships in their regions to hep identify and source complementary datasets that add value to evaluation of environmental water
  - Will work with other Area-scale projects, the Basin-scale project, Knowledge Exchange provider and CEWH as part of the Data Working Group.
  - Attend and participate in quarterly Data Working Group meetings to resolve issues and improve data quality, coordinate and promote data sharing and reflect on and improve business processes.

- **Mid-Murray Project Cultural Advisors (representative from one of the First Nations organisations involved in Mid-Murray Flow-MER Project. In 2024-25, Jeanette Crew from Yarkuwa Indigenous Knowledge Centre has been appointed as the Mid-Murray Project Cultural Advisor**

The Mid-Murray Cultural Advisor will be a member of the Cultural Network. As per the Data Management Strategy (Brooks et al. 2024), the Cultural Network will provide guidance to assist Flow-MER practitioners , including the Mid-Murray Project team, to:

- Define the intellectual property and develop appropriate data specifications and descriptions
- Understand free, prior and informed consent
- Establish a data management agreement that defines how ICIP will be managed during the project (including consent, publishing, data storage, and equitable and transparent processes for resolving issues, terminating agreement and/or restricting access to data).
- Clarify any provisions under Indigenous protocols for the use of the data
- Determine how to appropriately attribute provenance (records the names of people, community, and clan/language groups)
- Ensure acknowledgements and credits are appropriate and that they remain traceable in databases or records so that connections with the original sources of First Nations knowledge are not lost
- Determine the appropriate attribution for information shared with government and public, noting that data may be shared anonymously.
- Ensure members of the research team are aware of ICIP they use and the need to acknowledge it in publications and reporting.

11 Reporting

Annual Reporting for the Mid-Murray Flow-MER Project will follow the contractual requirements:

- Annual Report - At the end of each monitoring year we will provide an Annual Area-scale MER Report that is consistent with the contractual requirements. The draft Annual Area-scale MER reports will be submitted to the CEWH by 31 December each year and the Final Annual Area-scale reports submitted by 31 March. The Mid-Murray Team will collaborate to write this report and sections will be reviewed by the leadership team.
- Quarterly progress reports – The Project Leader and leadership team will produce the quarterly progress report.
- Quarterly snapshot -. The leader of the KECE activity will be responsibile for coordinating the quarterly snapshot.
- Meetings with CEWH staff – the leadership team will meet regularly with CEWH staff to provide updates on the Project, including milestones and fundings.

A timetable of the annual reporting to be undertaken in the Mid-Murray Area for the Flow-MER Program is presented in Table 11.1.

Table 11.1 Timeline of the annual reporting to be undertaken in the Mid-Murray Area for the Flow-MER Project from 2024 to 2029. [1] Annual Implementation Plan for the following watering year. [2] Annual Mid-Murray Flow-MER report for the previous water year.

Item. no	Annual Reporting Activity	Schedule of activities			
		July to Sep	Oct to Dec	Jan to March	April to June
1	Area-scale Project Team meeting	Quarterly, organised by the Project Leader			
2	Thematic working Groups	Quarterly, organised by Basin team			
3	Flow-MER Steering Committee	Mimumin 2 per year organised by CEWH			
4	Annual Flow-MER Forum				
5	Quarterly Progress Reports				
6	Quarterly Snapshot				
7	Draft Annual Implementation Plan[1]				
8	Final Annual Implementation Plan[1]				
9	Draft Annual Area-scale MER Report[2]				
10	Final Annual Area-scale MER Report[2]				
11	Data uploaded to MDMS				

12 Project Management

12.1 Overview of Project Governance

The Mid-Murray project governance structure includes:

- Project Leadership Team
- Project Management Team - CSU Lead organisation
- Working Group Teams for each theme and activity area.

Table 12.1 provides a summary of the members and roles of the Mid-Murray Flow-MER2.0 Team. Table 12.1 lists theme and activity leaders, the personnel who will be contributing to each theme and activity. It also summarises the personnel that will provide technical support across all themes and activities. First Nations people are embedded in the Mid-Murray Project Team across all themes and activities.

Table 12.1 Overview of Mid-Murray Flow-MER2.0 team across themes and activities.

Mid-Murray Area Project Team									
	Flow-MER2.0 Themes and activities								
Themes and Activities	**River flows and connectivity**	**Native vegetation**	**Waterbirds**	**Native fish**	**Cultural outcomes**	**Water Quality**	**Knowledge Exchange, Communication & Engagement**	**Data Management**	**CSU Project Management team**
Theme/ Activity Leaders	Dr Christine Lauchlan Arrowsmith	Co-leaders Prof Robyn Watts Ms Sascha Healy	Dr Jen Spencer	Dr Nicole McCasker	Ms Jeanette Crew[2]	Dr Shasha Liu	Prof Robyn Watts	Dr Nicole McCasker	New Appointment (Interim lead Robyn Watts[1])
Team Members	Prof Robyn Watts Dr Geoff Vietz Dr Jessica Heath Mr Thom Gower Cultural Advisor[2]	Mr Thom Gower Cultural Advisor[2]	Dr James Dyer Ms Monique McKenzie-Gay Cultural Advisor[2]	Dr Jerom Stocks Mr John Trethewie Dr Meaghan Duncan (eDNA) Mr Sam Lewis (sonar) Cultural Advisor[2]	Cultural Liaison Officers from each participating FN organisation[2] Mr David Crew Prof Robyn Watts	Prof Robyn Watts Dr Paul McInerney Cultural Advisor[2]	Mr John Trethewie Dr Shasha Liu Mr Roger Knight Ms Belinda Wielinga Ms Sascha Healy Mr Paul Childs Prof Catherine Allan Cultural Advisor[2]	Ms Deanna Duffy Dr Shasha Liu Prof Nick Bond Cultural Advisor[2]	Prof Robyn Watts Dr Nicole McCasker Dr Shasha Liu Gulbali Institute Business Team
Technical support across all themes and activities	CSU: Mr John Trethewie, Ms Deanna Duffy, Technical Officers (casual contracts), other staff on casual contracts NSW DPI Fisheries: Fisheries Technicians Level G3, G4 Technical staff employed through other partner organisations First Nations people employed though Aboriginal Corporations[2]: Yarkuwa Indigenous Knowledge Centre staff and Kolety Werkul River Rangers[2], Ranger Team from Barkindji Maraura Elders Environment Team (BMEET), Ranger Team from the First People of the Millewa-Mallee Aboriginal Corp (FPMMAC), other ranger teams, other First Nations peoples.								

1. A new appointment at CSU will transition to lead the Project Management Team. In the interim Prof Robyn Watts will lead the Project Management.
2. First Nations team members

Mid-Murray Project Leadership Team

The Mid-Murray Project Leadership Team includes all theme and activity leaders as well as one representative from each of the partner organisations that are not already represented by theme or activity leaders. The Leadership Team comprises the following roles:

- **Interim Project Leader:** Professor Robyn Watts. Robyn Watts has previously been Project Leader for the LTIM/Flow-MER 1.0 projects. As part of strategic succession planning process, CSU have made a commitment to appoint a new Level C/D staff team member to lead this Project. The new appointee will transition to be Project Leader of the Mid-Murray Team, replacing Prof Robyn Watts as part of a succession plan over the next five years. Prof Robyn Watts will lead the Project Management Team in the interim.
- **Mid-Murray Project First Nations Cultural Advisor**: A representative from one of the First Nations organisations involved in the Mid-Murray Project with be the Project Cultural Advisor. Jeanette

Crew (Yarkuwa Indigenous Knowledge Centre) will be the Project Cultural Advisor in the first year of the Project. Jeanette is the Chair of Yarkuwa Indigenous knowledge Centre, Aboriginal Corporation, and a Mutthi Mutthi/Wamba Wamba Traditional Owner and Elder. In 2021 Jeanette received an Order of Australia Medal for service to Indigenous Culture, and to conservation.

- **Mid-Murray Local First Nations Cultural Advisors/Liaison Officers**: Local Cultural Advisors/Liaison Officers will be appointed in each of the First Nations organisations that are collaborating on Mid-Murray activities, to assist with coordination of on-ground First Nations activities.
- **River flows and connectivity Team Leader**: Dr Christine Lachlan Arrowsmith will lead this team. She is a highly experienced waterways engineer with over 23 years' experience working on water related projects that focus on the hydrology of river systems, including the Murray River.
- **Native vegetation Team Leader:** Co-leaders of this theme are Professor Robyn Watts (CSU) and Ms Sascha Healy, Murray-Darling Wetlands Working Group. Robyn and Sascha have expertise in riverine and floodplain vegetation, environmental water delivery management, and working with local communities to deliver projects.
- **Waterbirds Team Leader:** Dr Jennifer Spencer will lead the Waterbirds team. Jen is a waterbird ecologist and is currently working on the NSW Monitoring environmental water in the MDB.
- **Native fish Team Leader:** Dr Nicole McCasker will lead the Native Fish team. Nicole has led the fish team throughout the Edward/Kolety-Wakool LTIM and Flow-MER 1.0 projects and will continue in this role with support from highly experienced team members.
- **Data Manager:** Dr Nicole McCasker has served as Data Manager throughout the Edward/Kolety-Wakool LTIM and Flow-MER1.0 projects and will continue in this role.
- **Knowledge Exchange Leader**: Professor Robyn Watts will lead this activity. She has been involved in a wide range of communications and engagement activities throughout the Edward/Kolety-Wakool LTIM and Flow-MER1.0 projects.
- **Water chemistry Team Leader:** Dr Xiaoying (Shasha) Liu is an environmental chemist and has experience in water chemistry of inland waters, including rivers, creeks and wetlands. She has led the water quality component of the Flow-MER1.0 Project (2019-2024). Although Water quality is not a Basin-scale theme for Flow-MER2.0 Program, it is an important theme for the Mid-Murray Area and will be the focus of some Area-scale projects, research and responsive monitoring.
- **Representatives from partner organisations who are not theme or activity leaders are:** Prof Nick Bond (La Trobe University) has extensive expertise in environmental flows projects and has previously been a member of the leadership team for the Edward/Kolety-Wakool LTIM/Flow-MER1.0 team. Dr Paul McInerney (CSIRO Land and Water) has broad knowledge of the Murray River and will provide valuable cross-linkages to the River Murray Channel project and Basin-scale Flow-MER2.0 Project and broad knowledge of the Murray River. Dr Jerom Stocks (NSW DPI Fisheries) will contribute extensive experience of native fish and maintain the project continuing collaboration with DPI Fisheries. Mr Paul Childs has worked in NRM for 20 years has expertise in the planning and delivery of environmental water in the Murray and Lower Darling valleys. Mr Roger Knight (Western Murray Land Improvement Group) will contribute a community perspective to the leadership team.

CSU Project Management Team

The Mid-Murray Flow-MER Project is led by Charles Sturt University and will be managed by the Gulbali Research Institute at CSU, providing administrative support and financial management. In addition to the Project Leadership Team, there will be a Project Management Team comprising researchers and an Administrative Officer from the Gulbali Institute, to oversee contract management, milestones, budgets and reporting schedules.

The Project Management Team includes:

- Interim Project Leader Prof Robyn Watts, who will remain on the Project Management Team after the appointment of the new Project Leader to provide mentoring and continuity
- New appointee - As part of strategic succession planning process, CSU have made a commitment to appoint a new Level C/D staff team member to lead this Project. The new appointee will lead the Project Management Team and will transition to be Project Leader of the Mid-Murray Team.
- Dr Nicole McCasker – Nicole has been Assistant Project Leader during LTIM/Flow-MER1.0 Project and will continue to provide expert contribution to the Project Management Team forMid-Murray Flow-MER Project.
- Dr Xiaoying (Shasha) Liu – Shasha has been a team member of LTIM and Flow-MER projects and is transitioning to contribute to project management as well as continue as leader of the water chemistry theme.
- Gulbali Admin Officer – Gulbali Institute Administration Officer – Water (currently Belinda McDonald) will provide administrative support the Project Management Team and Project Leader.

Mid-Murray Theme and Activity team members

The team includes specialists that have expertise in GIS and image analysis, social research, turtles, frogs, mussels, and invertebrates and are available to contribute to Area-scale responsive monitoring and Area-scale research in the Mid-Murray Area. Some team members are involved in other research projects in the Mid-Murray that will ensure we can incorporate data from other available datasets and monitoring programs in the Mid-Murray. Over the five years of the Flow-MER2.0 Project we may identify other skills that are needed to support the Project and invite additional staff from CSU, existing subcontractors or additional suppliers to join the Project following approval from the CEWH.

12.2 Risk Assessment

The Flow-MER Project will adhere to the Mid-Murray Area Risk Management Plan (McCasker et al. 2024). The Risk Management Plan follows the CSU Risk Management framework, including policies, guidelines and procedures, identifies major risks that are considered to have potential adverse effects or provide potential opportunities to meet the project objectives, risks to the environment and individuals and records the outcomes of the risk management process undertaken with the use of the Project Risk Register. This Risk Management Plan was prepared in accordance with:

- CSU Risk Management framework
- CSU Risk Management Policy
- CSU guidelines on How to complete a CSU Risk Assessment
- Australian Standard AS/NZS 4360:2004 Risk Management and revised AS/NZs ISO 31000:2009 Risk Management – Principles and Guidelines.

12.3 Quality assurance

A Quality Management Plan (QMP) for the Mid-Murray Area will be developed after the commencement of Stage 2 of the Flow-MER Program. The QMP will document quality control and quality assurance procedures for all activities undertaken for the Mid-Murray Area under this MER Plan. The plan will be in accordance with relevant standards such as AS/NZ ISO 10005:2006 Quality management systems – Guidelines for quality plans as well as ANZECC and ARMCANZ (2000) Australian Guidelines for Water Quality Monitoring and Reporting.

The Quality Assurance Plan will feature the three following components:

- Quality assurance – to ensure quality management processes;
- Quality control - to establish standards for acceptance of outputs, monitoring against the criteria to determine if quality has been achieved
- Quality improvement - review points to assess and improve quality where possible.

After completion of the QMP, this section (Section 12.3) of the Mid-Murray Area MER Plan will be updated and contain links to the QMP.

12.4 Workplace Health and Safety Plan

The Workplace Health and Safety Plan (WHSP) for the Mid-Murray Area (Watts et al. 2014c) has been developed in line with the current MER Plan. It will be revised and provided to the CEWH as a stand-alone document. The WHSP will be in line with Charles Sturt University policy and existing frameworks, including the Work Health and Safety Act 2011, Occupational Health and Safety Regulation, 2001 (NSW), Occupational Health and Safety Act, 1989 (ACT) and Occupational Health and Safety Regulations, 1991 (ACT). The plan describes the procedures and requirements for minimizing the risk of injury to persons and harm to the environment in relation to the Flow-MER2.0 Project.

Work Health and Safety (WHS) at CSU supports the identification, development and implementation of strategically based health and safety programs. These programs aim to ensure compliance with relevant health and safety legislation, as well as to assist managers and employees to maintain a workplace that is free from risk to health, safety and welfare and promotes staff health and wellbeing. These programs focus responsibilities and resources in the areas of accident and injury prevention, hazard removal and control, health and welfare preservation, the development of safe and healthy work practices, the promotion of health and safety awareness, the provision of training in safe and healthy work practices, the compliance with health and safety legislation and regulations, the rehabilitation of injured employees and consultative mechanisms.

All staff and students have a general responsibility in terms of the WHS Act (2011) to ensure a safe and healthy work environment. The broad parameters of these specific responsibilities are set out in the policy document Occupational Health, Safety and Welfare Objectives and Responsibilities.

To monitor and assist with the implementation of this policy, Occupational Health and Safety Committees have been established at each Campus pursuant to the provisions of the WHS Act 2011. Each Committee reports to the Executive Director, Division of Human Resources. The Presiding Officers of each OH&S Committee represent these committees on the University-wide Environment and Safety Management Committee established to coordinate occupational health and safety matters across the University.

Where Charles Sturt University has a presence at sites other than a designated campus, it is the responsibility of the management of that site, or the coordinating senior officer of the University in regard to joint ventures, to ensure the operations at that site are compliant with applicable health and safety legislation.

The CSU Safety Management System and framework is centered on a number of policies, procedures and induction/training modules, including:

- Driving hours policy and Guidelines
- First aid policy
- Occupational Health & Safety Consultation Statement
- Occupational Health, Safety and Welfare Objectives and Responsibilities
- Occupational Health and Safety Policy
- Occupational Health, Safety and Welfare Objectives and Responsibilities
- Indigenous Cultural Competency program
- Safety Management Plan Policy
- Accidents and incidents reporting
- CSU Risk Management Policy and Risk Register
- OH&S Induction and ELMO OHS Online Training.

Charles Sturt University also has specific policies and procedures relating to the management of WH&S related risks including:

- New staff safety induction processes (ELMO)
- Ergonomics
- Manual Handling
- Electrical Safety
- Thermal comfort
- Accidents and incidents reporting.

All persons in charge of workplaces at CSU coordinate the production of an annual Safety Management Plan by the commencement of May each year. This Plan details all planned WHS activities and targets for the current financial period. Longer term planning can also be incorporated where management of safety, needs to be staged over a number of years.

The WHSP includes information relating to the provision of safety information, the need for instruction, and the need for generic, specialist or on-the-job safety training in the coming year. The Plan includes objectives and targets to minimise risks resulting from hazards identified through observation, inspections, hazard reports, incident investigations and where changes occur to facilities or processes or through identified non-compliance with legislation, policies or standards. The planning and programming of risk assessments and risk control measures, including the production of administrative controls such as operating procedures are also included in the Plan when required. Emergency and contingency planning may also need development or improvement within the Plan.

Safety Management Plans form an essential part of the safety system at each workplace and active records of these plans are kept for the current plan and the previous four plans. Archived records to cover a span not exceeding 5 years are also kept.

The CSU team operates under the auspice of the Faculty of Science and will follow a number of faculty specific WHS policies and procedures through the delivery of this project. These include:

- Faculty of Science Risk Assessment Procedure, outlining the formal risk assessment process used by the Faculty of Science to ensure all activities conducted in on campus and off campus localities used for work, research or study implement controls to mitigate and/or reduce the risks of incidents, injury or damage
- Laboratory safety and standard operating procedures
- Field work procedures, including the completion of project safety risk assessments to be completed and approved prior to any project field work being undertaken; in particular the project safety risk assessment covers potential hazards relating to field sites and their access as well as well as field activities and the controls in place to minimize risks
- Emergency response; the field work procedure includes a subset relating to the procedure that is to be followed in case of an emergency and will be detailed in the final HSEP; whilst working in the laboratory, staff are to follow existing building emergency procedures (these are detailed as part of new staff induction processes)
- More specific Job Safety and Environment Assessment for all laboratory and field activities if not covered under existing Faculty of Science procedures; specific standard operating procedures are developed for the project and will include a safety aspect component
- First aid training; the final HSEP will include a list of first aid training requirements, in particular for field work, as well as a record of staff first aid qualification; training records will be reviewed and updates on a quarterly basis as a minimum
- Incident reporting; the project team will follow CSU Incident Reporting and Management procedures which will be detailed in the final HSEP.

All organisations sub-contracted by CSU will operate under CSU WHSP, with the exception of DPI Fisheries NSW, which has developed a separate WHSP. Fisheries NSW will submit their WHSP to the project manager for review. As a requirement of CSU sub-contracting procedures Fisheries NSW WHSP is to be approved by the CSU project manager prior to NSW DPI commencing work on the project.

13 Glossary

Term	Definition
AIP	Annual Implementation Plan
ANAE	Australian National Aquatic Ecosystem
BEWS	Basin-wide Environmental Watering Strategy
CSU	Charles Sturt University
CEW	Commonwealth environmental water
CEWH	Commonwealth Environmental Water Holder
DCCEEW	Department of Climate Change, Energy, Environment and Water
EWKR	Environmental Water Knowledge and Research projects (July 2014-2019)
Flow-MER	Flow-Monitoring, Evaluation and Research Program (July 2019- June 2024)
Flow-MER2.0	Flow-Monitoring, Evaluation and Research Program (July 2024-June 2029)
FPIC	Free and Prior Consent
HREC	Human Research Ethics Committee
IAP2	International Association of Public Participation
KECE	Knowledge Exchange, Communication and Engagement
LTIM	Long Term Intervention Monitoring Program (July 2014-July 2019)
MDBA	Murray-Darling Basin Authority
MDWWG	Murray Darling Wetlands Working Group
MER	Monitoring, Evaluation and Research
The Basin	The Murray-Darling Basin
TLM	The Living Murray Program
QMP	Quality Management Plan
RMC	The River Murray Channel Program
RMH	Risk Management Plan
SCBEWC	Southern Connected Basin Environmental Watering Committee
WHSP	Work, Health and Safety Plan

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