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Commonwealth Environmental Water Office

Commonwealth Environmental Water Office Water Management Plan 2021–22

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Acknowledgement of the Traditional Owners of the Murray–Darling Basin

The Commonwealth Environmental Water Office respectfully acknowledges the Traditional Owners, their Elders past and present, their Nations of the Murray–Darling Basin, and their cultural, social, environmental, spiritual and economic connection to their lands and waters.

Acknowledgement of Traditional Owners

The Commonwealth Environmental Water Office (CEWO) proudly acknowledges the First Nations communities of the Murray-Darling Basin and pays respect to their Elders past and present.

We acknowledge First Nations people as the Traditional Owners and custodians of the land and waters of the Basin. We recognise the intrinsic connection of First Nations peoples to Country, and we value their enduring cultural, social, environmental, spiritual, and economic connection to the rivers, wetlands, and floodplains of the Basin.

Over millennia, First Nations peoples have shaped, managed, and cared for the land and waterways that sustain them. The objectives of the CEWO correspond profoundly with the cultural values and obligations Traditional Owners have to Country and community. We are continuing to build relationships with First Nations communities, to learn from and identify ways to support cultural values alongside environmental outcomes with water for the environment.

We value the ongoing contribution that First Nations peoples make to the planning and delivery of water for the environment. We acknowledge this contribution is made largely through frameworks and processes that have not been determined, or endorsed, by First Nations people. More can be done to increase First Nations people's input and enable progress towards self-determination within and beyond the environmental watering program. We will continue to support and enable this where we can.

There are more than 40 First Nations in the Basin with many distinct cultures and practices. In each chapter of this Water Management Plan, we have endeavoured, using the best available information, to name the Traditional Owner groups and their Nations that live in the valleys across the Basin and who continue to maintain and enhance longstanding culture and traditions.

We embrace the spirit of reconciliation, working towards equity and an equal voice for First Nations people.

Foreword

It is a pleasure to introduce the Commonwealth Environmental Water Management Plan for 2021–22.

Planning for the use of Commonwealth environmental water is a collaborative effort that draws on local knowledge, the latest science and lessons learnt from previous actions. I am grateful to the many people who have contributed to our plans.

In particular, I welcome the input we have received from First Nations across the Basin, such as the *Statement on environmental water use in 2021–22* made by participants at the Southern Basin First Nations' Environmental Watering Forum 2021 (*see Chapter 2*). I look forward to continuing to build relationships with First Nations' organisations and communities, to learn from and identify ways to support cultural values alongside environmental outcomes.

Rainfall and inflows across much of the Murray-Darling Basin over the last 12 months have provided a welcome relief for both communities and the environment following three years of record-breaking drought. I am pleased to see the rivers of the north and south of the Basin connected, with the Darling River once again flowing from its headwaters in Queensland all the way to the River Murray.

Flows over the past year have seen the internationally significant Narran Lakes and Macquarie Marshes showing signs of partial recovery, while the lower Murrumbidgee wetlands supported large-scale waterbird breeding as well as the highest numbers of Southern bell frogs seen in 20 years. Native fish species spawned in high numbers in multiple valleys, including the Macquarie River (Murray cod), Lachlan, Goulburn (both Golden perch) and the Lower Murray (Silver perch). The Southern pygmy perch population in the Lower Lakes quadrupled in numbers, compared to the previous year.

We start the 2021–22 water year with the highest volume of Commonwealth environmental water carried over to date (as compared to last year, which was the lowest in a decade): 538 gigalitres in the southern-connected Basin, 36 gigalitres in the Lachlan and 150 gigalitres in the northern Basin. This water is deliberately set aside so that we can continue to provide water to priority wetlands across the Basin, whether that be building on the benefits from a wet winter, through to providing drought refuge when the next dry period begins.

Many of the floodplain wetlands in the southern Basin have not received water for a number of years. 'Thirsty' sites include the mid-Murrumbidgee wetlands, the NSW Central Murray Forests, Hattah-Kulkyne Lakes, and the Chowilla, Pike and Katarapko floodplains in South Australia. Natural high flows are already providing water to some of these sites, with opportunities to consolidate on these outcomes with water for the environment in scope as flows recede. With more water in the Menindee Lakes, water for the environment will be used to benefit native fish in the lower Darling/Baaka and provide the first flow down the Great Darling Anabranch since 2017.

In the northern Basin, the severity of the recent drought means the recovery of some river ecosystems will take time and require further large flows. Water for the environment will continue to be used to promote the recovery of native fish populations and the Macquarie

Marshes, Gwydir Wetlands and Narran Lakes. These environmental outcomes will be aided by the efforts of the NSW and Queensland governments to protect environmental flows into and along the Darling River.

If wet conditions continue across the Basin, this will present both risks and opportunities. We will be responsive to conditions and avoid delivering water where this will exacerbate third-party impacts from flooding. Where it is feasible and within allowable limits, we will look to capitalise on opportunities to extend the duration of flows into important wetlands and rivers to benefit native plants and support waterbird breeding. If flooding results in low-oxygen blackwater events, providing refuge flows (e.g. high oxygen water) is also in scope.

In 2021–22, we will continue working closely with First Nations, local communities and landholders, irrigation corporations, scientists, a range of delivery partners, other water managers and river operators. Individuals and groups are encouraged to get in touch with their nearest Local Engagement Officer to provide suggestions for how we can best use water for the environment.

Hilton Taylor
Interim Commonwealth Environmental Water Holder

Contents

Tables

Figures

Maps

Boxes

1 Introduction

1.1 Background

1.1.1 Water for the Environment

The rivers of the Murray–Darling Basin have experienced significant changes over the past 100 years. As agriculture, industries and communities have grown over time, water use has increased dramatically. While benefiting our food and fibre production, this has seen as much as 50% of natural flows removed from the river in some locations. The changes in river flows have seen the health of our environment decline over many decades, which has had negative impacts on native fish, waterbirds, forests, woodlands and wetlands.

'Water for the environment' is water that is managed with the aim of restoring the health of the Basin's rivers for the benefit of all users. Water is allocated to federal and state environmental water holders across the Basin, who make decisions about when, where and how much water is released for the environment and deliver flows to where nature needs it.

1.1.2 Commonwealth Environmental Water Holder

The Commonwealth Environmental Water Holder (CEWH) is a statutory position established by the *Water Act 2007* (the Water Act) to manage the Commonwealth environmental water holdings.

Mr Hilton Taylor is the interim CEWH. He is supported by staff of the Commonwealth Environmental Water Office (CEWO) within the Department of Agriculture, Water and the Environment. The CEWO employs 8 local engagement officers who live and work in regional centres across the Murray–Darling Basin.

The CEWH is governed by the Water Act and the Basin Plan 2012 (Basin Plan) and must comply with the specific requirements and standards of Commonwealth and state legal, policy and environmental legislation and frameworks.

The water managed by the CEWH are a mix of entitlement types held across 24 catchments. The rules governing the entitlements vary across states and across valleys, but they are subject to the same fees, allocations, carryover and other rules as equivalent entitlements held by other water users.

1.1.3 Options for managing water for the environment

Commonwealth water for the environment is managed efficiently and effectively, focused on maximising beneficial outcomes. The options for managing this water include:

- use – delivering water to a river or floodplain to meet an identified environmental demand
- carryover – leaving water in storage and carrying it over for use in the next water year
- trade – trading water, which includes:
  - transferring water between connected catchments
  - buying and selling water allocations
  - using the proceeds from selling water to invest in activities that improve the outcomes from the use of water for the environment.

Each year the CEWO considers and plans for how it will manage Commonwealth water for the environment. This document explains the process by which we plan and manage this water and captures the key information that will inform the CEWH's decisions in 2021–22.

1.1.4 Collaboration across communities

Commonwealth environmental water cannot be delivered without the coordinated effort of many stakeholders. The planning, delivery and monitoring of Commonwealth environmental water is undertaken in partnership with a range of organisations and communities across the Basin.

This plan reflects the collective effort of a multitude of government agencies, First Nations, scientists, local environmental watering advisory groups, wetland managers, landholders and community organisations that have provided valuable input.

Local information and experience are critical to being able to effectively manage and deliver Commonwealth environmental water. We are very grateful for the expertise, advice, feedback and support provided by our delivery partners, environmental water holders and members of regional advisory groups who invite us to participate in their processes, and the many landowners who work with us to plan, manage and monitor the use of environmental water in the Basin.

The CEWH has entered into formal partnership agreements with the Victorian Environmental Water Holder, the New South Wales Department of Planning, Industry and Environment, the South Australian Department for Environment and Water, the South Australia Murraylands and Riverland Landscape Board, and the Renmark Irrigation Trust. A formal partnership with the Nari Nari Tribal Council is also being finalised. These agreements outline the way in which the CEWH and staff of the CEWO will work with partners to coordinate the management of environmental water. The CEWH also continues to work collaboratively with other partners where formal agreements are not in place.

1.1.5 Providing feedback

The CEWO welcomes information from the community on how environmental water can best be managed. If you have any comments or suggestions, call 1800 218 478 or email ewater@awe.gov.au.

Learn more about Commonwealth water for the environment.

1.2 Planning Commonwealth environmental water use

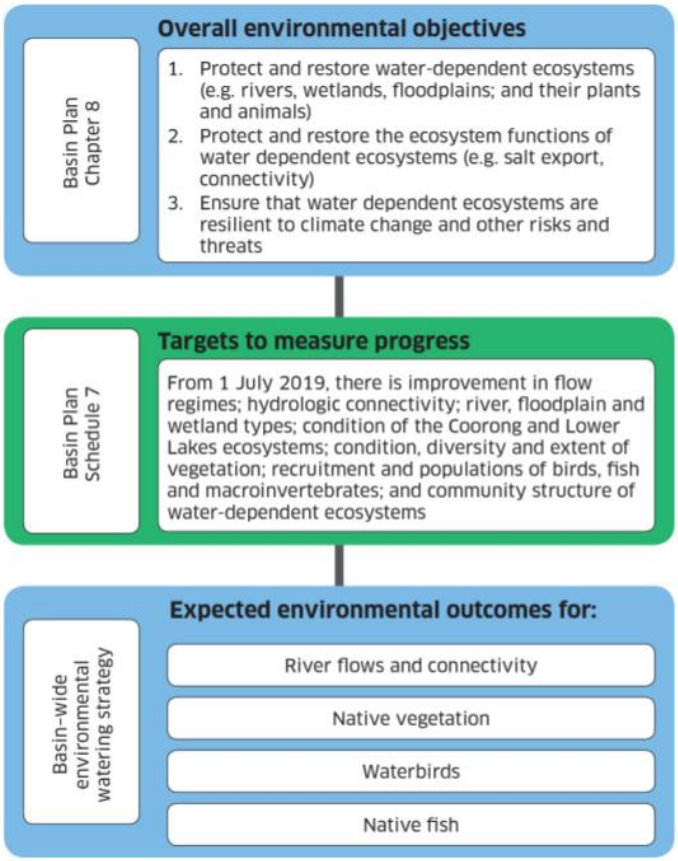
1.2.1 What we are trying to achieve for the environment

Commonwealth environmental water must be managed to protect or restore the rivers, wetlands and floodplains (and the native animals and plants they support) of the Murray–Darling Basin, to give effect to relevant international agreements., such as the Ramsar and Bonn conventions, and migratory bird agreements with Japan, China and Republic of Korea (s105(3) of the Water Act). The water must also be managed in accordance with the Basin Plan's environmental watering plan (s105(4a)).

The environmental watering plan (Basin Plan, chapter 8) establishes the objectives, processes and principles that guide the management of water for the environment. Schedule 7 of the Basin Plan sets broad targets to measure progress towards meeting the objectives (Figure 1).

The Basin-wide Environmental Watering Strategy (2019) provides the next level of detail on the environmental objectives and targets. The CEWH must act consistently with this strategy. It describes the environmental outcomes expected over the next decade from implementing the Basin Plan and associated water reforms. These outcomes focus on 4 components (Figure 1): river flows and connectivity; native vegetation; waterbirds; and native fish.

Figure 1 Hierarchy of environmental objectives, targets and expected outcomes for the Murray–Darling Basin



Source: Basin-wide Environmental Watering Strategy (MDBA 2019)

At a valley scale, long-term watering plans are prepared by Basin state governments. These plans identify the key rivers and floodplains in each valley, and the objectives, targets and environmental watering requirements for each river or floodplain. They provide the key information on the long-term environmental water requirements within the valley. For information about long-term watering plans, see:

- Victorian long-term watering plans
- South Australian long-term watering plans
- Queensland long-term watering plans
- New South Wales long-term watering plans

Prior to the start of each water year, annual environmental watering priorities are prepared by Basin state governments (for each valley) and by the MDBA (for the Basin as a whole). These articulate the environmental water needs (or demands) for the coming year.

The Basin annual environmental watering priorities establish both the context and key environmental water needs at a basin scale through describing the priority environmental values and the desired trend from a whole of basin perspective. For 2021–22 Basin priorities, see section 2.2.

1.2.2 First Nations environmental and cultural outcomes

Under the Basin Plan, environmental water holders must have regard to Indigenous values when undertaking environmental watering. One way this is occurring is through incorporating First Nations environmental objectives into planning processes. This occurs at the local level, with First Nations representatives typically engaged by state government agencies in the development of watering proposals and plans for specific wetlands, or through participation in valley-based environmental water advisory groups.

This site and valley-based planning is being complemented by increasing involvement in system-scale planning for environmental water. Representatives from the Murray Lower Darling Rivers Indigenous Nations (MLDRIN) participate in the Southern Connected Basin Environmental Watering Committee (SCBEWC), the main coordination forum for the use of water for the environment in the southern Basin. Workshops to inform water for the environment use in the Barwon-Darling (with Northern Basin Aboriginal Nation representatives) and the southern Basin (see section 2.1) were also held as part of the planning process.

There is variation between the level of First Nations input and consistency of engagement across the Basin. This reflects CEWO's journey to enhance how we work with First Nations people in the management of environmental water. We still have work to do and are continuously looking for opportunities to improve.

1.2.3 Providing water to meet environmental demands

Commonwealth environmental water planning is primarily driven by supply (how much water is available) and how this can be used to meet identified demands (what are the environment's needs).

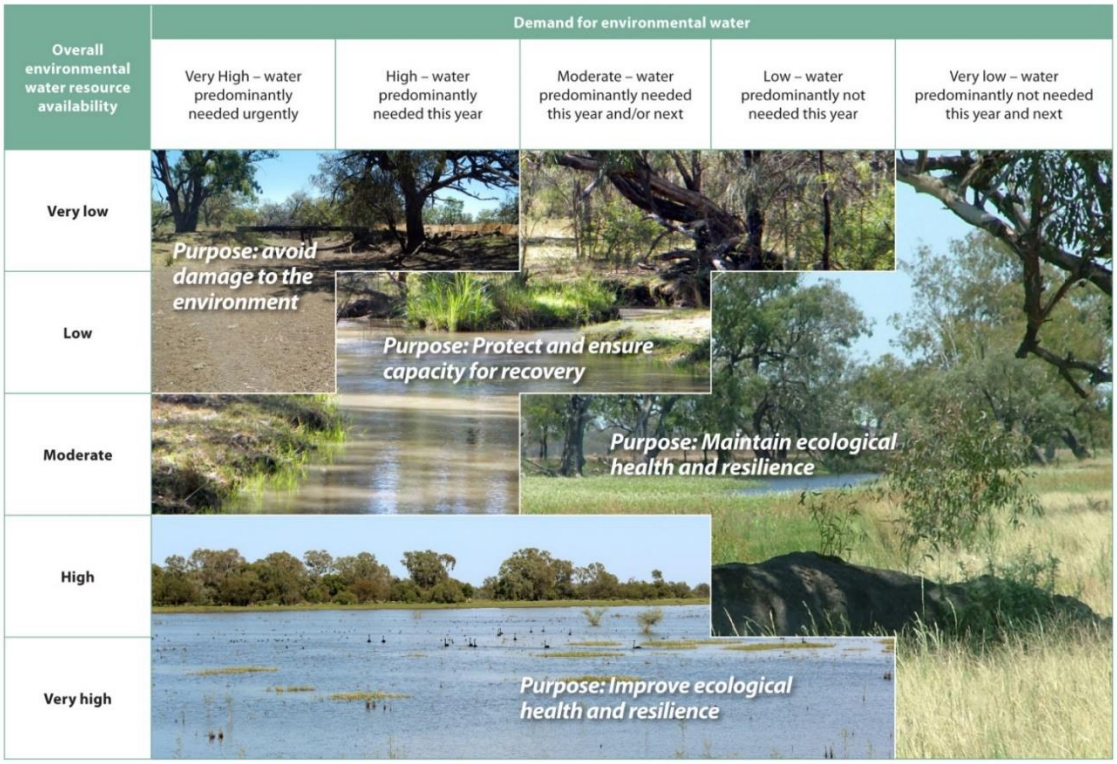
The scope of watering actions and the environmental outcomes that can be achieved will be limited by availability of water (or 'supply') to achieve these outcomes. The Commonwealth

considers current water availability and estimates its likely future supply of environmental water based on factors such as rainfall, flow conditions and forecasts of water allocations. Other important considerations include the availability of other sources of water and other likely demands in the system that can either assist or hinder the ability to deliver water to meet environmental demands.

The Commonwealth Environmental Water Portfolio Management Framework has been developed to support decisions on the best mix of water delivery, carryover and trade under different levels of supply and demand. By considering both supply and demand, the framework identifies 4 different purposes for managing the portfolio (Figure 2) and the outcomes that are in scope under each purpose.

In planning for the new water year, we need to be prepared for all scenarios – from very dry through to very wet, providing flexibility and ability to adapt quickly to changing conditions.

Figure 2 Four purposes for managing environmental water based on demand and water availability



Our water management planning occurs at both the valley and Basin-scale. Valley annual water management plans (see chapter 3 onward), include a summary of the objectives and long-term flow regime required to meet environmental demands. A multi-year approach is then taken to identifying water management intentions, considering the:

- past watering history and its impact on environmental demands and asset condition
- likely effects of planned actions on environmental demands in future years.

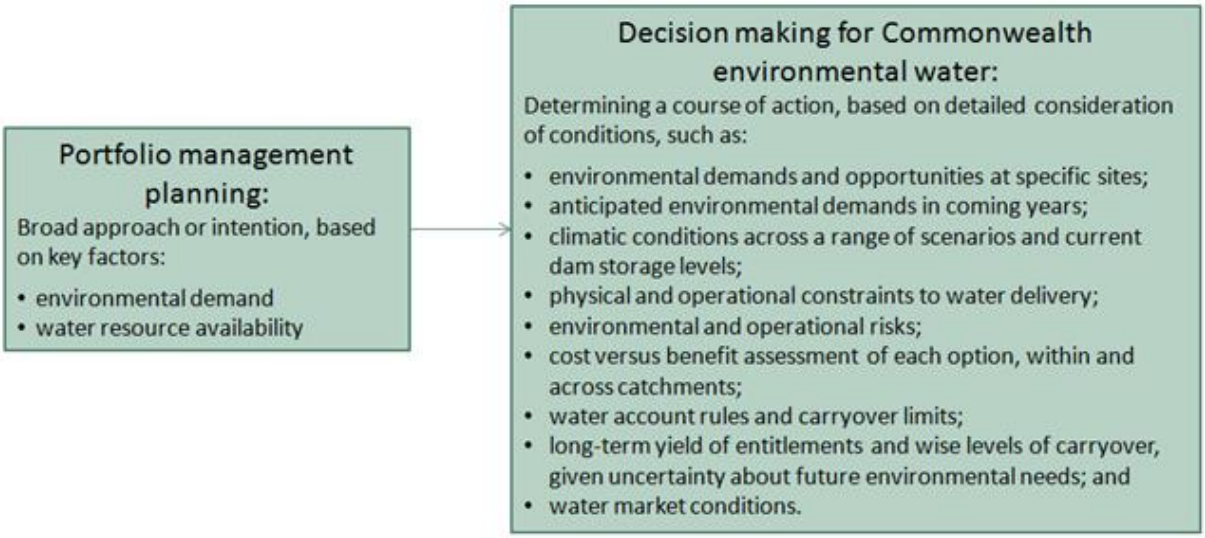
Once initial valley planning has been undertaken, this is then fed into a Basin-wide planning process. This process considers:

- key demands across the Basin
- opportunities to use allocation trade (purchase, sale or transfer) to rebalance the portfolio to better match differing demands across catchments
- opportunities to align environmental outcomes from watering, such as multi-site watering events in hydrologically connected catchments.

1.3 From planning to decision-making

Once planning is completed, decisions on the use of Commonwealth environmental water need to be made. Many local factors influence these decisions on water delivery, carryover and trade (Figure 3).

Figure 3 Factors informing planning and decision-making for Commonwealth environmental water



1.3.1 Decisions to use water

Towards the beginning of the new water year, the focus shifts from planning to implementation. Greater consideration is given to current and forecast catchment conditions and water availability to determine whether the watering intentions identified during the planning process can feasibly be implemented.

Once an action has been scoped in more detail, an assessment is undertaken against these criteria:

- ecological value of the river, floodplain or wetland
- expected outcomes from providing water
- potential risks
- long-term sustainability and management of the site
- cost effectiveness and feasibility.

When a decision is made by the CEWH to proceed with an action, arrangements for implementation are made with delivery partners.

Learn more about our Framework for Determining Commonwealth Environmental Water Use.

1.3.2 Carryover

Carryover rules are set by state governments and vary markedly for different entitlements and in different water plan areas across the Basin. The carryover limits, account limits and use limits apply to all entitlement holders including the Commonwealth.

When making carryover decisions, under the rules set by Basin states, considerations include:

- having sufficient water in accounts for environmental water use early in a water year (e.g. winter and spring flows)
- the risk of carryover of water in accounts that may be subject to trade or use restrictions through the following water year
- the cost-effectiveness with regard to the cost of water delivery and transfer fees against the potential market cost of water being reallocated under state rules
- minimising the risk of water being reallocated under state rules by carrying over water in accounts with better carryover provisions
- during droughts, the minimum amount of water that can be used to sustain environmental assets whilst maintaining some carryover for future years.

1.3.3 Trade

The primary purpose behind any selling or purchase of Commonwealth environmental water is to improve environmental outcomes. The trade of Commonwealth environmental water can only occur on the open water market when the volume held in an account is excess to environmental requirements and there is no risk of harm to the ecosystems if environmental water is not provided in the near term. Under the law, water set aside for the environment cannot be given away or borrowed.

Decisions to sell water allocations are made by the CEWH consistent with Water Act (s106). Broadly, Commonwealth environmental water can be sold if one of 2 conditions are met:

1) If allocations are not required during the water year and either:
    a) cannot be carried over, or
    b) retaining the water is likely to result in forgoing future allocations due to account limits.
2) If the proceeds will be used to purchase water and/or invest in environmental activities, where the CEWH reasonably believes this will provide greater capacity to achieve environmental objectives.

The decision to trade water is made after considering:

- the current and forecast volume of water available in Commonwealth accounts
- the balance of available environmental water (supply) to meet identified environmental demands
- (where appropriate) the prudent level of carryover.

Decisions to trade also include undertaking a market assessment, which informs the mechanisms available to trade water, the volume of water to be pursued or made available from the holdings, the price at which the CEWH is willing to enter the market and (in the case of purchases) the available budget.

For information about current trading actions and trade intentions, see:

- Trade of Commonwealth environmental water.
- Trade rules and legislation.

1.4 Monitoring, Evaluation, Reporting and Improvement

Monitoring, evaluation and reporting are essential to improving the planning and use of water for the environment. Each year the evaluation of monitoring results and past delivery events expands our knowledge of managing water for the environment. This knowledge is then used to inform next year's planning enabling adaptation and trialling of new ways to achieve improved outcomes.

The CEWO Monitoring, Evaluation and Research Program (Flow-MER) is a core component of this adaptive management process. The Flow-MER program has the following components:

- Basin scale – Basin evaluation, research and engagement
- 7 selected areas – On-ground monitoring, evaluation, research and engagement in these areas
  - Junction of the Warrego and Darling rivers
  - Gwydir River system
  - Lachlan River system
  - Murrumbidgee River system
  - Edward/Kolety-Wakool River system
  - Goulburn River
  - Lower Murray River

The CEWO's program is complemented by work of state governments, including monitoring through The Living Murray program.

2 Planning for 2021–22

2.1 First Nations statement on environmental water use in the southern Basin 2021–22

In April 2021, a forum on Latji Latji Country in Mildura brought together Traditional Owner representatives from many parts of the southern Murray-Darling Basin to share information about the health of Country and discuss preferred outcomes from the management of water for the environment. The forum was funded by the CEWO and organised with the Murray-Darling Basin Authority's The Living Murray Program and the Murray Lower Darling Rivers Indigenous Nations. This forum aimed to share information about the health of Country and discuss preferred outcomes from the management of water for the environment.

The *Statement on environmental water use in 2021–22* made by participants at the Southern Basin First Nations' Environmental Watering Forum 2021 is reproduced on the following pages. This statement is being used to guide environmental water planning for the 2021–22 water year, including through the Southern Connected Basin Environmental Watering Committee.

Box 1 Southern Basin First Nations' Environmental Watering Forum 2021

Statement on environmental water use in 2021–22

In April 2021, Traditional Owners from many parts of the Southern Murray Darling Basin came together on Latji Latji Country, in Mildura to share information about the health of Country and discuss preferred outcomes from the management of environmental water.

We want water holders, managers and decision makers to hear these key messages:

Respect water, Country and lore

First Nations are willing to share and collaborate with Government agencies to improve river health. But the inherent risks of the settler – colonial water management systems, that have been imposed on our Country, must be addressed. The current water regime in the Murray-Darling Basin ignores the principles and knowledges that underpin our practices of caring for Country.

Water can never be 'owned'. Water and rivers have life and spirit which cannot be bought and sold. All 'ownership' of water in this Country is based on the dispossession of First Nations and imposition of colonial legal frameworks. We have never ceded our inherent rights as guardians and caretakers of rivers and waters. First Nations lore provides a holistic, interconnected management system, where all elements contribute to the good of the whole.

We want to collaborate, but we do not accept or endorse the legal and management frameworks that have been imposed on our rivers. We ask our partners to respect our water spirits, knowledge and lore.

Address our concerns

We have major concerns about the legal, policy and governance setting that dictate how our rivers flow and how we get a voice. These include:

- Overallocation of water and water allocation decisions which do not leave enough in our rivers to sustain their survival or meet our cultural needs
- Over Reliance on damaging infrastructure to regulate and replicate complex natural systems, with little real benefit to our Country
- Short term decision making that doesn't properly account for a changing climate
- Limited commitment to and resourcing for First Nations participation and empowerment
- Decision making that marginalises First Nations' rights and interests
- Commodification and trading of water that disregards the limitations of natural systems
- Water theft and illegal extraction
- Inequitable access to water and poor distribution of the social and economic benefits it can bring.

The settler-colonial water framework has generated perverse outcomes which we contend with on a daily basis. The mindset of water management needs to change.

Recognise that our rivers are at risk

We see powerful examples where environmental water is helping to heal Country, but the overall policy and legal settings mean our waterways and cultural values are at risk.

Our biodiversity is suffering. We are struggling to save remnants of our ecologically and culturally significant landscapes. We are being asked to prioritise some places, while we watch others decline or die. We are grappling with this reality.

Infrastructure, including dams, weirs, regulators and pumps, is segmenting our waterways and damaging our Country with little real benefit. There is too much regulation of the floodplain and huge investment in infrastructure without proper engagement with our people.

Fluctuating river levels and unseasonably high flows, driven by consumptive demand, are degrading our waterways and cultural values. Land Use is driving unsustainable water demands and limited channel capacity means we can't get water to where we need it.

Water holes are silting up. Bank erosion and slumping is causing huge impacts on cultural heritage.

Poor water quality, algal blooms and salinity are being compounded by the disruption of natural systems that flush and clean our rivers and wetlands. Waterways, creeks and wetlands are being left to dry out, exposing cultural sites and degrading cultural values.

The health of significant trees and medicinal plants is declining because of lack of water, impacting on our cultural sustainability, health and wellbeing. Culturally significant birds and animal species are not seen where they used to be. There are not enough native fish in the system.

Delivering water to our wetlands and billabongs through artificial systems can mean delivering the wrong water for Country. Legal and infrastructure constraints restrict us from being able to direct water to where we need it.

Help us protect and grow the things that are important to us

We are passionate about working together to protect and sustain our waterways.

We need the agency and life force of the river to be respected. We want to see more water going out onto Country and filling all our creeks and billabongs. We want water holders and managers to work with us, looking at the whole system and how to restore it to what it was, with adequate flows and proper timing. We want overbank flows to support total system health.

We want increased recovery of water for the environment, not decreased.

We want to see the Murray Mouth open and salt being flushed from the system.

We want the lakes, billabongs, creeks, wetlands and rivers that are important to us to get the water they need to thrive. We want to see dry and degraded wetlands restored to life with culturally informed watering to protect our cultural heritage values.

We want regular re-connecting flows from floodplains and billabongs, allowing the life in our natural nurseries to restock and replenish the river. We need adequate, sustained flows through our rivers to keep them connected and mitigate variation from irrigation demand.

We want healthy water to flow out of our Country to all mobs downstream. We want the nutrition and healthy water from upstream to replenish Country. We want to build back biodiversity and Traditional Owner management to improve water quality. We want to collaborate with all mobs to ensure a healthy system, renewing cultural connections between Nations.

We need to exercise self-determination over the development and operation of infrastructure on Country. We want to be empowered to use our natural and cultural infrastructure, billabongs, fish traps and breeding structures, to slow down flows and recharge the landscape.

We need adequate healthy water for improved tree health and thriving floodplain forests with red gum, black box and yellow box.

We need flows to replenish the floodplain and support our important cultural plants like old man weed, grasses and sedges, nardoo, cumbungie and milfoil.

We want to see water birds, ducks, swans and brolgas, returning and thriving in our wetlands.

We need connectivity and good water quality to support native fish including black bream, congolli, crayfish, mussels, small bodies fish, shrimp, shield shrimp, yabbies, yellowbelly, Murray cod, catfish, black fish, Murray hardyhead and trout cod. We want turtles, platypus, frogs and all the other animals that rely on water to be able to return to Country.

We want co-management of all environmental water. We want to be empowered to make the decisions about how environmental water is used. Prioritisation and water planning should be

driven from the ground up, by First Nations. Give us control and we will show you how to heal Country and, in doing so, we will maintain intergenerational transfer of knowledge.

We want water managers to listen deeply to what Traditional Owners and Elders have to say and to help us access your science to back our objectives (not the other way round).

We need policy changes, transparency and reviews of the existing entitlement system. We need to review and amend the Basin Plan to reflect our knowledge, science and human rights. We need Traditional Owners involved in the highest level of all Government agencies and we need our own agencies and statutory bodies.

The CEWO is committed to working with First Nations across the Basin in how we plan, deliver and monitor water for the environment.

The health of the Murray-Darling Basin benefits from meaningful partnerships with First Nations, and their involvement in water planning, coordination and delivery from the local to the basin scale is a priority for environmental water holders.

To complement the system-scale planning, First Nations objectives and outcomes have also been identified for particular sites or valley-scale (see Chapter 3 onwards). There is variation between the level of First Nations input and consistency of engagement across the Basin. This reflects CEWO's journey to enhance how we work with First Nations people in the management of environmental water. We still have work to do and are continuously looking for opportunities to improve. This includes pilot projects in the Gwydir valley (see Chapter 6), and follow-up gatherings to the Barwon-Darling and southern Basin forums.

2.2 Basin annual environmental watering priorities

Prior to the start of each new water year, the MDBA must publish Basin annual environmental watering priorities (Table 1). They are developed having regard to the annual environmental watering priorities developed by Basin States for each catchment. All environmental watering, including by the CEWH, must be undertaken having regard to these priorities.

Commonwealth environmental watering actions will seek to contribute to the Basin annual environmental watering priorities, subject to conditions as they unfold throughout the year.

Table 1 Basin annual environmental watering priorities, 2021–22

Category	Rolling, multi-year priorities	2021–22 annual guidance
River flows and connectivity	Support longitudinal connectivity along the river system. Support lateral connectivity to inundate key wetlands. Support inundation of mid and outer floodplains. Support freshwater connectivity through and between the Lower Lakes, Coorong and Murray Mouth. Maintain an open Murray Mouth to support exchange with the adjacent	**North** Support cross-border system connectivity opportunities. Support connectivity between the northern and southern Basin via Lower Darling. Provide baseflow to areas with extended cease-to-flow conditions. Enhance variability of freshes (i.e., small, medium and large) to meet varied ecological requirements in river reaches. Support water quality in Menindee Lakes.

Category	Rolling, multi-year priorities	2021–22 annual guidance
	ocean and to prevent overfilling of the Coorong.	**South** Re-instate small to medium in-channel flows and overbank flows where practical – particularly at key sites. Enable appropriate salinity and water levels in the Coorong lagoons at the appropriate season to support seed set of *Ruppia*. Where practical, water high conservation areas that have not received water since the 2016 flood.
Native vegetation	Provide opportunities for growth of non-woody riparian vegetation that fringes or occurs within river corridors and key wetlands. Maintain extent, improve condition and promote recruitment of forests and woodlands. Maintain extent, improve condition and promote recruitment of lignum shrublands. Expand extent and improve condition of Moira grass in Barmah-Millewa Forest. Maintain riparian vegetation in Lower Lakes with seasonally appropriate water levels. Expand extent and improve resilience of *Ruppia* in the Coorong.	**North** Support riparian vegetation and Lignum in key wetlands of the Northern Basin. Extend inundation duration on key sites at Macquarie Marshes. Support inundation of inner western floodplain. Support inundation of Lower Balonne floodplain. **South** Increase inundation higher on the floodplain to support parched and stressed forests, woodlands. Extend inundation of wetlands and floodplains to improve soil moisture and regenerate understory vegetation; where practical provide multiple watering events to further extend duration of inundation. Enhance recovery of *Ruppia* extent, turion production and seed bank through improved, seasonally appropriate, water levels and salinities. Where practical, promote wetting of bank substrate and snags to promote biofilm growth.
Waterbirds	Maintain diversity and improve abundance of the Basin's waterbird populations. Maintain abundance of key shorebird species in the Lower Lakes and Coorong.	**North** Provide water to support colonial nesting waterbird breeding and recruitment triggered by natural flows in the Narran Lakes, Macquarie Marshes and Gwydir Wetlands. Support foraging and nesting of waterbirds by ensuring shallow-water and shoreline habitat. **South** Provide flows at adequate levels to support productive shorebird habitat, foraging resource availability, and local breeding – allowing for varying requirements within the different habitats offered by the Coorong and Lower Lakes. Avoid loss of adequate foraging and roosting habitat in Lower Lakes by ensuring water level is not too high.
Native fish	Support Basin-scale population recovery of native fish by reinstating flows, improving variable flow regimes, and enhancing connectivity to promote	**North** Water to support recovery, recruitment and dispersal of native fish populations.

Category	Rolling, multi-year priorities	2021–22 annual guidance
	key ecological processes (such as feeding, breeding, recruitment, migration and dispersal) across local, regional and system scales. Support viable populations of threatened native fish and maximise opportunities for range expansion and establishing new populations. Support diadromous fish migration and recruitment via connectivity between the Murray Mouth and ocean.	Enhance connectivity between fish refuge water holes. Support Basin-scale downstream dispersal of Golden Perch juveniles (e.g., from Warrego and Condamine-Balonne via the Darling). Provide small pulses (freshes) to support productivity and movement of native fish including reintroduction sites of relocated fish. **South** Provide water for Lower Darling (Baaka) to support survival of young cohorts of Murray cod and dispersal of Golden Perch including if required in the Darling Anabranch. Ensure small winter flows to support migrations and progressive recovery of diadromous lamprey and congolli. Maintain fast-flowing habitats to cue movement and spawning for native fish. Provide off channel habitat to support the entire life cycle of threatened of small-bodied native fish including at reintroduction sites of rescued native fish and translocated threatened fish.

Note: See Basin environmental watering priorities – 2021.

2.3 Adaptive management

Outcomes from monitoring, evaluation and research play a key role in informing adaptive management of Commonwealth water for the environment. Collectively, we draw on the best available science, and the knowledge, insights and experiences of those people living and working in the Basin.

Environmental water delivery is still a relatively new practice, which means trialling and learning by doing from various events and outcomes. These learnings continue to be incorporated into the way water for the environment is managed to support adaptive management and help build knowledge.

2.3.1 Lessons learned

Table 2 and Table 3 provide a summary of key learnings and considerations at a Basin scale that are contributing to inform water planning for 2021–22. The findings are drawn from the results of the past 6 years of the CEWO's monitoring and research programs. For site-scale lessons, see the Valley Water Plans in chapter 3 to 14.

Table 2 Basin-scale key learnings from LTIM, EWKR and Flow-MER projects

Theme	Learnings
Hydrology	• Delivery of water for the environment has contributed to restoring flow regimes through the provision of base flows. • Water for the environment has contributed to restoring and maintaining longitudinal and lateral connectivity.
Productivity	• In-channel flows using water for the environment can result in increased productivity.

Theme	Learnings
	• Source of water does not matter (although some exceptions apply).
Fish	• Fish responses such as spawning, recruitment and migration are linked to provision of fresh and baseflows. • Impact of fish death events will be significant, and recovery will take time. • Low flow conditions and river regulation result in limited spring/summer flow pulses which is linked to limited spawning and recruitment of golden perch.
Vegetation	• Water for the environment has been important in maintaining plant species diversity, including culturally significant and exotic species, both locally and at Basin scales. • Wetting and drying regimes are important for promoting diversity and seedling growth. • Over watering can compromise native vegetation outcomes just as underwatering may result in reduced diversity of vegetation communities at the landscape scale. • Active management of environmental water is important for supporting instream and riverbank vegetation, contributing to bank stability.
Ecosystem and biodiversity	• Water for the environment is supporting a diverse array of aquatic ecosystems that are representative of the Basin. • Southern bell frogs require longer durations of shallow water inundation in well-vegetated areas for breeding and are sensitive to high fish numbers.
Waterbirds	• There is a common movement route between the north and the south of the Basin. • Waterbird chicks require a large quantity (8 tonnes of small fish) of food to support survival.

EWKR Environmental Water Knowledge and Research project. **LTIM** Long-Term Intervention Monitoring project. Note: See reports on EWKR, LTIM and Flow-MER projects.

Table 3 Key considerations for water planning

Theme	Learnings
Hydrology	• Promoting lateral and longitudinal river connectivity to support Basin Watering Strategy outcomes is beneficial for the health of the Basin.
Productivity	• Small amounts of extra water are valuable in boosting food for fish and waterbirds. Timing for delivery is important and should be considered in terms of the intended outcome e.g., linking timing with needs for fish and waterbird populations at different life-stages. • Likely to get more benefit (higher-quality food resources) if water can be reconnected from floodplain and backwaters following the initial inundation. Timing and duration are critical to avoid blackwater events.
Fish	• For fish outcomes, water for the environment should provide a range of hydraulic diversity (flow rate and depth) and hydrological connectivity. • During drought conditions, the primary objective is to support native fish persistence, including base flows. Fresh flows are important to maintain refuges, water quality and food availability. • After fish death events, it is critical to provide base flows and freshes to maintain refugia habitats, water quality and promote connectivity. • For golden perch, where possible spring and summer freshes or pulse events should be used to trigger spawning, recruitment and dispersal of young. Water for the environment should also aim to consider the large spatial scale in which this species operates, the need for hydrological and physical connectivity for all life stages.
Vegetation	• All watering is likely to enhance plant species and vegetation community diversity at the Basin scale in some way. • Watering lignum once in every 1 to 3 years assists in greatest clump size which supports waterbird recruitment. • There is an opportunity to support culturally significant species using environmental water.

Theme	Learnings
	• Vegetation diversity is promoted by differing wetting and drying cycles, however, to maintain the existence of some aquatic vegetation communities e.g. Moira grass wetlands, repeated annual watering is important.
Ecosystem and biodiversity	• Sustained high flows in summer, and periods of very low flow may negatively impact platypus populations. • Multi-year watering approaches are encouraged to help maintain ecological character of Ramsar sites – consider both wetting and drying cycles and protecting biodiversity hotspots.
Waterbirds	• Basin-scale thinking and coordination in planning water for the environment is required for waterbird recruitment outcomes. • For maximum impact, water for the environment could be managed to support foraging habitat and stopover within the north and south route. This could occur both between and during breeding events. • Improvements in productivity (see Table 3, row 2) will help ensure food sources are available to support waterbird breeding events and survival of juveniles.

2.4 Current conditions and seasonal outlook

Despite more recent rains, the Murray–Darling Basin is still recovering from the hottest and driest 3-year period on record during 2017–2019. This period significantly affected water resources throughout the Basin, including groundwater, soil moisture and water held in storages, with devastating and lasting impacts on both communities and the environment. Large-scale fish deaths, permanent waterholes drying up, limited waterbird breeding and declines in the health of some floodplain woodlands were all observed.

Recent rainfall and inflows have provided some welcomed relief. In the Murray–Darling Basin, above average rainfall during spring 2020, built on the earlier high rainfall in February–April 2020, resulting in generally average streamflow conditions throughout the latter half of 2020. High rainfall across most of the northern Basin in late March 2021 resulted in well above average river flows, including major flooding in valleys near the New South Wales–Queensland border. Throughout April–May 2021, floodwaters from the March rainfall made their way downstream, filling the Menindee Lakes system to its highest level in four years.

Water for the environment has played an important role in assisting the recovery of key parts of the Basin's environment over this period, including:

- replenishing important refuge habitat across the Border Rivers, the Gwydir, Macintyre, Lower Balonne, Warrego and Barwon-Darling – with golden perch spawning and recruitment observed in some of these rivers
- improving the condition of wetland vegetation and waterbird habitat and increasing frog populations in the Macquarie Marshes, Narran Lakes and Gwydir wetlands
- supporting breeding and recruitment of Murray cod in the Macquarie River, helping recovery of these populations following the devastating fish deaths and rescue efforts in 2018 and 2019
- supporting a seven-fold increase in total native fish numbers between Spring and Autumn surveys and evidence of Murray cod breeding with young-of-year fish found in latest survey in the Baaka/lower Darling

- maintaining in-stream and off-channel refuge habitat and improving water quality in the Lachlan and Murrumbidgee river systems
- supporting breeding of over 18,000 straw-necked and glossy ibis nesting pairs, and a diverse range of other waterbird species, including royal spoonbills, egrets, herons and threatened Australasian bitterns at Gayini Nimmie-Caira
- supporting southern bell frogs in the Lowbidgee, with highest numbers seen in over 20 years
- supporting important colonial waterbird nesting habitat in the Barmah-Millewa Forest
- supporting high numbers of golden and silver perch spawning in the Goulburn and Murray rivers
- maintaining connectivity between the River Murray and its estuary to support the movement of migratory fish species, including pouched and short-headed lamprey and congolli, which need to move between fresh and saltwater environments to complete their breeding cycles
- providing favourable conditions in the Coorong for estuarine fish spawning opportunities and helping to maintain salinities to support flowering and seed set in *Ruppia tuberosa*
- supporting inundation of submergent and fringing vegetation to provide habitat and favourable spawning conditions for threatened small-bodied fish and frogs in the Lower Lakes, with a four-fold increase in southern pygmy perch population over the past year.

In the northern Basin, the severity of the recent drought means the recovery of many river and wetland ecosystems will take time and require further large flows. This includes the Macquarie Marshes, Gwydir Wetlands and Narran Lakes. The recovery of native fish populations throughout the Darling/Baaka and its tributaries remains a priority, with a focus on supporting connectivity all the way through to the Murray (including via the Great Darling Anabranch).

Many of the floodplain wetlands in the southern Basin have not received water for a number of years. 'Thirsty' sites include the mid-Murrumbidgee wetlands, the NSW Central Murray Forests, Hattah-Kulkyne Lakes, and the Chowilla, Pike and Katarapko floodplains in South Australia. Sites higher on the floodplain and outside the influence of the CEWO have seen ongoing declines, with floodplain woodlands increasingly stressed due to lack of flows.

2.4.1 Outlook

Wet conditions have continued over the winter months, with rainfall across the Basin 81% above average for June and 19% above average in July 19%. In response, water storages are rising, with whole of Basin storage 77% full, with 73% in the north and 78% in the south (as at 4 August, 2021). Overall, the Bureau of Meteorology is forecasting wetter conditions in spring, with greater than 80% chance of above median rainfall for most of the Basin.

2.5 Water availability

Box 2 Water words

Entitlement – Also known as a licence or holding. An entitlement is a legal right to a share of the water available at a location, subject to rules and conditions. Water entitlements can be used for a range of purposes, including household use, industry, irrigated farming or the environment. A bucket is a good metaphor for a water entitlement – the bigger the water entitlement, the bigger the bucket.

Allocation – the amount of water made available in proportion to the entitlement (how full the bucket is). Available water varies from year to year, depending on how much water is in storage and how much it has rained. Dry will have low water allocation, while wet years have a higher water allocation. Whether or not an allocation is made may depend on the type and/or security of the entitlement. Generally, each entitlement (bucket) gets filled with water (allocation) as more water becomes available. Some entitlements are not linked to water storage (unregulated entitlements) and allow diversion of in-river flows above a certain height/rate of flow in excess of what is needed to supply consumptive users.

Carryover – the amount of water allocated and not used in a water year that can be used in subsequent years, depending on the rules and conditions of the entitlement.

Security/reliability – the higher the security/reliability level of the entitlement, the more certainty of a water allocation each year.

Commonwealth water entitlements are subject to the same state government regulations, fees, allocations and other rules as apply to equivalent entitlements held by other water users. In valleys where carryover is available, Commonwealth entitlements are governed by the same rules as other water users. Environmental water managers need to make careful decisions about how much water to use, trade or carryover, just like other water users.

In unregulated river systems, water cannot be ordered from public storages at a particular time – environmental water can only be sourced as a share of an unregulated flow event. Thus, carryover and management of account balances cannot generally be used to influence the timing and volumes of environmental water in these river systems.

Table 4 summarises the carryover and allocation forecasts for regulated Commonwealth environmental water. Allocation forecasts through until 30 June 2022 are sourced from the relevant state agencies where the information is available and long-term averages where state agencies do not provide these forecasts.

Table 4 Carryover and forecast allocation of regulated (surface water) Commonwealth environmental water, 2021–22

Catchment	Carryover from 2020-21 (GL)	Forecasts of regulated allocations (including carryover) in 2021–22 (GL) (from very dry to very wet)					
		95 percentile	90 percentile	75 percentile	50 percentile	25 percentile	10 percentile
Border Rivers	6.6	9.4	9.7	11.0	13.9	15.9	16.3
Gwydir	59.9	74.2	74.2	74.2	90.5	114.2	138.8
Namoi	12.9	14.4	14.4	15.2	18.3	22.9	26.6
Macquarie	70.8	86.0	87.0	94.8	155.4	197.1	197.1
Lower Darling	0	25.8	25.8	25.8	25.8	25.8	25.8

Catchment	Carryover from 2020-21 (GL)	Forecasts of regulated allocations (including carryover) in 2021–22 (GL) (from very dry to very wet)					
		95 percentile	90 percentile	75 percentile	50 percentile	25 percentile	10 percentile
Lachlan	35.6	45.8	46.1	46.1	96.5	133.0	150.4
Murrumbidgee	81.9	290.8	302.4	350.5	351.8	351.8	351.8
Ovens	0	0.1	0.1	0.1	0.1	0.1	0.1
Upper Broken Creek and Broken River	0	0.1	0.3	0.4	0.5	0.5	0.5
Goulburn	190.9	369.3	413.9	445.7	509.5	530.7	551.9
Campaspe	2.0	4.0	4.3	8.1	8.6	8.6	8.6
Loddon	1.4	2.8	3.4	3.4	3.4	3.6	3.9
Wimmera	0	0	0	0	0	0	0
Murray – NSW	120.6	221.9	288.7	334.9	427.7	444.7	444.7
Murray – Vic	141.0	304.0	369.3	445.4	496.1	503.3	521.0
Murray – SA	0	162.2	162.2	162.2	162.2	162.2	162.2
Total for Southern-connected Basin [a]	538	1,381	1,570	1,776	1,985	2,031	2,070
Regulated total	724	1,611	1,802	2,018	2,360	2,514	2,600

a The Southern-connected Basin is the network of rivers that feed into the Murray River between the Hume Dam and the Murray Mouth. This includes the lower Darling/Baaka, Murrumbidgee, Murray, Ovens, Goulburn-Broken, Campaspe and Loddon valleys.

Learn more about allocations and volumes transferred for delivery for Commonwealth environmental water holdings. This information is updated monthly.

2.6 Water delivery in 2021–22

Environmental water use in the Southern-connected Basin in winter and spring could include providing freshes to support native fish survival, migration and spawning in several valleys (such as the northern Victorian tributaries, the River Murray, the Lower Darling/Baaka, the Great Darling Anabranch, and the creeks and rivers in the Edward-Wakool system), as well delivering water (including via infrastructure) to support the recovery and improvement in the condition of floodplain wetlands (such as the NSW Murray forests, Hattah/Kulkyne Lakes, and the Chowilla, Pike and Katarapko floodplains). If wet conditions continue and we see colonial waterbird breeding, environmental flows can be used to maintain water levels until the juvenile birds have fledged. Natural overbank flows over the warmer months could also lead to hypoxic (low-oxygen) blackwater events. If this eventuates, environmental flows will look to provide refuge habitat for native fish, where this is feasible. Opportunities to deliver water in autumn to consolidate on the outcomes from high winter-spring flows are also in scope, particularly for the Mid-Murrumbidgee wetlands.

In the northern Basin, water for the environment will be used to support native fish populations and internationally significant wetlands (including Narran Lakes, Macquarie Marshes and the

Gwydir wetlands). Unregulated flow events are also expected to continue to occur, increasing connectivity. These flows could continue the ecological recovery of the northern rivers that commenced in 2020–21. However, if these significant inflows don't eventuate, water use may be limited to contributing to refuges for native fish and possibly some small flows to internationally significant wetlands, in addition to protecting a share of unregulated flow events.

2.7 Trading water in 2021–22

2.7.1 Commercial trade

The CEWH has no plans to either buy or sell entitlements and is unlikely to enter the entitlement market until water recovery to meet the volumetric water recovery targets established in the Basin Plan 2012 have been reached.

The opportunity to buy or sell water allocations is being actively reviewed in all valleys throughout the water year and as conditions change. The CEWH's trade intentions are updated and published each quarter. Should the CEWH decide to enter the retail water market at any time during 2021–22, this will be publicly disclosed in advance on our trade of Commonwealth environmental water webpage.

2.7.2 Administrative transfers

In 2021–22, administrative transfers may be required between environmental water accounts in the Southern-connected Basin trade zones 6, 6B, 7, 10A, 10B, 11, 12 and 14 to enable environmental water delivery. Based upon water resource availability at the time of the watering event and scale of the event, this may include:

- small transfers for environmental watering activities
- moderate transfers (around 50 gigalitres) through the Barmah choke from trade zone 7, if required and allowable given the Barmah Choke trade limit
- large transfers (greater than 100 gigalitres)
- within trade zones, due to the large size of environmental watering activities.
- from New South Wales Murray and Victorian Murray to South Australia, most likely during Summer-Autumn for environmental outcomes in the Coorong and Lower Lakes.

2.8 Carrying over water for use in 2022–23

The volume of water carried over for use in 2022–23 will depend upon how the 2021–22 water year unfolds, overall water availability and both current and future environmental demands.

In the southern Basin, water carried over into 2022–23 will help meet environmental needs in winter-spring. Should wet conditions continue in 2021–22, the reserved water will also allow the opportunity to deliver water to the rivers and wetlands with the aim of consolidating on the recovery and improvements achieved from natural flows.

Similarly in the northern regulated valleys, under drier scenarios water carried over into 2022–23 would be set aside to maintain key environmental needs. Under moderate to wet scenarios, carryover volumes may be used to assist in the recovery of core wetland and native fish communities over multiple water years.

Targeted carryover volumes will be adjusted throughout the year as the season unfolds in response to both current and future demands and the water available to meet these demands. These decisions will be based upon best information available at the time.

3 Border Rivers Valley Water Plan

3.1 Region overview

3.1.1 River system

The Border Rivers Valley covers around 49,500 km^2 in southern Queensland and northern NSW, with roughly an equal area in each state (MDBA 2021). Major rivers in the Border Rivers Valley include the Macintyre and Dumaresq rivers, which merge upstream of Boggabilla and continue as the Macintyre River; and the Severn River which rises in Queensland south of Stanthorpe and enters the Macintyre River around 60 kilometres downstream of Pindari Dam (Map BR1) (NSW DPI 2012; MDBA 2021). The Dumaresq, Macintyre and the part of the Barwon River downstream of the junction of the Weir River to Mungindi (the end of the Border Rivers system) forms the border between NSW and Queensland for approximately 470 km (MDBA 2021). The Weir River, wholly in Queensland, is the only significant tributary of the lower Macintyre River (MDBA 2021).

Rainfall in the Border Rivers Valley is summer-dominant and highly variable, resulting in highly variable stream flows between years (CSIRO 2007; NSW OEH 2018; MDBA 2021).

The major public storages are Pindari Dam on the Severn River in NSW (312 gigalitres), Glenlyon Dam on Pike Creek in Queensland (254 gigalitres), and Coolmunda Dam on Macintyre Brook in Queensland (69 gigalitres) (MDBA 2021). The total volume of on-farm storage is comparable to the sum of these public storages, reflecting the importance of unregulated flows to irrigation supplies in the catchment (MDBA 2021). On a long-term average basis, unregulated entitlements (supplementary water licences in NSW and unsupplemented water allocations in Queensland) and use in the Border Rivers Valley exceed regulated water entitlements and use (MDBA 2021).

3.1.2 Traditional Owners

The lands of the Border Rivers catchment have been important to Aboriginal people for thousands of generations (MDBA 2021; NMA 2021). Aboriginal nations of the region include the Bigambul, Euahlayi, Githabul, Kambuwal, Gomeroi/Kamilaroi, Kwiambul, and Ngarabal (MDBA 2021). Traditional owners have longstanding and continuing ties to country and hold the rivers and the many billabongs along the rivers in this catchment in high regard. Of particular importance is the Morella Watercourse/Boobera Lagoon/Pungbougal Lagoon complex located on the Macintyre River floodplain south of Goondiwindi (MDBA 2021). The Commonwealth Environmental Water Office (CEWO) respectfully acknowledges these Nations, their Elders past and present, as the Traditional Custodians of the lands on which this chapter is focused.

3.1.3 Important sites and values

Key environmental assets in the Border Rivers catchment include:

- Border Rivers main channels (Severn, Dumaresq, Macintyre and Lower Macintyre rivers to Mungindi and the Weir River
- anabranches downstream of Yetman/Texas
- Queensland Macintyre River billabongs

- wetlands, billabongs and lagoons in the Lower Dumaresq/NSW Severn and Lower Macintyre rivers
- Toomelah station near the junction of the Macintyre and Dumaresq rivers.

The Border Rivers Valley supports several species and endangered ecological communities listed under the *Environment Protection and Biodiversity Conservation Act 1999*, the NSW *Biodiversity Conservation Act 2016*, or the NSW *Fisheries Management Act 1994*.

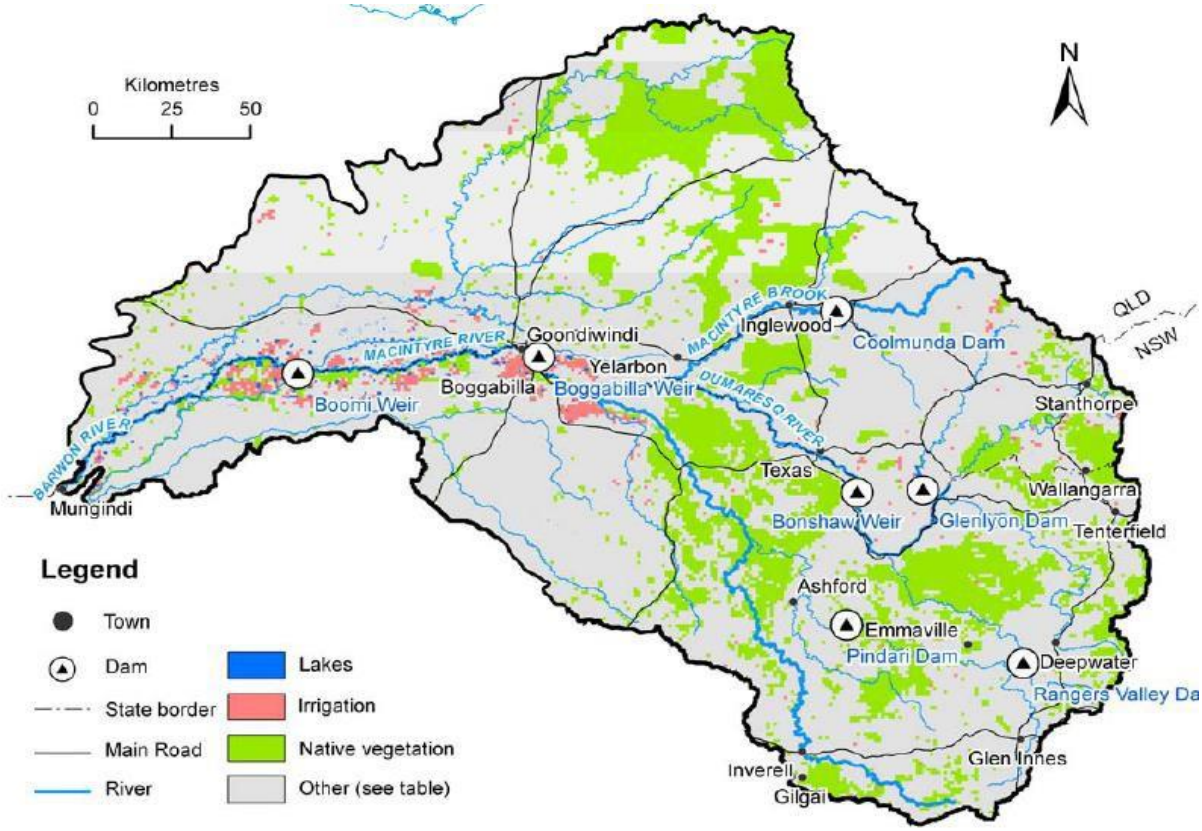
These include native fish species such as Murray cod, silver perch, purple-spotted gudgeon, olive perchlet and eel-tailed catfish. Various wetlands and waterholes also support internationally, nationally and state significant waterbirds, e.g. brolgas, Australian painted snipe, black-necked stork and magpie geese.

Parts of the Border Rivers are also included in the Lowland Darling River aquatic ecological community, which is listed as endangered under the NSW *Fisheries Management Act 1994*. This includes the Macintyre River below Graman Weir, Severn River below Pindari Dam and the Dumaresq River below the junction with the Mole River, along with their associated lagoons, billabongs, anabranches and floodplains.

3.1.4 Stakeholder engagement

In the Border Rivers Valley, the planning, management, and delivery of Commonwealth water for the environment is undertaken in conjunction with a range of partners and stakeholder groups. Key stakeholders in the NSW part of the catchment include the NSW Department of Planning, Industry and Environment (DPIE), the Department of Primary Industries (DPI) – Fisheries, Local Land Services and WaterNSW. In Queensland, key stakeholders include the Department of Regional Development, Manufacturing and Water (DRDMW), Department of Agriculture and Fisheries (DAF), Department of Environment and Science (DES) and Southern Queensland Landscapes. Advice on the use of Commonwealth water for the environment in the Border Rivers is also provided by landholders, traditional owners, the Boomi Trust, local and regional councils, and Border Rivers Food and Fibre.

Map BR1 Border Rivers Valley



Source: CSIRO (2007)

3.2 Environmental objectives

Based on long-term environmental objectives in the Basin Plan, state long-term watering plans, site management plans, and best available knowledge, the following objectives are relevant for environmental watering in the Border Rivers Valley.

The objectives that are targeted in a particular year may vary, depending on available water, catchment conditions, operational feasibility, and demand for environmental water. These objectives will continue to be revised as part of the CEWO's commitment to adaptive management. The objectives are:

- Vegetation – Maintain the condition, growth and survival of riparian, in-channel, floodplain and wetland vegetation.
- Waterbirds – Increase waterbird abundance and maintain species diversity by supporting naturally triggered breeding events, and maintaining suitable refuge, feeding and breeding habitat at targeted floodplain sites.
- Native fish – Prevent loss of native fish species and improve population structure and distribution, by supporting opportunities for movement, dispersal, reproduction, and recruitment.

- Other vertebrates and invertebrates – Support opportunities for the reproduction and recruitment of other native aquatic species, including frogs, platypus, native water rats, turtles, and freshwater mussels.
- Connectivity – Support longitudinal connectivity, including with the Barwon River, and lateral connectivity between the river, wetlands and floodplains.
- Processes/water quality/resilience – Support key ecosystem functions and promote productivity, maintain water quality in channels and pools, and maintain drought refuge habitat.

3.3 First Nations environmental watering objectives

First Nations representatives from across the northern Basin identified environmental objectives for their country for 2020–21. These objectives were developed through the First Nations Environmental Guidance project undertaken by the Northern Basin Aboriginal Nations organisation. This project was an important first step in incorporating First Nations objectives into environmental water planning.

Following on from this important work, the CEWO, in collaboration with State Environmental Water Managers as appropriate, will continue to work with First Nations groups to learn from them and to better understand and include First Nations objectives and values when planning and managing environmental flows. As the next steps, CEWO will develop and implement a work program to work with First Nations groups in the northern Basin. The work program will refine and build on the work already undertaken, be developed in collaboration with First Nations groups and will be integral in continuing to build relationships and our capacity with First Nations groups. This work will also ensure First Nations groups actively participate in the planning and management of environmental flows.

Sharing the outcomes from environmental flows with First Nations Groups will be a key step in this process and will include a two-way exchange of knowledge. This information exchange and collaboration will improve the outcomes achieved from providing water for the environment, whilst also ensuring First Nations values are part of the environmental water decision-making and management processes.

3.4 Recent conditions and seasonal outlook

3.4.1 Recent conditions and environmental water use

In the first half of 2020–21, the Border Rivers experienced a mix of dry to moderate rainfall conditions which rapidly turned wet in March 2021.

Drier and warmer than average conditions presented in summer 2020–21, with some areas experiencing heatwave conditions (BOM 2021a). Cease-to-flow conditions occurred in some sections of the Macintyre and Dumaresq Rivers (as well as the Barwon–Darling) in December 2020.

The Dumaresq River was particularly dry in the first half of 2020–21, with largely cease-to-flow conditions at Bonshaw, Roseneath and Glenarbon gauges from July 2020 to March 2021 (WaterNSW 2021). Storage levels in the Border Rivers remained low throughout the first half of the water year, with both Pindari and Glenlyon Dams at less than 20% and Coolmunda dam mostly below 30% during spring and summer.

The NSW portion of the catchment was managed at Stage 3 of the NSW Extreme Events Policy at the start of the 2020–21 water year, with water delivery prioritised for essential supplies and low or no allocations for some entitlement holders. This was eased to Stage 2 in September 2020, but with ongoing limited allocations for some entitlement holders. Around 4.5 gigalitres of NSW planned environmental water (stimulus flow) was released from Pindari Dam during October 2020 (NSW DPIE 2020).

The Commonwealth had limited access to held environmental water holdings in the Border Rivers in the first half of 2020–21. However in late 2020, 0.9 gigalitres of Commonwealth environmental water along with 2 GL of NSW planned environmental water (translucency payback) was released from Pindari Dam to improve water quality of waterholes for native fish along the Macintyre and Barwon rivers as part of the Northern Waterhole Top-Up (DAWE 2021). Releases from Glenlyon Dam occurred in February 2021 to supply the upper reaches of the Dumaresq River, Boggabilla and Goondiwindi for consumptive use.

Conditions improved significantly in March 2021, with widespread heavy rainfall across the catchment, resulting in major flooding for the Macintyre River, some parts of the Barwon–Darling River and minor flooding for some tributaries. At Goondiwindi, 84% of the annual total of 437 mm fell between 1 December 2020 to 31 March 2021 (DRDMW 2021).

These flows provided lateral and longitudinal connectivity all the way from the Dumaresq River at Texas to the Barwon River at Mungindi (DRDMW 2021). In-channel flows replenished waterholes, provided flows in anabranch channels and watered instream and riparian vegetation. Approximately 456 gigalitres were accounted as “losses to the floodplain” – this water would have filled floodplain wetlands and improved the condition of floodplain soils and vegetation. This extensive flow connectivity provided opportunities for fish movement, and spawning events in channel and floodplain habitats.

Widespread rainfall also led to a significant improvement in soil moisture across the catchment and rapid increase in storage levels. Coolmunda Dam reached full capacity and both Pindari and Glenlyon dams exceeded 50% of full capacity (as of May 2021). The NSW portion of the Border Rivers moved to Stage 1 under the NSW Extreme Events Policy in April 2021, representing a return to normal river operations. The rainfall of autumn 2021 followed an extended dry period since January 2017, during which rainfall across the catchment was generally below average to very much below average.

‘Unsupplemented’ (unregulated) access was announced in the Queensland Border Rivers in Macintyre, Barwon and Dumaresq zones during March, April and June 2021, with almost 12 gigalitres of Commonwealth water for the environment contributing to natural flows. Supplementary access was also announced in the NSW Border Rivers in March and April 2021. In May 2021, 5 gigalitres of NSW planned environmental water (the remainder of the translucency payback water) was released from Pindari Dam as an extended base flow (Matthew Miles 2021 [NSW Department of Planning, Industry and Environment], pers. comm., 13 May).

Resource availability has now improved with a return to normal operational arrangements in the Border Rivers. The CEWO is likely to be able to call on its entitlements in the Border Rivers in 2021–22.

Learn more about previous Commonwealth environmental water use in the Border Rivers Valley.

3.4.2 Seasonal outlook

According to the Bureau of Meteorology outlook released on 3 June 2021, above average rainfall is predicted in the Border Rivers Valley over winter and early spring (BOM 2021b). The Bureau of Meteorology also predicts slightly below long-term average maximum temperatures but above average minimum temperatures for the catchment (BOM 2021c, d).

The Murray–Darling Basin Authority (MDBA) identifies that the Border Rivers Valley is likely to experience wetter than average conditions for at least July through to September 2021 (MDBA forthcoming). However, persistent, widespread, and above average rainfall is needed to:

- further lift areas out of rainfall deficiencies at the multi-year timescales
- provide relief from the longer-term impacts of the long period of low rainfall, such as by further recharging water storages.

3.4.3 Water availability

The volume of Commonwealth environmental water carried over in the Border Rivers for use in 2021–22 is 6,543 megalitres (5,243 megalitres in Queensland and 1,300 megalitres in NSW).

The Commonwealth works with Queensland and NSW partner agencies to plan, implement and evaluate the delivery of Commonwealth environmental water in conjunction with planned environmental water managed by NSW (e.g. the Pindari stimulus flow). Other flows such as tributary flows, consumptive water and other water orders may also support environmental demands in the Border Rivers Valley.

The Commonwealth also has 1,437 megalitres in NSW supplementary entitlement, and up to 19, 986 megalitres in Queensland 'unsupplemented' (unregulated) entitlements. However, these entitlements rely on large inflows more than regulated river requirements. Unregulated entitlements provide opportunistic access to river flows when water levels exceed trigger values at certain locations, as specified in the entitlement conditions. Each triggered Commonwealth environmental water entitlement leaves water in the river which could otherwise be extracted. This contributes to restoring natural flows, reflecting its flow access windows, take rates and location. The location and size of the event will influence which environmental demands Commonwealth environmental water contributes to. In general, the Commonwealth accounts for the full allowable volume of unregulated entitlements when they are triggered, apart from a small unregulated entitlement in the Dumaresq which we do not account use against in winter.

Based on the expected available volume of water held by the Commonwealth and other water holders, as well as recent and forecast catchment conditions, it is expected that the overall resource availability will be moderate to high in 2021–22 (MDBA forthcoming).

3.4.4 Environmental demands

The environmental water demands for assets in the Border Rivers Valley in 2021–22 are shown in Table BR1. The capacity to contribute to most of these environmental demands is contingent on continued wet conditions in the catchment.

Table BR1 Environmental demands and watering priorities, 2021–22, and outlook for coming year, Border Rivers Valley

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	Required frequency (maximum dry interval)		Environmental demands for water (all sources)	Potential Commonwealth environmental water contribution?	Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22
Border Rivers main channels: Dumaresq, Severn (NSW), Macintyre, lower Macintyre to Mungindi (including Weir River) Native fish Instream aquatic ecosystems	Native fish resilience, reproduction, conditioning and maintenance. Maintain in-channel habitats during low flows, water quality and longitudinal connectivity. Instream aquatic ecosystem processes e.g. scouring habitat inundation.	**Dumaresq** 100 ML/day baseflow at Glenarbon.	As required in extreme dry conditions or to provide variability. Potential trigger: 10 ML/day for more than 25 days gauged at Glenarbon, impacting on persistence of larger waterholes.	Demand was met annually since 2012 to 2019–20. Demand was also met in 2020–21 but flows at Glenarbon were <10 ML/day from October 2020 to end of January 2021. Baseflows are required annually therefore a high demand in 2021-22, remaining high the following year if the demand is met.	High	A high priority for watering in 2021–22, including under a low resource availability scenario, but likely to be met incidentally by operational dam releases.	High
		Severn/Macintyre Rivers 50 ML/day baseflow at Ducca Marrin.	Potential trigger: <2 ML/day for more than 25 days gauged at Ducca Marrin, impacting on persistence of larger waterholes.	Demand was met annually from 2012 to 2019. The demand was only partially met in 2019–20 and met in 2020–21. These flows are required annually therefore have a high demand in 2021–22, remaining high the following year if the demand is met.	High	A high priority for watering in 2021–22, including under a low resource availability scenario, but likely to be met incidentally by operational dam releases.	High
		Lower Macintyre River 400 ML/day at Mungindi for connectivity Duration and frequency of baseflows dependent on outcomes required (e.g. 7 days in Sept to March in 1 in 1 to 2 years to provide connectivity and sufficient depth for fish movement).	To provide variability (triggers: cease-to-flow (<30ML/day) for more than 30 days at Mungindi).	Demand was met annually from 2012 to 2018 apart from 2014–15. Demand was not met 2018–19. Met in 2019–20 and 2020–21. These flows are required annually therefore have a high demand in 2021–22, remaining high the following year if the demand is met.	High	A high priority for watering in 2020–21, including under a low resource availability scenario.	High
		Dumaresq River Spawning: 515 to 1,040 ML/day at Roseneath for minimum 14 days (small fresh).	Eight in 10 years July to August (Priming pulse before spawning and recruitment).	Demand was not met between 2012 and 2015 nor in 2018–19. Demand was met 2015–16, 2016–17 and 2017–18. Dumaresq recruitment demand not met in 2019–20 but spawning demand was met. Dumaresq spawning or recruitment demands were not met in 2020–21 because the duration requirements were not met. Therefore, this environmental demand is assessed as critical in 2021–22. This would reduce to high the following year if the demand is met.	**Critical**	A high priority for watering in 2021-22, but environmental demand cannot be met through Commonwealth water alone (will also require water from other sources).	High
		Dumaresq River Recruitment: 340 to 600 ML/day at Roseneath for minimum 20 days.	Eight in 10 years Aug to Oct (Peak recruitment season for Murray cod and freshwater catfish).	Demand met or partly met in 6 out of the last 10 years (partly met in 2019–20 and 2020–21 by flow thresholds but duration not met). High environmental demand in 2021–22, remaining high the following year if the demand is met.	High	A high priority for watering in 2021-22, but environmental demand cannot be met through Commonwealth water alone (will also require water from other sources).	High
		NSW Severn / Macintyre rivers Priming pulse: initial peak of 2,000 ML/day at Ducca Marrin followed by recession (duration variable) (large fresh). NSW Severn/Macintyre Spawning and recruitment: Flow height, duration and volume unknown.	Eight in 10 years July to August (Priming pulse before spawning and recruitment).	The priming pulse was met in 2010–11, 2011–12, 2013–14, 2016–17 and 2017–18. However, was not met in 2012–13, 2014–15, 2015–16, 2018–19, 2019–20 or 2020–21. This demand was not met in the last three years, therefore has a critical environmental demand in 2021–22, moving to high the following year if the demand is met.	**Critical**	A high priority for watering in 2021-22, but environmental demand cannot be met through Commonwealth water alone (will also require water from other sources).	High
		Lower Macintyre River Large scale spawning and recruitment aligned with large unregulated pulse in the Weir River post winter (at least two metre rise and water temperature >23°C).	Eight in 10 years July to August (Priming pulse before spawning and recruitment). August to October (Peak recruitment season for Murray cod and freshwater catfish).	Met 2015–2017. Not met in 2017–18, 2018–19 or 2019–20. Met in 2020–21 (large unregulated pulse in the Weir River with >2 metre rise and water temperature around 23°C in March 2021). Demand assessed as high in 2021–22, reducing to moderate the following year if the demand is met.	High	Secondary priority for Commonwealth environmental watering. Will occur only if natural trigger is met, or under moderate–high resource availability. Demand may be met by other sources of water.	Moderate
		Lower Macintyre River Spawning	Eight in 10 years July to August	Demand met between 2012–13 and 2020–21 apart from 2018–19. Demand assessed as low in 2021–22, remaining low the following year if the demand is met.	Low	Secondary priority for Commonwealth environmental watering. Will occur only if natural	Low

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	**Required frequency (maximum dry interval)**		**Environmental demands for water (all sources)**	**Potential Commonwealth environmental water contribution?**	**Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22**
		3,100 ML/day at Boggabilla for minimum 14 days (Boggabilla Management Reach).	(Priming pulse before spawning and recruitment).			trigger is met, or under moderate–high resource availability. Demand may be met by other sources of water.	
		Lower Macintyre River **Spawning** 5,400 ML/day at Mungindi for minimum 14 days (Mungindi Management Reach).	Eight in 10 years July to August (Priming pulse before spawning and recruitment).	Demand was partially met in 2019–20 because the duration was insufficient. The demand was met in 2020–21. Therefore, the demand is low, remaining low the following year if the demand is met.	Low	Secondary priority for Commonwealth environmental watering. Will occur only if natural trigger is met, or under moderate–high resource availability. Demand may be met by other sources of water.	Low
		Fish spawning/recruitment flow targeting long-lived flow dependent specialists (small to medium fresh for at least three days) **Dumaresq River** Flow height with at least a two-metre rise and water temperature >23°C.	Eight in 10 years October to April (Recruitment season for silver and golden perch). At least every second year (prefer annually). September to March Maximum inter-flow period of two years.	Demand was not met between 2012 to 2015 nor in 2018–19. The demand was achieved between 2015 to 2018, 2019–20 and 2020–21. Therefore, a moderate to high demand in 2021–22, reducing to moderate the following year if the demand is met.	Moderate to high	Secondary priority for Commonwealth environmental watering. Will occur only if natural trigger is met, or under moderate–high resource availability. Demand may be met by other sources of water.	Moderate
		NSW Severn/Macintyre rivers Flow height with at least a two-metre rise and water temperature >23°C.	Eight in 10 years October to April (Recruitment season for silver and golden perch). At least every second year (prefer annually). September to March Maximum inter-flow period of two years.	Demand has not been achieved since 2012. Therefore, the demand is critical in 2021–22, remaining critical the following year even if the demand is met in 2021–22.	**Critical**	Secondary priority for Commonwealth environmental watering. Will occur only if natural trigger is met, or under moderate–high resource availability. Demand may be met by other sources of water.	**Critical**
		Lower Macintyre River Large flow pulse of at least 10,900 ML/day at Boggabilla for minimum 20 consecutive days (optimum flow). Some outcomes achieved with small pulse of 840 ML/day at Boggabilla Weir.	Eight in 10 years October to April (Recruitment season for silver and golden perch). At least every second year (prefer annually). September to March Maximum inter-flow period of two years.	The demand has only been met 4 of the last 9 years (2012–13, 2016–17, 2019–20 and 2020–21). Therefore, the demand is assessed as high in 2021–22, moving to moderate the following year if the demand is met.	High	Secondary priority for Commonwealth environmental watering. Will occur only if natural trigger is met, or under moderate–high resource availability. Demand may be met by other sources of water.	Moderate
Border Rivers main channels (ctd)		Fish condition and maintenance flow targeting long lived in-channel specialists and flow-dependent fish guilds (small/large fresh for minimum 5 days). **Dumaresq River** Up to 2,300 to 6,250 ML/day at Roseneath.	One in one to two years (Maximum dry interval unknown). June–July (Pre-spawning conditioning). March–May (Pre-winter maintenance).	**Dumaresq River** Not met 2018–19. Met in 2019–20 and 2020–21. Low to moderate demand in 2021–22, moving to low the following year if the demand is met.	Low to moderate	Secondary priority for Commonwealth environmental watering. Will occur only if natural trigger is met, or under moderate–high resource availability. Demand may be met by other means.	Low
		NSW Severn / Macintyre rivers Peak up to 2,000 ML/day at Ducca Murrin.	One in one to two years (Maximum dry interval unknown). June–July (Pre-spawning conditioning). March–May	Met 2015–2018. Demand not met 2018–19 or 2019–20. Partly met in 2020–21(pre-winter maintenance). Moderate to high demand in 2021–22, moving to moderate the following year if the demand is met.	High	Secondary priority for Commonwealth environmental watering. Will occur only if natural trigger is met, or under moderate–high resource availability. Demand may be met by other means.	Moderate

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	**Required frequency (maximum dry interval)**		**Environmental demands for water (all sources)**	**Potential Commonwealth environmental water contribution?**	**Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22**
			(Pre-winter maintenance).				
		Lower Macintyre River Natural inflows in the lower Macintyre River reach, including Weir river. Optimal flow height, duration and volume unknown.	One in one to two years (Maximum dry interval unknown). June–July (Pre-spawning conditioning). March–May (Pre-winter maintenance).	The demand was not met from 2017–2019. Met in 2019–20 and 2020–21. Therefore, the demand is low in 2021–22, and will remain low the following year if the demand is met.	Low	Secondary priority for Commonwealth environmental watering. Will occur only if natural trigger is met, or under moderate–high resource availability. Demand may be met by other means.	Low
	Fish movement/spawning/ reproduction/ recruitment flows targeting short-lived stable low flow spawning fish species.	Stable low flow for 7 to 60 days (spawning/reproduction/recruitment). A minimum stable low flow 7 to 21 days needed for spawning. **Dumaresq River** Up to 100 ML/day at Roseneath.	One in one to two years (low uncertainty). Up to three years (high uncertainty). September to December (Peak spawning season for olive perchlet, includes purple-spotted gudgeon).	Demand met in 2015–16, 2016–17 and 2018–19 and 2020–21). Therefore, the demand is moderate in 2021–22, reducing to low the following year if the demand is met.	Moderate	Secondary priority for Commonwealth environmental watering. Will occur only if natural trigger is met, or under moderate–high resource availability. Demand may be met by other water sources.	Low
		NSW Severn and Macintyre rivers 50 ML/day at Ducca Marrin.	One in one to two years (low uncertainty). Up to three years (high uncertainty). September to December (Peak spawning season for olive perchlet, includes purple-spotted gudgeon).	Stable flows were not met 2015–20. The flows were met in 2020–21. The demand is high in 2021–22, which would reduce to moderate the following year if the demand is met.	High	Secondary priority for Commonwealth environmental watering. Will occur only if natural trigger is met, or under moderate–high resource availability. Demand may be met by other water sources.	Moderate
	Scouring, inundate inter-connected riparian areas and improved longitudinal connectivity for fish movement, (including maintenance and conditioning) of all native species	Large in-channel fresh (Aug to Dec) **Dumaresq River** Peak between 6,250–19,000 ML/day at Roseneath	All reaches Up to three years for scouring (Maximum dry interval unknown). Anytime (only if naturally occurring).	Large in-channel fresh flows were last achieved 2016–17, not achieved 2017–18 or 2018–19. The flow rates were achieved at Roseneath in February 2020 and March 2021 but not within the required August to December timeframe. Therefore, there is a moderate demand in 2021–22, which would reduce to low the following year if the demand is met.	Moderate	Secondary priority for Commonwealth environmental watering. Will occur only if natural trigger is met, or under moderate–high resource availability. Demand may be met by other water sources.	Low
		NSW Severn and Macintyre rivers Flows >2,000 ML/day at Ducca Marrin to change periphyton species	All reaches Up to three years for scouring (Max. dry interval unknown). Anytime (only if naturally occurring).	Large fresh flows were achieved between 2016–17 and 2018–19 and again 2020–21. Therefore, there is a low demand in 2021–22, remaining low the following year if the demand is met.	Low	Secondary priority for Commonwealth environmental watering. Will occur only if natural trigger is met, or under moderate–high resource availability. Demand may be met by other water sources.	Low
	Inundate key habitat (large woody debris), support key ecosystem functions (nutrient, sediment and carbon cycling) and support recruitment opportunities for a range of native aquatic species (fish, frogs, turtles and invertebrates)	Small in-channel fresh **Lower Macintyre and Barwon Rivers** 4,000 ML/day at Mungindi (end of system) for a minimum five to 11 days.	**Inundate habitat and meet needs of threatened fish species** (October to December timing). One in three to four years (maximum dry interval of seven to 14 years for habitat inundation, maximum dry interval for threatened fish species unknown).	**Inundate habitat and meet needs of threatened fish species (October to December)** This demand has only been met three times in the last 10 years and was last met in 2016–17. Therefore, the environmental demand is critical in 2021–22, remaining critical the following year if the demand is not met.	**Critical**	Unable to receive Commonwealth environmental water due to constraints.	**Critical**
		Small in-channel fresh **Lower Macintyre and Barwon Rivers** 4,000 ML/day at Mungindi (end of system) for a minimum five to 11 days.	**Key ecosystem functions** (October to March timing). One in two to three years (maximum dry interval of six to eight years).	**Key ecosystem functions (October to March)** Met in 2012–13 (not met between 2013–14 and 2018–19) and met in 2019–20 and 2020–21. Environmental demand moderate in 2021–22, moving to moderate to high the following year if the demand is not met.	Moderate	Unable to receive Commonwealth environmental water due to constraints.	Moderate to high

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	**Required frequency (maximum dry interval)**		**Environmental demands for water (all sources)**	**Potential Commonwealth environmental water contribution?**	**Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22**
In channel assets – Boomi River	Inundate key habitat Boomi (large woody debris and fallen timber on bench platforms and inset floodplain areas), native fish assets (including recorded or expected threatened native fish species).	Baseflows of >five ML/day for seven days (September to March) at Boomi River upstream of Boomi Weir Offtake	One in one to two years (75%) (baseflow) (maximum dry interval unknown).	Baseflows met annually since 2013–14. Required every 1 to 2 years. Therefore, there is a low environmental demand in 2021–22, moving to moderate the following year if the demand is not met.	Low	A low priority for Commonwealth environmental water contribution under low water resource availability scenarios, however Commonwealth unregulated entitlements could contribute unregulated flows, if triggered.	Moderate
		Small fresh 1: >20 ML/day at Boomi River upstream of Boomi Weir Offtake for minimum 10 days (October to April)	Annual (100%) (maximum dry interval one year).	Small fresh 1 demand has been met in each year since 2013–14. Required annually, therefore the demand is high in 2021–22, moving to critical the following year if the demand is not met.	High		**Critical**
		Small fresh 2: 20 to 750 ML/day for minimum 14 days (September to April)	One in one to two years (75%) (maximum dry interval unknown).	Small fresh 2 demand has been met in each year since 2013–14. These are required every 1 to 2 years therefore the demand is low in 2021–22, moving to low to moderate the following year if the demand is not met.	Low		Low to moderate
		Large fresh 1: >750 ML/day for five days (July to September)	One in one to two years ((75%) (maximum dry interval unknown).	Large fresh 1 demand was not met from 2013–14 to 2019–20. These flows were met in 2020–21. These flows are required every 1 to 2 years, therefore the demand is high in 2021–22, moving to critical the following year if the demand is not met.	High		**Critical**
		Large fresh 2: >750 ML/day for five days (October to April)	One in two to three years (42%) (commencing as a rising flow only). (maximum dry interval unknown).	Large fresh 2 flows were not met in 2013–14, 2014–15, 2015–16, 2017–18 or 2018–19, but were met in 2016–17, 2019–20 and 2020–21. These flows are required every 2–3 years, therefore have a low to moderate demand in 2021–22, moving to moderate the following year if the demand is not met.	Low to moderate		Moderate
Anabranches downstream of Yetman/Texas Nutrient and carbon cycling enhanced primary production. Support fish movement and condition.	Infrastructure assisted watering to maintain refuge habitat E.g. Morella watercourse lagoons (if agreed with landholders) 1,500 to 4,000 ML per action (infrastructure assisted) to target specific wetlands with long-term flow deficit.	1,500 to 4,000 ML per action (infrastructure assisted) to target specific wetlands with long-term flow deficit.	Maximum: up to 10 years between filling (Morella watercourse).	Little to no inflows since 2010, however local rainfall provided some water to Morella watercourse and Boobera Lagoon in 2019–20 and 2020–21. Therefore, the demand is low to moderate in 2021–22, moving to moderate if the demand is not met.	Low to moderate	Additional information is needed before supporting a watering action.	Moderate
Wetlands, lagoons and billabongs	Support movement, spawning and recruitment of aquatic species. Riparian vegetation health. Nutrient and carbon cycling Maintain refuge for aquatic biota and fish Lateral and longitudinal connectivity, support movement, spawning and recruitment of aquatic species. Maintain riparian habitat for other species i.e. water birds Fish (all guilds) and other aquatic dependent biota refuge Aquatic ecosystems	Connection to lower Dumaresq wetlands/NSW Severn wetlands **Dumaresq River** Small fresh to connect >30% of wetlands in the Dumaresq reach > 1,040 ML/day at Roseneath	One in three to four years for wetland vegetation. One in two to three years for fish outcomes.	This demand was not met between 2012–2017 but has been met since then (from 2017 to 2020–21). Therefore, the demand is low in 2021–22, moving to moderate the following year if the demand is not met.	Low	A low priority for CEW under low to moderate water resource availability scenarios. Potential for contribution under a high water resource availability scenario, in conjunction with similar flow requirements for fish outcomes	Moderate
		NSW Severn and Macintyre rivers: 1,200 ML/day at Ducca Marrin to connect upper reach wetlands	One in three to four years for wetland vegetation. One in two to three years for fish outcomes.	Demand met annually from 2012 to 2018–19 but not met in 2019–20. Met in 2020–21. Therefore, the demand is low in 2021–22, moving to moderate the following year if the demand is not met.	Low	A low priority for CEW under low water resource availability scenarios, however, Commonwealth unregulated entitlements could contribute unregulated flows, if triggered.	Moderate
		Connection to lower Macintyre River wetlands **Connect wetlands and anabranches - Goondiwindi to Mungindi** >20,000 ML/day (low connectivity) (bankfull-small overbank flow) >60,000 ML/day (high connectivity) (large overbank event) at Goondiwindi for seven days	One in three to four years for wetland vegetation. One in two to three years for native fish outcomes. Every three years for small fish outcomes.	Not met from 2012–13 to 2019–20. Low connectivity (>20,000 ML/day) demand met, and high connectivity demand partially met in 2020–21 (duration not met) (flows gauged at Goondiwindi >60,000 ML/day for three days between 25 March and 27 March 2021). Therefore there is a moderate environmental demand for these flows in 2021–22, moving to moderate to high the following year if the demands are not met).	Moderate	Unable to receive Commonwealth environmental water due to constraints. Unregulated entitlements could contribute to flows at Goondiwindi if there are in-range announced flows.	Moderate to high

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	Required frequency (maximum dry interval)		Environmental demands for water (all sources)	Potential Commonwealth environmental water contribution?	Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22
		Low level wetland connection in Lower Macintyre 10,000 to 15,000 ML/day at Goondiwindi (bankfull) 4,000 to 6,000 ML/day at Terrewah (large fresh and bankfull) for four to eight days in October to March	One in three to four years for wetland vegetation. One in two to three years for native fish outcomes. Every three years for small fish outcomes.	Not met from 2012–13 to 2018–19. Met in 2019–20 and in 2021. Therefore, the demand is low in 2021–22, moving to moderate the following year if the demand is not met.	Low		Moderate

Note: Contributions to meet Barwon–Darling environmental requirements may be considered subject to water availability, antecedent conditions and environmental demands (see chapter 9 of the CEWO Water Management Plan 2021-22). All watering history sourced from NSW Department of Planning, Industry and Environment and Queensland partner agencies, WaterNSW Water Balance Reports, and data from the following gauges (WaterNSW 2021 and DRDMW 2021) – 416040 Dumaresq River at Glenarbon, 416067 Severn River at Ducca Marrin, 416001 Barwon River at Mungindi, 416011 Dumaresq River at Roseneath, 416207A: Weir River at Mascot, 416201A, Macintyre River at Goondiwindi, 416047 Macintyre River at Terrewah, 416037 Boomi River at Boomi Weir offtake, 416002 Macintyre River at Boggabilla, , 416047 Macintyre River at Kanowna.

Key

Potential watering in 2021–22

- High priority for Commonwealth environmental watering (likely to receive water even under low water availability)
- Secondary priority for Commonwealth environmental watering (watering to occur only if natural trigger is met, or under moderate – high water resource availability); or water demand likely to be met via other means
- Low priority for Commonwealth environmental watering (under high – very high water resource availability); or unable to provide water because of constraints or insufficient water

Environmental demands (demand is considered at a generalised scale; there may be specific requirements that are more or less urgent within the flow regime)

- High to critical demand for water (needed in that particular year or urgent in that particular year to manage risk of irretrievable loss or damage)
- Moderate demand for water (water needed in that particular year, the next year, or both)
- Low demand for water (water generally not needed in that particular year)

3.5 Water delivery in 2021–22

Based on the demand for water for the environment, water availability (supply), and catchment conditions, the overall purpose for managing Commonwealth water for the environment in the Border Rivers Valley in 2021–22 is to further support recovery and protect the health and resilience of native fish and aquatic ecosystems. Under dry conditions and due to the relatively small volume of regulated river entitlements, the focus would be on in-channel habitats, drought refugia and fish condition and resilience, particularly in the Border Rivers main channels. Should there be further inflows, the CEWO could add water and/or protect these natural inflows to maximise their ecological benefits.

Consistent with the demands and purpose identified, the CEWO is considering supplying water for the environment to the following actions in 2021–22:

- Avoid extended cease-to-flow conditions, provide flowing water habitats, and maintain suitable river depth (particularly in the Severn-Macintyre and Dumaresq). This will help to support native fish and other native aquatic animals such as freshwater mussels and shellfish, shrimp, platypus, turtles, frogs, water dragons, water rats (rakali).
- Contribute to suitable flow regimes to help maintain and restore instream and riparian vegetation at important sites in the Dumaresq, Severn and Macintyre river systems.
- Contribute to suitable flow regimes in the Dumaresq, Macintyre and Severn rivers to support priming, reproduction, conditioning and movement opportunities for native fish communities, including Murray cod, silver perch, freshwater catfish, purple-spotted gudgeon and olive perchlet.
- Contribute to suitable flow regimes to support refuges, feeding resources and breeding opportunities for waterbirds including listed migratory and threatened species, and species of economic, social and cultural importance.
- Contribute to connected flow events to meet within-catchment outcomes and the downstream Barwon–Darling river system.

As in previous years, the use of Commonwealth water for the environment in the Border Rivers will be adaptively managed throughout 2021–22, in response to changing water resource availability and environmental conditions and demands.

3.6 Monitoring and lessons learned

3.6.1 Monitoring

In the Border Rivers, monitoring is undertaken by NSW and Queensland agencies including NSW DPI Fisheries (native fish), NSW DPIE Water (water quality) and Queensland DRDMW, DAF and DES. The CEWO has also funded several short-term intervention monitoring projects to evaluate the environmental responses of native fish, and to map aquatic habitat in the Dumaresq and Macintyre Rivers.

Learn more about monitoring activities funded by the CEWO in the Border Rivers Valley.

3.6.2 Lessons learned

Outcomes from monitoring and lessons learned in previous years are a critical component for the effective and efficient use of Commonwealth water for the environment. These learnings are incorporated into the way environmental water is managed.

Key findings from fish (NSW DPI & DAF 2019; Marshall & Lobegeiger 2020), aquatic habitat (NSW DPI 2018, forthcoming) and flow monitoring (DAWE 2020; Eco Logical Australia 2020) in the Border Rivers Catchment is summarised in Table BR2.

Table BR2 Key lessons learned in the Border Rivers Catchment

Theme	Lessons learned
Native fish and aquatic invertebrates	• Water for the environment benefits the relatively healthy and diverse native fish community in the Border Rivers, which includes a few nationally and state listed threatened species (e.g. Murray cod, olive perchlet) (NSW DPI & DAF 2019.) Water for the environment helps maintain habitat, supports condition and recruitment, and provides opportunities for movement and increased productivity. • The unregulated Weir River in the Border Rivers catchment supports a relatively healthy population of golden perch, including evidence of natural spawning and recruitment (Rolls et al. 2013; Stuart and Sharpe 2020). These golden perch juveniles may then end up in other Northern Basin catchments including the Lower Balonne (Greg Ringwood [Murray–Darling Basin Authority] 2021, pers. comm., 20 March); and contribute to downstream golden perch populations as far as Menindee Lakes and the Lower Darling. The mainstem Macintyre and Barwon River may also contribute golden perch juveniles to downstream habitats (Rolls et al 2013; Stuart & Sharpe 2020). • A relatively large proportion (22%) of the river channel in the Queensland Border Rivers (including the Weir River) remained wet during peak drought compared to other catchments (Marshall & Lobegeiger 2020). • Water for the environment in the Border Rivers during late winter/early spring contributes to increased Murray cod and freshwater catfish spawning and recruitment. It also provides benefits to unspecked hardyhead, Murray–Darling rainbowfish and carp gudgeon (abundance, spawning and recruitment). • Rapid assessment of priority refuge pools in parts of the Border Rivers through the NSW native fish drought response process in 2019–20 suggests that the Lower Macintyre fish community may be in relatively poor condition. Extensive die-off of freshwater mussels was also observed at some sites. There are also concerns about the status of the Darling River hardyhead in the Border Rivers. • NSW DPI Fisheries sampled upland and montane unregulated systems of the Border Rivers in 2020-21, with preliminary results showing a diverse fish community including ten native fish species and three introduced species. Threatened native fish species including freshwater catfish, Murray cod, olive perchlet and purple-spotted gudgeon were present, as well as the iconic golden perch. Olive perchlet and purple-spotted gudgeon were detected in reasonable numbers, a great finding after the prolonged drought and recent floods in 2021 (Charlie Carruthers 2021, [NSW Department of Primary Industries Fisheries], pers.comm., 16 June),
Aquatic habitat	• Mapping of aquatic habitat features in parts of the Border Rivers (Dumaresq from Pike Creek to connection with the Macintyre and from the Macintyre-Dumaresq junction to Mungindi) has identified habitat that is important for native fish and other animals. Riparian

Theme	Lessons learned
	vegetation condition was also mapped. Key habitat features noted included large woody habitat, refuge pools, and bars and benches.
Connectivity	• The Northern Connectivity Event in 2017–18, Northern Fish Flow in 2018–19 and Northern Waterhole Top Up in 2020–21 highlighted the importance of coordinated flow delivery and protection of environmental flows from the Border Rivers and Gwydir system into the Barwon–Darling river system. The Northern Waterhole Top-Up in 2020–21 was the first time the CEWO and NSW have delivered a connectivity event during summer in the Northern Murray–Darling Basin. The Northern Waterhole Top-Up demonstrated that summer connectivity events can help refill refuge pools and connect tributaries with the Barwon–Darling. • The Border Rivers is estimated to have contributed around 312 gigalitres of water (from all sources) to flows in the Barwon–Darling during March to May 2021. Commonwealth held environmental water contributions to these flows are small relative to the total proportion of water. However, completion of the cross-border accounting project between NSW and Queensland in combination with active management in the Barwon–Darling by NSW will support better tracking and protection of Commonwealth environmental water from upstream tributaries to the Barwon–Darling. Future monitoring by Queensland and NSW partner agencies could also help better understand the role of protecting unregulated tributary flows for waterhole persistence and connectivity, water quality and native fish response.
Other aquatic animals	• There are platypus colonies in the Border Rivers catchment, including in the Severn River (Sundown National Park, near Ashford and reaches downstream of Pindari Dam), Tenterfield Creek; the Dumaresq River downstream of Glenlyon Dam; and also, possibly Macintyre Brook. There are historical records of platypus in lowland areas of the Border Rivers as far downstream as Goondiwindi, but these populations are now considered unlikely to be present. • Delivery of the Pindari stimulus flow in previous years (NSW planned environmental water) took the flow needs of platypus into account, and research in other parts of Australia has also sought to better understand their environmental flow needs. The rakali or native water rat is also widespread throughout the Border Rivers, but little is known about their flow requirements in the catchment. • Persistence of health populations of freshwater mussels (particularly *Alathyria jacksoni,* which is endemic to the Murray–Darling Basin) is dependent on permanent river reaches and waterholes. The provision and protection of minimum baseflows is vital to their persistence, and for populations to recover from the significant losses experienced during the 2017–20 drought. • Recolonisation of freshwater mussels is dependent on the recovery and movement of native fish populations through the northern Basin. Therefore, the minimum flow requirements of native fish also need to be provided to support recovery of both fish and mussel populations. • Bankfull and overbank flows are required to maintain the condition of waterholes and adequate depth to support freshwater mussels (Sheldon et al. 2020). • Additional information on these water dependent species is required to better inform the future management of water for the environment.

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4 Condamine–Balonne Valley Water Plan

4.1 Region overview

4.1.1 River system

The Condamine–Balonne Valley is one of the largest catchments in the Murray–Darling Basin and covers the north eastern corner of the Basin. The system is bounded by the Moonie Valley to the east, the Warrego Valley to the west and the Barwon River in the south (Map CB1). The main rivers of the Valley, the Condamine and the Maranoa, originate in elevated country in Queensland to the east and north respectively. Two-thirds of the Valley is flat floodplain country further to the west and south, with a complex system of rivers and creeks joining and breaking away from the Balonne River as it moves downstream of St George – this region is generally referred to as the Lower Balonne Floodplain (MDBA 2021).

While the Culgoa and Bokhara rivers flow to the Barwon River, most rivers in the Valley end in lakes and wetlands in south west Queensland and north-west New South Wales (NSW). Most of the Valley is located in Queensland with only 16% in NSW (MDBA 2021).

The Valley's extensive floodplains provide habitat for a diverse range of plants, including endangered vegetation communities. The region also provides habitat for waterbirds, native fish and many vulnerable and endangered species. There are several wetlands of national importance in the region, as well as the Ramsar-listed Narran Lake Nature Reserve.

The extent of river regulation in the Condamine–Balonne is relatively low. Public dams account for only 13 % of stored water in the Valley. The two largest public storages are Leslie Dam (106 gigalitres) near Warwick, and Beardmore Dam (82 gigalitres) near St George, which were built in the 1960s to secure town water and irrigation supplies (MDBA 2021).

Large-scale irrigation in the region is supported by large capacity pumps or regulating structures that divert water during natural flow events into private on-farm storages for later use. Most of the water use and entitlement is in the form of diversion of river flows and water during natural flow events that breaks out of rivers and becomes overland flows across floodplains.

4.1.2 Traditional Owners

The lands of the Condamine–Balonne Valley have been important to Aboriginal people for thousands of years. Many First Nations retain a connection with the region, and their history, culture and livelihoods are closely intertwined with its river systems. First Nations of the region include Barunggam, Bidjara, Bigambul, Euahlayi, Gomeroi/Kamilaroi, Giabel, Githabul, Gunggari, Guwamu/Kooma, Jarowair, Kambuwal, Mandandanji, Murrawarri, and Wakka Wakka. The Commonwealth Environmental Water Office (CEWO) respectfully acknowledges these Nations, their Elders past and present, as the Traditional Custodians of the lands on which this chapter is focused.

4.1.3 Important sites and values

The floodplains of the Condamine–Balonne Valley are ecologically significant because they support endangered ecological communities, such as the brigalow–gidgee woodland/shrubland in the Mulga Lands and Darling Riverine Plains Bioregions (DSITI and DNRM 2017). The wetlands support a diverse range of flora and fauna, provide habitat for migratory birds and vulnerable and endangered species, such as silver perch, Murray cod, freckled duck, Australian painted snipe, the great egret and the cattle egret.

The Lower Balonne is a complex floodplain channel system containing a number of nationally significant wetlands, as well as the internationally significant Narran Lakes Ramsar-listed wetlands. Wetlands of national importance include the Great Artesian Basin Springs, Lake Broadwater, the Gums Lagoon, the Culgoa River Floodplain, and the Dalrymple and Blackfellow creeks (MDBA 2021).

Narran Lake Nature Reserve

The Ramsar site within the Narran Lake Nature Reserve is in north-west NSW about 50 km east of Brewarrina. One section of the site was listed under the convention in 1999, and a further 3,104 ha section was added in 2015. The site was extended to encompass more breeding and feeding habitat for waterbirds. Currently the site covers a total area of 8,447 ha and comprises the whole floodplain area within Narran Lake Nature Reserve. The site was listed under the Ramsar Convention because of its significant values, which include:

- some of the largest expanses of lignum in NSW
- the ability to support:
  - three wetland dependent threatened species – Australasian bittern, Murray cod and winged peppercress
  - a large number of migratory bird species, including 19 listed under international agreements
  - substantial breeding of waterbirds, including colonial nesting species such as ibises, cormorants, egrets and spoonbills.
- the capacity to provide drought refuge for waterbirds following floods (Butcher et al. 2011).

The Nature Reserve is also important to Aboriginal people and they are involved in managing the site through the Narran Lake Nature Reserve Aboriginal Co-Management Committee. Key values of the site for Aboriginal people include:

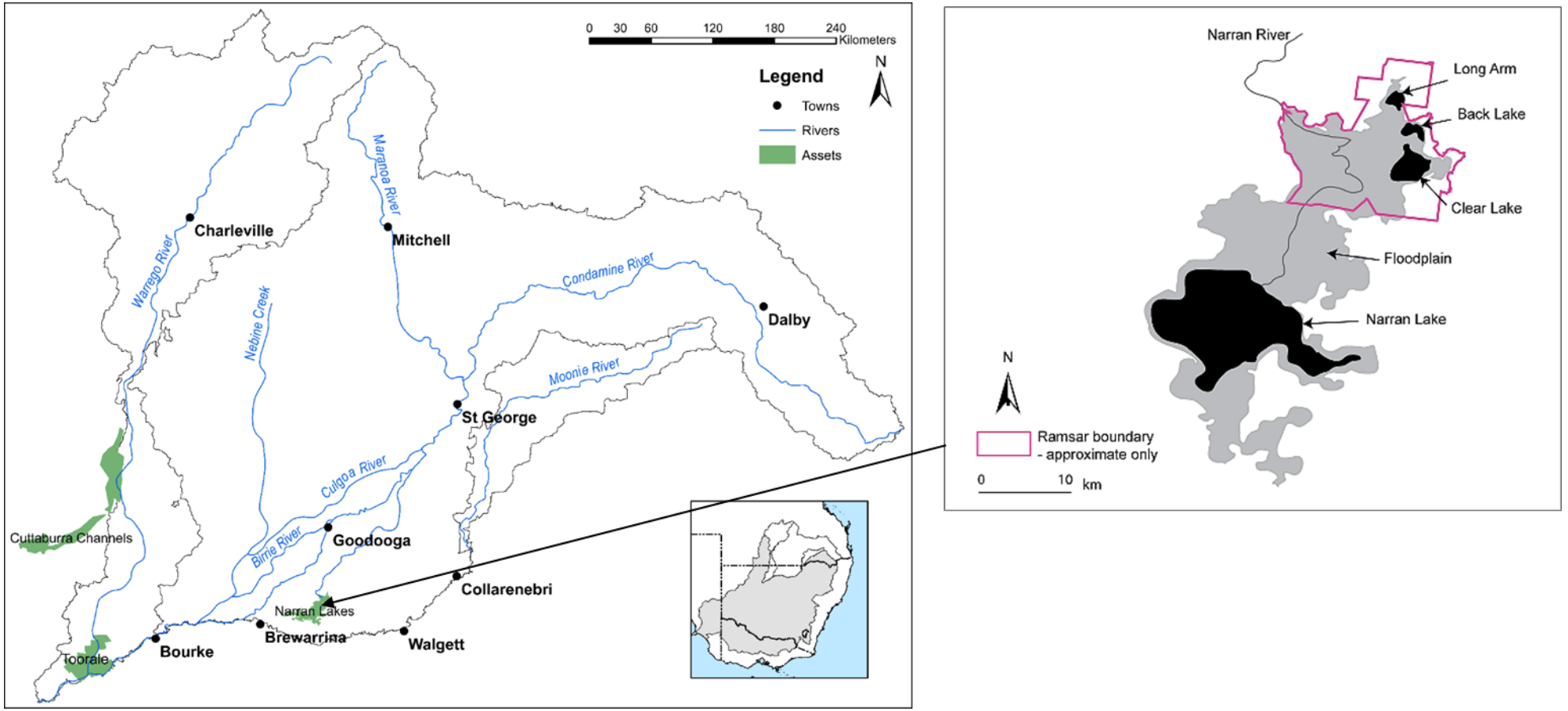
- its role as a traditional meeting place for Aboriginal tribes in the region
- the culmination of several Dreaming paths at the lakes
- many relatively undisturbed Aboriginal objects.

4.1.4 Stakeholder engagement

In the Condamine–Balonne system, the planning and management of Commonwealth water for the environment is undertaken in conjunction with a range of partners and stakeholder groups. Key stakeholders include: the Queensland Department of Regional Development, Manufacturing and Water (DRDMW); Queensland Department of Environment and Science (DES); Queensland Department of Agriculture and Fisheries (DAF); NSW Department of Planning, Industry and Environment (DPIE); NSW Department of Primary Industries (DPI) – Fisheries, NSW National

Parks and Wildlife Service, SunWater; WaterNSW; several Aboriginal organisations in the Lower Balonne; the Narran Lake Nature Reserve Aboriginal Joint Management Committee; and the Lower Balonne Working Group.

Map CB1 Condamine–Balonne Valley and surrounding systems, including an inset of the internationally significant Narran Lakes system.



Source: CSIRO (2007)

4.2 Environmental objectives

Based on long-term environmental objectives in the Basin Plan, state long-term watering plans, site management plans, and best available knowledge, the following objectives are relevant for environmental watering in the Condamine-Balonne Valley.

The objectives that are targeted in a particular year may vary, depending on available water, catchment conditions, operational feasibility, and demand for environmental water. These objectives will continue to be revised as part of the Commonwealth Environmental Water Office's (CEWO) commitment to adaptive management. The objectives are:

- Vegetation – Maintain and improve the condition, growth and survival of riparian, in-channel, floodplain and wetland vegetation.
- Waterbirds – Increase waterbird abundance and maintain species diversity by supporting naturally triggered breeding events, and maintaining suitable refuge, feeding and breeding habitat at targeted floodplain sites.
- Native fish – Improve habitat condition, and support different life stages (migration, spawning, recruitment and refuge), natural flow variability, and connectivity between river channels, wetlands, anabranches and floodplains.
- Other vertebrates and invertebrates – Support opportunities for the reproduction and recruitment of other native aquatic species, including frogs, platypus, native water rats, turtles, and freshwater mussels.
- Connectivity – Support longitudinal connectivity, including with the Barwon River, and lateral connectivity between the river, wetlands and floodplains.
- Processes/water quality/resilience – Support key ecosystem functions and promote productivity, maintain water quality in channels and pools, and maintain drought refuge habitat.

4.3 First Nations environmental watering objectives

The CEWO is committed to working with First Nations groups to better understand their objectives. The CEWO will use environmental flows to contribute to these objectives where possible and where this is consistent with the Commonwealth Environmental Water Holder's statutory responsibility of protecting and restoring environmental assets in the Basin (see Chapter 2).

As the next steps, CEWO will develop and implement a work program to work with First Nations groups in the northern Basin. This work program will be developed in collaboration with First Nations groups and will be integral in continuing to build relationships and our capacity with First Nations groups. It will also ensure First Nations groups actively participate in the planning and management of environmental flows.

4.4 Recent conditions and seasonal outlook

4.4.1 Recent conditions and environmental water use

Following flows in early 2020, most of the upper Condamine catchment experienced below or very much below average rainfall for the remainder of the calendar year. Rainfall in late October and November 2020 produced inflows into Beardmore Dam totalling 1,500 megalitres. This

water was released for environmental, stock and domestic use over six days from 11 to 16 November 2020 and the flow reached Hastings Weir on the Balonne-minor River.

Widespread rainfall across the Valley began in January 2021 with some areas receiving up to 200mm in March. This rainfall led to further environmental stock and domestic releases from Jack Taylor Weir with water harvesting announcements commencing on Sunday 21 March for 21 days. The flow event rule to support Narran Lakes was applied from 22 March, which reduced daily rates of take by 10 per cent for 10 days.

More than 330 gigalitres (GL) flowed passed the St George gauge from January to May 2021. This inflow was important, but relatively small: only one-third of the historical annual average and less than a quarter of the 1,442 GL that passed St George in early 2020. Commonwealth water for the environment contributed around 43 GL across the Queensland Lower Balonne rivers during March and April 2021. Over 36 GL of this water passed the New South Wales border, contributing to flows downstream in the Darling River. The Commonwealth portfolio also contributed around 3 GL from the Nebine Creek at the NSW border.

Flow rates and total flow volumes for various parts of the Lower Balonne network are shown (Table CB1). This water will help build on the environmental benefits achieved from last year's flow event.

Table CB1 Maximum flow rate, duration and total flow volume at key flow gauges across the Lower Balonne distributaries from 1 February to 30 May 2021

Site	Description	Maximum Flow Rate (ML/d)	Flow Duration (Days)	Total Flow Volume (ML)
Wilby Wilby (Narran River)	Located mid-way between the Queensland/NSW border and the Narran Lake Nature Reserve	2,394	50	34,860
Narran Park (Narran River)	Located on the western boundary of the Narran Lake Nature Reserve	1,821	50	31,291
Brenda (Culgoa River)	Located near the Queensland/NSW border	3,714	97	88,272
Downstream of Collerina (Culgoa River)	Downstream of where Nebine and Birrie systems connect to the Culgoa River. The most downstream gauge	4,817	107	150,064
Bokhara (Bokhara River)	The most downstream gauge	468	73	13,122

Learn more about previous Commonwealth environmental water use in the Condamine–Balonne Valley.

4.4.2 Seasonal outlook

According to the Bureau of Meteorology outlook on 3 June 2021, above median rainfall is forecast to occur across the Condamine–Balonne system through winter into spring (BoM 2021a,b). Follow up rain over the coming summer is needed to ensure continued recovery from the drought. Despite river flows ceasing again in early-winter, wetter conditions can return suddenly in this region. Maximum temperatures are also forecast to remain below average over the coming months (BoM 2021c,d).

4.4.3 Water availability

The Condamine-Balonne's two main public storages have a combined storage volume of 188 gigalitres, while the average annual stream flow at St George is 1,305 gigalitres. Thus, entitlements reliant on regulated releases from these storages are relatively small compared to the entitlements used to access unregulated or natural flow events. Consistent with this, Commonwealth environmental water holdings in the Condamine–Balonne system are almost exclusively made up of unregulated entitlements and can only be sourced as a share of an unregulated flow event determined by entitlement conditions.

Availability of water for the environment in the Condamine–Balonne depends on the nature of flow events that occur. Unregulated entitlements provide opportunistic access to unregulated river flows and overland flows when water resource plan rules are triggered, and a period of access is announced. Each entitlement will contribute to restoring flows reflecting its particular flow access windows, take rates and location. Daily, instantaneous, annual or multi-year limits cap overall diversions in any given year or flow event, and likewise the flow contributions that can be attributed to unregulated Commonwealth entitlements.

4.4.4 Environmental demands

The environmental water demands for assets in the Condamine-Balonne Valley in 2021–22 are shown in Table CB2. The capacity to contribute to these environmental demands is contingent on the Commonwealth licences being triggered by natural flow events.

Table CB2 Environmental demands in 2021–22 in the Condamine–Balonne Valley

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22
	Physical and process assets	Flow/volume	Required frequency (maximum dry interval)		Environmental demands for water (all sources)
Lower Balonne River channels (Culgoa River, Narran River and inner distributary channels) and Barwon–Darling	Drought refuge (waterholes)	Flow reaches end of all channels within a three-month period, indicated by: • 30 ML/day Birrie River at Talawanta for 1 day • 30 ML/day Bokhara River at Bokhara for 1 day • 30 ML/day Culgoa River at Weilmoringle for 1 day • 30 ML/d Narran River at Narran Park for 1 day	Annually (no longer than 12 months between last flow)	Since 2011–12 flow requirements for the maintenance of drought refuges in the four rivers have been met in most years, including 2020–21. Water is required annually to replenish refugial waterholes (contributing to persistence, connectivity and quality). Therefore the demand is high. The demand should be met by planned environmental water (environmental, stock and domestic flows). After a water harvesting event has been announced, water left in the river as a result of the Commonwealth owning licences will be distributed across channels in the lower Balonne	High
	Culgoa River for longitudinal connectivity	Small in channel fresh 1,000 ML/day at Brenda for 7 days	8 in 10 years	Small freshes have occurred 7 in 10 years, including this year. However, the average required frequency has not been met so the requirement for this demand is high.	High
	Narran River for fish migration	Large in-channel fresh 1,700 ML/day at Wilby (August–May) for 14 days	4–6 in 10 years	Large in-channel freshes have been met in 3 of the past 10 years and only once (in 2020) since 2013. The average required frequency has not been met so the requirement for this demand is critical.	**Critical**
	Culgoa River for fish migration	Large in-channel fresh 3,500 ML/day at Brenda (August–May) for 14 days	4–6 in 10 years	The last large in-channel fresh that met the demand occurred 9 years ago. A large fresh is required in 2021–22 to provide opportunities for the dispersal and recruitment of native fish species.	**Critical**
Lower Balonne floodplain	Connectivity with the riparian zone	9,200 ML/day Culgoa River at Brenda for 12 days	Every 2 to 3 years	The last flow of this magnitude occurred 9 years ago, which exceeds the critical interval (3 years) to maintain condition of river red gum, ephemeral wetlands and lignum communities. Inundation is required in 2021–22 to maintain ecosystem health and function.	**Critical**
	Connectivity with the inner floodplain	15,000 ML/day Culgoa River at Brenda for 10 days	Every 3.5 to 4 years	The last flow of this magnitude occurred 9 years ago. Inundation is required in 2021–22 to maintain ecosystem health and function.	**Critical**
	Connectivity with the mid floodplain	24,500 ML/day Culgoa River at Brenda for 7 days	Every 6 to 8 years	The last flow that met the demand occurred 9 years ago. Inundation is required within the next year to maintain ecosystem health and function.	**Critical**
	Connectivity with outer floodplain	38,000 ML/day Culgoa River at Brenda for 6 days	Every 10 to 20 years	The last flow that met the demand occurred 9 years ago. Inundation is required within the next year to maintain ecosystem health and function.	**Critical**
Narran Lakes	Waterbird breeding habitat in northern lakes (Ramsar site)	25 GL at Wilby Wilby (Narran River) over 60 days	Every 1 to 1.3 years	This demand has been met 4 out of the past 10 years, which is much less than the overall required frequency range, despite being met the last two years. This demand is considered a priority for event-based mechanisms.	High
	Waterbird breeding and foraging habitat northern lakes zone	50 GL at Wilby Wilby over 90 days	Every 1.3 to 1.7 years	This demand has been met 3 out of the past 10 years, which is much less than the required frequency range, and most recently in 2020. This demand is considered a priority for event-based mechanisms.	**Critical**
	Trigger and maintain large scale colonial waterbird breeding	154 GL at Wilby Wilby over 90 days	Twice in every 8 to 10 years	This demand was last met 9 years ago. An acute and chronic shortage of waterbird breeding across the Basin and the likelihood of this demand not being met in the long term, increases its urgency. This demand is considered a priority for event-based mechanisms.	**Critical**

	Water all floodplain and wetland habitat in Narran Lakes complex, initiate waterbird breeding, provide long-term refuge	250 GL over 180 days at Wilby Wilby	Every 10 to 12 years	This demand was met 9 years ago. Following the 2010–11 and 2011–12 floods, the critical interval for inundation will be from 2022 (if not received before then).	Low

Key

Environmental demands (demand is considered at a generalised scale; there may be specific requirements that are more or less urgent within the flow regime)

- High to critical demand for water (needed in that particular year or urgent in that particular year to manage risk of irretrievable loss or damage)
- Moderate demand for water (water needed in that particular year, the next year, or both)
- Low demand for water (water generally not needed in that particular year)

4.5 Water delivery in 2021–22

Unregulated entitlements provide opportunistic access to river flows and overland flows when water levels exceed trigger values at certain locations, as specified in the entitlement conditions. Each triggered Commonwealth environmental water entitlement leaves water in the river which could otherwise be extracted. This makes a contribution to restoring natural flows, reflecting its particular flow access windows, take rates and location. The location and size of the event will influence which environmental demands Commonwealth environmental water contributes to (Table CB2).

The Commonwealths water harvesting allocations will contribute to all flows during water harvesting periods, and thus are able to contribute to all environmental demands listed in Table CB2. The characteristics of the overland flow licences are such that in wetter years there will be a higher yield of water against these overland flow licences than in drier years. These licences will generally contribute to meeting fish migration, Lower Balonne floodplain and Narran Lakes demands during wetter years.

The CEWO will consider implementing an event-based mechanism in 2021–22 to contribute to meeting the waterbird breeding and foraging habitat demands that are listed as high and critical in Table CB2. If a medium sized flow event occurs, the CEWO may offer to reimburse water licence holders in the Lower Balonne river system (via an ad-hoc grant) to not pump water from the river. The trigger flow volume will be between 250 to 500 gigalitres at St. George. If colonial nesting waterbird occurs in the Narran Lakes Nature Reserve in 2021–22, a release from storage option may be considered to mitigate the risk of nest abandonment.

4.6 Monitoring and lessons learned

4.6.1 Monitoring

In the Condamine–Balonne Valley, monitoring is undertaken by Queensland and NSW agencies, including Queensland DRDMW and DES (flow, hydrology, water quality, native fish) and NSW DPIE (vegetation, waterbirds and other animals), NSW DPI – Fisheries (native fish), and WaterNSW (hydrology and flow delivery data). The CEWO is also funding several short-term intervention monitoring projects to evaluate the environmental responses of native fish, waterbirds and vegetation in the Condamine–Balonne.

Learn more about monitoring activities funded by the CEWO in the Condamine-Balonne Valley.

4.6.2 Lessons learned

Outcomes from monitoring and lessons learned in previous years are a critical component for the effective and efficient use of Commonwealth water for the environment. These learnings are incorporated into the way environmental water is managed.

Key findings from fish, aquatic habitat and flow monitoring in the Condamine–Balonne Valley are summarised in Table CB3.

Table CB3 Key lessons learned from monitoring in the Condamine–Balonne Valley

Theme	Lessons learned
Native fish and aquatic invertebrates	• Only 10% of the river channel network in the Condamine–Balonne retained water at the peak of the 2018–20 drought. Native fish moved from the few remaining refuges into previously dry waterholes during the autumn 2020 flow. The project findings are helping to identify river segments where drought poses the greatest risks to fish population viability and the barriers that pose the greatest threat to post-drought recovery. The project will help assess and prioritise the management of risks to fish population viability from drought and fragmentation by barriers in any non-perennial river setting (Marshall & Lobegeiger 2020; Marshall & Lobegeiger 2021).
Aquatic habitat	• The CEWO has funded a short-term intervention monitoring (STIM) project on vegetation condition at Narran Lakes from early 2020 to December 2021. Preliminary results suggest that vegetation of all community types suffered as a result of drought in recent years. River red gums were the most affected tree species. The vegetation in some areas of the Nature Reserve is showing signs of recovery following inundation in autumn 2020, but in other areas, the vegetation is yet to show signs of recovery. Monitoring has shown that follow-up watering was required to consolidate condition and resilience benefits from the 2020 watering (UNE 2020).
Connectivity	• The Condamine–Balonne, including the Nebine Creek, provide important tributary inflows to the Barwon–Darling during unregulated flow events (WaterNSW 2021). Cross-border accounting arrangements being developed by Queensland and NSW with input from the Commonwealth will help track environmental water from the Queensland Condamine–Balonne into the NSW downstream to the Barwon–Darling. Active management arrangements in NSW will also provide better protection of the Commonwealth's environmental water in the Barwon–Darling from water flowing from the Condamine–Balonne and other unregulated Barwon–Darling tributaries.
Waterbirds	• Regular waterbird surveys undertaken by state agencies since flows in 2020 detected thirty species, including freckled duck, plumed duck, pelicans and darters. Straw-necked ibis were also detected but no breeding was evident. During the March-April 2021 flow event to the Nature Reserve 33 species of waterbird were observed.

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5 Warrego and Moonie Valleys Water Plan

5.1 Region overview

5.1.1 River system

The Warrego and Moonie River Valleys are characterised by highly variable rainfall and ephemeral (intermittent) stream flows (Map WMV1) (MDBA 2021a,b). Significant flow events generally result from heavy rainfall in elevated headwater areas (CSIRO 2007,2008; DEHP 2016, MDBA 2021a,b). No flow periods of several months are common, extending to several years during prolonged dry conditions (CSIRO 2007, 2008; DEHP 2016, MDBA 2021a,b).

The flat landscape, low local runoff and intermittent flow conditions in both the Warrego and Moonie Valleys have led to the evolution of distinctive ecology in lowland river reaches (Balcombe et al. 2006). Aquatic and floodplain species are adapted to high flow variability and 'boom and bust' cycles (Balcombe et al. 2006). This is characterised by episodes of intense reproduction and high productivity by opportunistic plants and animals – the boom – associated with periods of flooding, followed by periods of stress and reduced production – the bust (Balcombe et al. 2006).

The Warrego River is largely unregulated, other than the State-owned Allan Tannock Weir at Cunnamulla (MDBA 2021a). Only a small volume of surface water in the Warrego catchment is diverted for irrigation and urban use (MDBA 2021a). Some water is also taken from the river by diversion of flow or overland flows into private off-channel storages (MDBA 2021a).

Similar to the Warrego, the Moonie River is a predominantly unregulated system and has no major water storages. A weir was built over the river at Thallon in 1959 to supply town water (MDBA 2021b). Almost all irrigation in the Moonie depends on surface water. However, these diversions are small compared to overall surface water available (CSIRO 2008).

5.1.2 Traditional Owners

The lands and waters of the Warrego and Moonie Valleys hold significant spiritual and cultural importance for Aboriginal people. Many Aboriginal nations retain a connection with the two regions and their history, culture and livelihoods are closely intertwined with their river systems. The Commonwealth Environmental Water Office (CEWO) respectfully acknowledges these Nations, their Elders past and present, as the Traditional Custodians of the lands on which this chapter is focused.

The Warrego Valley takes in (or closely borders) the traditional lands of the Yuwaalaraay/Euahlayi, Bidjara, Gwamu/Kooma, Gunggari/Kungari, Kunja, Mandandanji, Mardigan, Githabul and Murrawarri nations (MDBA 2021a).

The Moonie catchment includes the traditional lands of the Bigambul, Gomeroi/Kamilaroi and Mandandanji nations (MDBA 2021b).

5.1.3 Important sites and values

There are many environmental assets in the Warrego Valley including species and communities of fish, waterbirds and vegetation and important habitats such as wetlands and drought refuges.

The Warrego Valley supports large areas of wetlands. The nationally significant Cuttaburra Channels and Yantabulla Swamp (a mosaic of channels, floodways and wetlands) consistently support large numbers and a high diversity of waterbirds and provides breeding sites for ducks and colonial waterbirds when flooded (Kingsford et al. 1997,1999, 2013; Bino et al. 2015; NSW DPIE 2020; MDBA 2021a). Waterholes along the Warrego River near Charleville are an important breeding area for native fish including Murray cod and silver perch (MDBA 2021a). Toorale's Western Floodplain is also an ecologically important floodplain wetland, providing important feeding and breeding habitat for a range of water dependent species in wet conditions (ELA 2019; NSW DPIE 2020; UNE & 2 Rog Consulting 2020a,b, 2021).

These ecological populations and habitats are connected to the Barwon–Darling River, providing a critical drought refuge and movement corridor for fish and waterbirds (NSW DPIE 2020).

Native vegetation in the Warrego Valley includes important riparian and floodplain communities such as lignum, river red gum, river cooba, black box and coolabah (NSW DPIE 2020). There is a high proportion of remnant vegetation in good condition in some areas including the floodplains of the Warrego, such as stands of coolibah, black box and lignum (NSW DPIE 2020). The Western Floodplain also supports 'tiny teeth' (*Dentella minutissima*) a plant species listed as threatened under NSW legislation (NSW DPIE 2020).

In between boom periods, channels in the Warrego typically dry to a series of disconnected waterholes, which are drought refuges that are reconnected by the next significant flow event (Marshall & Lobegeiger 2020). Semi-permanent and permanent waterholes in the main river channels and distributary creeks and anabranch systems are critical to ensuring the survival of species between boom periods and their capacity to recolonise the system in subsequent flow periods (Marshall & Lobegeiger 2020). Much of the riverine fauna (e.g. fish, turtles, invertebrates) of the Warrego Valley is dependent upon the persistence of a network of refugial waterholes during frequent and often prolonged no flow periods (NSW DPIE 2020; Marshall & Lobegeiger 2020).

The Warrego and Moonie Valleys support several species listed as endangered or vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999*. These include Murray cod, silver perch, Australian painted snipe, Australasian bittern, and examples of the threatened ecological community of coolibah-blackbox woodland (NSW DPIE 2020).

Over 100 wetlands exceeding one hectare in area have been mapped in the Moonie, many of which are in the lower catchment below Nindigully (CSIRO 2008; DES 2018). Thallon waterholes have been observed to support between 10,000 and 20,000 waterbirds (Kingsford et al. 1997). There is past evidence of black swans, grey teal and little black cormorants breeding at the waterholes (DNR 1999). Banded lapwing and wandering whistling-duck have also occurred in high abundance (Bino et al. 2015; DES 2018).

The Moonie flows through the endangered southern Brigalow belt, which contains remnants of Brigalow forests, poplar box, Wilga and white cypress pine (DES 2018).

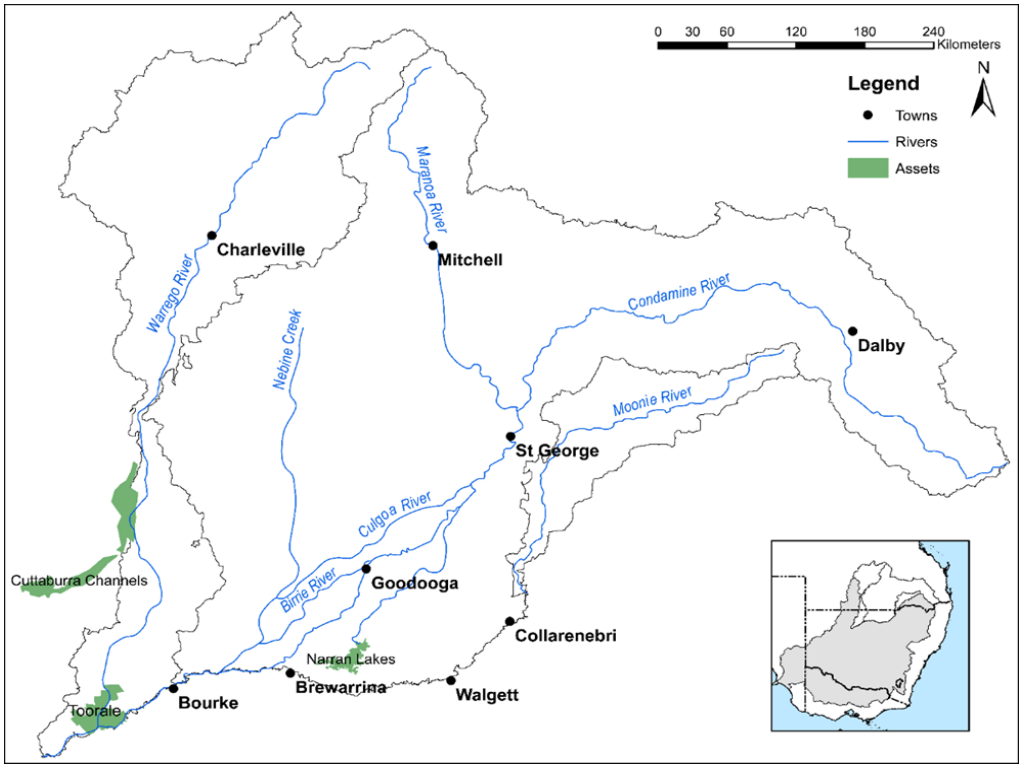
The Moonie has relatively long and deep waterholes that have been shown to be critical refugia for sustaining native fish populations in the often long periods between flows in the system. Waterhole habitat has been identified in three main spatial areas in the Moonie: upstream of Flinton, downstream of the confluence of the Moonie River and Teelba and Bidgel creeks, and within the Nindigully floodplain assessment reach (DES 2018). Species including golden perch, bony bream, eel tailed catfish and smelt moved significant distances (up to 70 kilometres) in response to waterhole reconnecting flows, enabling recolonisation of the system and genetic mixing (Marshall et al. 2016). Native fish species recorded in the Moonie include the threatened silver perch and freshwater catfish as well as the environmentally, socially and economically important golden perch (DRNME 2018).

5.1.4 Stakeholder engagement

In the Warrego and Moonie Valleys, planning, management, and delivery of Commonwealth water for the environment is undertaken in conjunction with a range of partners and stakeholder groups. Key stakeholders in the Warrego Valley include the Queensland Departments of Regional Development, Manufacturing and Water (DRDMW), Environment and Science (DES), and Agriculture and Fisheries (DAF), NSW Department of Planning, Industry and Environment (DPIE), NSW Department of Primary Industries (DPI) – Fisheries, NSW National Parks and Wildlife Service (NPWS) and the Toorale Joint Management Committee.

Local Engagement Officers from the Commonwealth Environmental Water Office (CEWO) also work with different stakeholders as part a broader program of engagement around the management of the Commonwealth's portfolio of environmental water entitlements. As part of this work, the CEWO's Local Engagement Officers have been engaging directly with members of the local Aboriginal community. This work has focused on aligning priorities for water use with Aboriginal community objectives for sites, values and species significant to all Nations in the Warrego and Moonie Valleys.

Map WMV1 Warrego and Moonie River Valleys



Source: Department of Agriculture, Water and the Environment (n.d.)

5.2 Environmental objectives

Based on long-term environmental objectives in the Basin Plan, state long-term watering plans, site management plans, and best available knowledge, the following objectives are relevant for environmental watering in the Warrego Valley. These objectives will continue to be revised as part of the CEWO's commitment to adaptive management.

- Vegetation – Maintain and improve the condition, growth and survival of riparian, in-channel, floodplain and wetland vegetation.
- Waterbirds – Maintain foraging, roosting and breeding habitats at targeted sites on the floodplain to support waterbirds.
- Native fish – Improve habitat condition, and support different life stages (migration, spawning, recruitment and refuge), natural flow variability, and connectivity between river channels, wetlands, anabranches and floodplains.
- Invertebrates – Maintain and improve the micro- and macro-invertebrate communities by providing a variety of habitat and flow conditions.
- Other vertebrates – Support survival and recruitment of other native aquatic species, including frogs and turtles.
- Connectivity – Support longitudinal connectivity, including with the Barwon River, and lateral connectivity between the river(s), wetlands and floodplain.

- Processes/water quality/resilience – Support key ecosystem functions, biotic dispersal, and promote productivity; maintain water quality in channels and pools; and maintain drought refuge habitat.

5.3 First Nations environmental watering objectives

The CEWO is committed to working with First Nations groups to better understand their objectives. The CEWO will use environmental flows to contribute to these objectives where possible and where this is consistent with the Commonwealth Environmental Water Holder's statutory responsibility of protecting and restoring environmental assets in the Basin (see Chapter 2).

As the next steps, the CEWO will develop and implement a work program to work with First Nations groups in the northern Basin. This work program will be developed in collaboration with First Nations groups and will be integral in continuing to build relationships and our capacity with First Nations groups. It will also ensure First Nations groups actively participate in the planning and management of environmental flows.

5.4 Recent conditions and seasonal outlook

5.4.1 Recent conditions and environmental water use

During the first half of the 2020–21 water year, the Moonie catchment experienced largely average to drier than average rainfall conditions and warmer than average temperatures (BOM 2021f-k). Wetter conditions occurred in summer and autumn 2020–21, particularly in January to March 2021 (BOM 20211f-k). There was around 450 mm of rainfall recorded at the Flinton gauge in the upper Moonie catchment in 2020–21 (with minimal rainfall in April and May 2021), and around 400 millimetres of rainfall at the Nindigully gauge over the same period (DRDMW 2021b). There were flood warnings issued for the Moonie river at Flinton and Nindigully in January-April 2021.

The Commonwealth's unregulated Queensland licenses in the Moonie were triggered in January through to April 2021, with an estimated total contribution of around 5.7 gigalitre and all licence volumes exhausted by mid April 2021. Around 114 gigalitres flowed past the most downstream gauge at Gundablouie from 1 January 2021 to the end of May 2021, contributing an estimated 100 gigalitres of inflows to the Barwon-Darling (WaterNSW 2021c).

There was periodic rainfall across the Warrego Valley throughout the water year (BOM 2021a). Most rainfall occurred in March 2021 with the upper and lower Warrego catchment receiving 100 to 200 mm and central areas around Charleville, Wyandra and Cunnamulla receiving up to 100 mm (BOM 2021b,c).

Unregulated licences in the Queensland portion of the Warrego Valley were triggered in March and April 2021, with an estimated environmental contribution of 5.2 gigalitres in the Lower Queensland Warrego (gauged at Cunnamulla weir) and 198 megalitres in the upper Warrego (gauged at Augathella).

Commonwealth environmental water in combination with natural flows entered the nationally significant Cuttaburra and Yantabulla wetland areas downstream of Cunnamulla, with around 27 gigalitres flowing past the Turra gauge (WaterNSW 2021a). This was a much smaller event

compared to 2019–20, for example around 95 gigalitres total volume past the Cunnamulla gauge in 2020–21, compared to around 1,000 gigalitres in 2019–20 (DRDMW 2021a).

The Commonwealth's Toorale licences on the Warrego River were not activated in 2020–21, as the multi-year account limit was reached last year. The high flow licence at Toorale was also not triggered in 2020–21. Around five gigalitres flowed from the Warrego River into the Darling River between March and April 2021, helping meet downstream environmental demands (WaterNSW 2021b). While the Western Floodplain at and around Toorale National Park received local rainfall in March 2021, there was no flow from the Warrego River onto the Western Floodplain in 2020–21 (Paul Frazier [2 Rog Consulting] 2021, pers. comm. 11 May).

Native fish in the upper Warrego have responded well to flows over the last two years, with refuge pools near Charleville supporting abundant golden perch and some Murray cod, with a relatively low carp presence (Marshall & Lobegeiger 2020). Waterbirds in the Cuttaburra and Yantabulla area have also benefited from flows to the area (Kingsford & Wainwright 2020; Thorburn 2020).

Vegetation on the Western Floodplain at Toorale near the junction of the Warrego and Darling rivers dried back during the first half of 2020–21, with lignum showing a decrease in condition (UNE & 2 Rog Consulting 2020b). However, plant height and size increased, showing longer term benefits of flows to the area (UNE & 2 Rog Consulting 2020b).

Drier conditions in the first half of 2020–21 may have confined native fish to refuge pools along the system (UNE & 2 Rog Consulting 2020b). However, the flow events in March and April 2021 improved conditions for golden perch and other native fish species, and would likely have provided spawning and recruitment opportunities and connectivity with the Barwon-Darling river system (UNE & 2 Rog Consulting 2021).

A return to dry conditions before flows in early 2021 also limited the abundance and diversity of waterbirds and frogs, although the longer-term productivity and food web benefits of flows are apparent in resident bird species including sea eagles (UNE & 2 Rog Consulting 2020b). These species are expected to respond positively to the most recent flows. Yabbies and turtles are also doing well in the Toorale area, showing the benefits of both environmental water and natural flows (UNE & 2 Rog Consulting, 2021).

Learn more about Learn more about previous Commonwealth environmental water use in the Warrego and Moonie valleys.

5.4.2 Seasonal outlook

According to the Bureau of Meteorology's outlook issued on 3 June 2021, there is some chance of above average rainfall across the Warrego and Moonie Valleys from June to September 2021 (BOM 2021c). Maximum temperatures are also forecast to remain average or above average over the coming months (BOM 2021d,e).

This forecast suggests weather patterns may further improve the condition of rivers and wetlands across the Warrego and Moonie Valleys (and other Northern Basin systems). However, it is also possible that dry conditions may re-eventuate over coming months, which would hinder recovery.

5.4.3 Water availability

The Warrego and Moonie Valleys have fewer regulating structures than other areas of the Murray–Darling Basin, which limits options for the managed delivery of water for the environment at a predetermined volume and time. Instead, Commonwealth water for the environment in these two river systems can generally only be sourced as a share of an unregulated flow event or in some cases targeted management within an event. Most Commonwealth unregulated entitlements are left in-stream to provide environmental benefits by restoring flows that were formerly extracted, which improves flow variability.

Water availability depends on the flow events that occur. Unregulated entitlements provide opportunistic access to river flows when water levels exceed trigger values at certain locations, as specified in entitlement conditions. Each triggered Commonwealth environmental water entitlement leaves water in the river which could otherwise be extracted. This makes a contribution to restoring natural flows, reflecting its particular flow access windows, take rates and location. Daily, instantaneous, annual or multi-year limits cap overall diversions in any given year or flow event, and likewise the in-stream contributions that can be attributed to unregulated Commonwealth entitlements.

There is some capacity to direct flows at the junction of the Warrego and Darling rivers through infrastructure on the Toorale site (managed by the NSW National Parks and Wildlife Service in consultation with the Toorale Joint Management Committee). However, this is limited by the nature of the Commonwealth's entitlements in the Warrego and Darling rivers and day to day operations of the Toorale infrastructure. Upgrades and changed management of the Toorale structures is underway through the Toorale Infrastructure Project (NSW DPIE 2021).

5.4.4 Environmental demands

For the environmental water demands for assets in the Warrego and Moonie Valleys in 2021–22, see Table WMV1 (Moonie Valley) and Table WMV2 (Warrego Valley). The capacity to contribute to these environmental demands is contingent on the Commonwealth licences being triggered by natural flow events.

Table WMV1 Environmental demands in 2021–22 for the Moonie Valley

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	Environmental demands for water (all sources) in 2021-22
		Flow/volume	Required frequency (maximum dry interval)		
Moonie River (at Gundablouie)	Native fish dispersal and condition Native fish spawning and recruitment Native vegetation Aquatic ecosystem function	Very low flow (VLF) (>30 ML/day) Timing in line with natural (anytime). Minimum duration: typically 60 days/year exceed VLF threshold but not less than nine days/yr.	At least 96% of years. (Max. interval 70 days (but not more than 283 days))	Met in all years since 2010–11 excluding 2018–19. Required annually therefore a high demand for water in 2021–22, remaining high in 2022–23 if watering occurs.	High
		Small fresh 1: >300 ML/day any time (ideally October to April). Minimum duration ten days	3 to 8 years in 10 (55%). (Max. interval four and a half years)	Met or partially met in seven of the last ten years, including in 2019–20 and 2020-21. Low environmental demand in 2021–22, remaining low in 2022–23 if watering occurs.	Low
		Small fresh 2: >314 ML/day (September to April) Minimum duration 14 days	1 to 5 years in 10 (30%) (Max. interval seven years)	Met or partially met in six of the last 10 years, including in 2019–20 and 2020–21. Low environmental demand in 2021–22, remaining low in 2022–23 if watering occurs.	Low
		Large fresh 1: >3,900 ML/day (any time) duration five days	2 to 6 years in 10 (45%). (Max. interval 6.5 years)	Met or partially met in six of the last 10 years, including being partially met in 2019-20 and fully met in 2020–21. Low environmental demand in 2021–22, remaining low in 2022–23 if watering occurs.	Low
		Large fresh 2: >3,900 ML/day (October to April) duration five days.	2 to 5 years in 10 (35%) (Max interval 6.5 years)	Met or partially met in six of the past 10 years, including being partially met in 2019–20 and met in 2020–21. Low environmental demand in 2021–22, remaining low in 2022–23 if watering occurs.	Low
		Large fresh 3: 5,100–18,800 ML/day (any time) duration three days	2 to 7 years in 10 (45%). (Max. interval 5 years)	Met or partially met in five of the last 10 years, including in 2020–21. Moderate environmental demand in 2021–22, moving to low in 2022–23 if watering occurs.	Moderate
		Overbank: >18,800 ML/day (any time) duration three days.	0 to 3 years in 10 (10%). (Max. interval 20 years)	Met in three years in the last 10 years, but not met since 2013–14. High environmental demand, moving to moderate in 2022–23 if watering occurs.	High

Note: All watering history sourced from NSW Department of Planning, Industry and Environment, WaterNSW Water Balance Reports, and data from the following gauge (WaterNSW 2021a): 417001 – Moonie River at Gundablouie.

Key

Environmental demands (demand is considered at a generalised scale; there may be specific requirements that are more or less urgent within the flow regime)

- High to critical demand for water (needed in that particular year or urgent in that particular year to manage risk of irretrievable loss or damage)
- Moderate demand for water (water needed in that particular year, the next year, or both)
- Low demand for water (water generally not needed in that particular year)

Table WMV2 Environmental demands in 2021–22 for the Warrego Valley

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	Environmental demands for water (all sources) in 2021-22
		Flow/volume	Required frequency (maximum dry interval)		
Cuttaburra Creek (at Turra)	Native fish dispersal and condition Native fish spawning and recruitment Native vegetation Aquatic ecosystem function Wetland inundation Waterbird breeding	Small fresh 1: <1,000 ML/d for 23 days (anytime)	4 years in 10	Met or partially met in nine out of the last 10 years, including in 2019–20 and 2020–21. Low environmental demand in 2021–22, remaining low in 2022–23 if watering occurs.	Low
		<20% wetland inundation – foraging and feeding habitat, small breeding of non–colonial species 82,000 ML in 60 days (anytime)	1 to 2 years in 10 (Maximum dry interval three years)	Met in 5 out of the last 10 years including 2019–20, but not met in 2020–21. Low environmental demand in 2021–22, remaining low in 2022–23 if watering occurs.	Low
		50% wetland inundation – small waterbird breeding events may occur 166,000 ML in 90 days	1 to 2 years in 10	Met in 3 out of the last 10 years, including in 2019–20. Not met in 2020–21. Low environmental demand in 2021–22, remaining low in 2022–23 if watering occurs.	Low
Warrego River at Barringun	Native fish dispersal and condition	Small fresh 1: >220 ML/day anytime (ideally October to April) for 10 days (native fish dispersal and condition	Annual	Met or partially met in 9 of the last 10 years, including in 2019–20 and 2020–21. These flows are required annually, therefore the environmental demand is high in both 2021–22 and 2022–23.	High

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	Environmental demands for water (all sources) in 2021-22
		Flow/volume	**Required frequency (maximum dry interval)**		
	Native fish spawning and recruitment Native vegetation Support refuge habitat (frogs, fish, waterbirds) Aquatic ecosystem function		(Maximum dry interval one and a half years)		
		Small fresh 2: 220 to 2,200 ML/day (September to April) for 14 days (spawning of in–channel specialists and generalists)	5 to 10 years in 10 (75% of years). (Maximum dry interval five years)	Met or partially met in 9 out of the last 10 years, including 2019–20 and 2020–21. Low environmental demand in 2021–22, remaining low in 2022–23 if watering occurs.	Low
		Large fresh 1: >2,200 ML/day any time for 5 days	5 to 10 years in 10 (75% of years) (Maximum dry interval four years)	Met or partially met in 6 out of the last 10 years, including being fully met in 2019–20 and partly met in 2020–21. Moderate demand in 2021–22, remaining moderate in 2022–23 if watering occurs.	Moderate
		Large fresh 2: >2,200 ML/day (October to April) for 5 days	4 to 5 years in 10 (40%) (Maximum dry interval five years)	Met or partially met in 6 out of the last 10 years, including being fully met in 2019–20 and partially met in 2020–21 (duration not met). Therefore there is a low demand in 2021–22, remaining low in 2022–23 if watering occurs.	Low
		Overbank flows: >5,400 ML/day any time for 2 days	4 to 5 years in 10 (Maximum dry interval nine years)	Met in 4 out of the last 10 years, including 2019–20 but not met in 2020–21. Moderate demand in 2021–22 reducing to low in 2022–23 if watering occurs.	Moderate
Warrego River (Boera Dam to Darling)	Refuge habitat (waterbirds, frogs, fish) Instream aquatic ecosystems Riparian vegetation In-stream aquatic ecosystems Fish connectivity and movement Riparian vegetation	Flows to replenish refuges and connect to the Darling River.	Annually (Maximum dry interval one year)	Met every year except 2012–13. Required annually, therefore high demand in 2021–22, remaining high in 2022–23 if watering occurs.	High
		In-channel flows: Up to 600 ML/day for minimum 10 days to enable fish passage and movement	Ideally: 5 to 10 in 10 years (Maximum dry interval two years)	Met every year except 2012–13. Moderate environmental demand in 2021–22, moving to low in 2022–23 if watering occurs.	Moderate
Toorale Western Floodplain	Wetland and floodplain vegetation Threatened species (Atriplex infrequens, Dentella minutissima, and Osteocarpum scleropterum) and ecological communities such as coolibah-blackbox woodland Migratory birds (e.g. Eastern great egret; glossy ibis; oriental pranticole; rainbow bee-eater)	Wetland inundating flow(WL1) Minor inundation: Cumulative volume 7,000 ML past Fords Bridge (combined) over 30 days (anytime). Minor inundation to inundate vegetation such as lignum, coolibah, river cooba, chenopod, forbs. Northern and Central parts of the floodplain (2,420 ha)	Preferably: 1 to 1.5 years (lignum); One to three years (river cooba, river red gum, black box); 7 to 15 years (Coolibah). 5 to 10 years in 10 (Maximum dry interval 2 years)	Met in 5 out of the last 10 years, including 2018–19 and 2019–20. Not met in 2020–21. Cumulative volume past Fords Bridge combined between 3 April and 3 May 2021 was almost 12 gigalitres, however all of this water was passed through Boera Dam, meaning minimal wetland inundation occurred (Paul Frazier [2 Rog Consulting] 2021, pers. comm. 11 May). High environmental demand in 2021–22, moving to moderate in 2022–23 if watering occurs.	High
		Wetland inundating flow (WL2) – half inundation: Cumulative volume 16,000 ML past Fords Bridge combined over 30 days. Inundation of around half the floodplain to inundate vegetation such	Anytime Ideally: 4 to 8 in 10 years (Maximum dry interval 3 years)	Met or partially met in five out of the last 10 years, including in 2018–19 and 2019–20. Not met in 2020–21. Moderate environmental demand in 2021–22.	Moderate

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	Environmental demands for water (all sources) in 2021-22
		Flow/volume	**Required frequency (maximum dry interval)**		
	Native fish nursery and frog habitat	as lignum, coolibah, river cooba, chenopod, forbs. (4,459 ha)			
		Wetland inundating flow (WL3) – full inundation: Cumulative volume of 33,000 ML past Fords Bridge combined over 30 days. Inundation of around the full floodplain to inundate vegetation such as lignum, coolibah, river cooba, chenopod, forbs. (7,104 ha)	Any time Ideally: 3 to 6 years in 10 (Maximum dry interval six years)	Met in 3 out of the last 10 years, including in 2019–20. Not met in 2020–21. Moderate environmental demand in 2021–22.	Moderate
		Boom inundation of more than entire Western Floodplain, Uteara lake, reconnections to Darling and return flows to the Warrego. Darling may backup to provide greater inundation. (11,847 ha) 75,000 ML/year to the Western Floodplain to inundate vegetation such as lignum, coolibah, river cooba, chenopod and forbs.	Any time Ideally: 1 to 3 years in 10 (Maximum dry interval 10 years)	Met in two of the last 10 years, including in 2019–20, not met in 2020–21. Low environmental demand in 2021–22.	Low
Darling River (downstream of the junction with the Warrego)	Native fish habitat, movement, refuge and spawning In–stream aquatic ecosystems and riparian vegetation Provides connectivity and movement between Darling and Warrego catchments Support refuge habitat Frog and waterbird habitat and refuge Improve water quality	Darling River is considered a priority (above all other priorities) when conditions in the Darling River at Louth exceed one or more environmental water requirements from the Barwon Darling Long -Term Water Plan: When cease to flow conditions have occurred for more than 110 days; There has been more than 135 days of flow less than 450 ML/day, or; It has been more than one year since a small fresh of at least 1,500 ML/day occurred for at least 10 days as measures at the Louth gauge.	Annually	Refer to Barwon–Darling Plan 2021–22 for a detailed watering history. As of 27 May 2021 nearly 1,255 GL had passed the Louth gauge with flows receding to a rate of 1,619 ML/day. Therefore this demand has been assessed as moderate in 2021–22, remaining moderate in 2022–23 if watering occurs.	Moderate

Note: All watering history sourced from NSW Department of Planning, Industry and Environment and Queensland partner agencies, WaterNSW Water Balance Reports, and data from the following gauges (WaterNSW 2021a and DRDMW 2021a,b): 423005 – Cuttaburra Channel at Turra, 423004 – Warrego River at Barringun, 423001 Warrego River at Fords Bridge, 423002 Warrego River at Fords Bridge Bywash and 425004 – Darling River at Louth.

Key

Environmental demands (demand is considered at a generalised scale; there may be specific requirements that are more or less urgent within the flow regime)

- High to critical demand for water (needed in that particular year or urgent in that particular year to manage risk of irretrievable loss or damage)
- Moderate demand for water (water needed in that particular year, the next year, or both)
- Low demand for water (water generally not needed in that particular year)

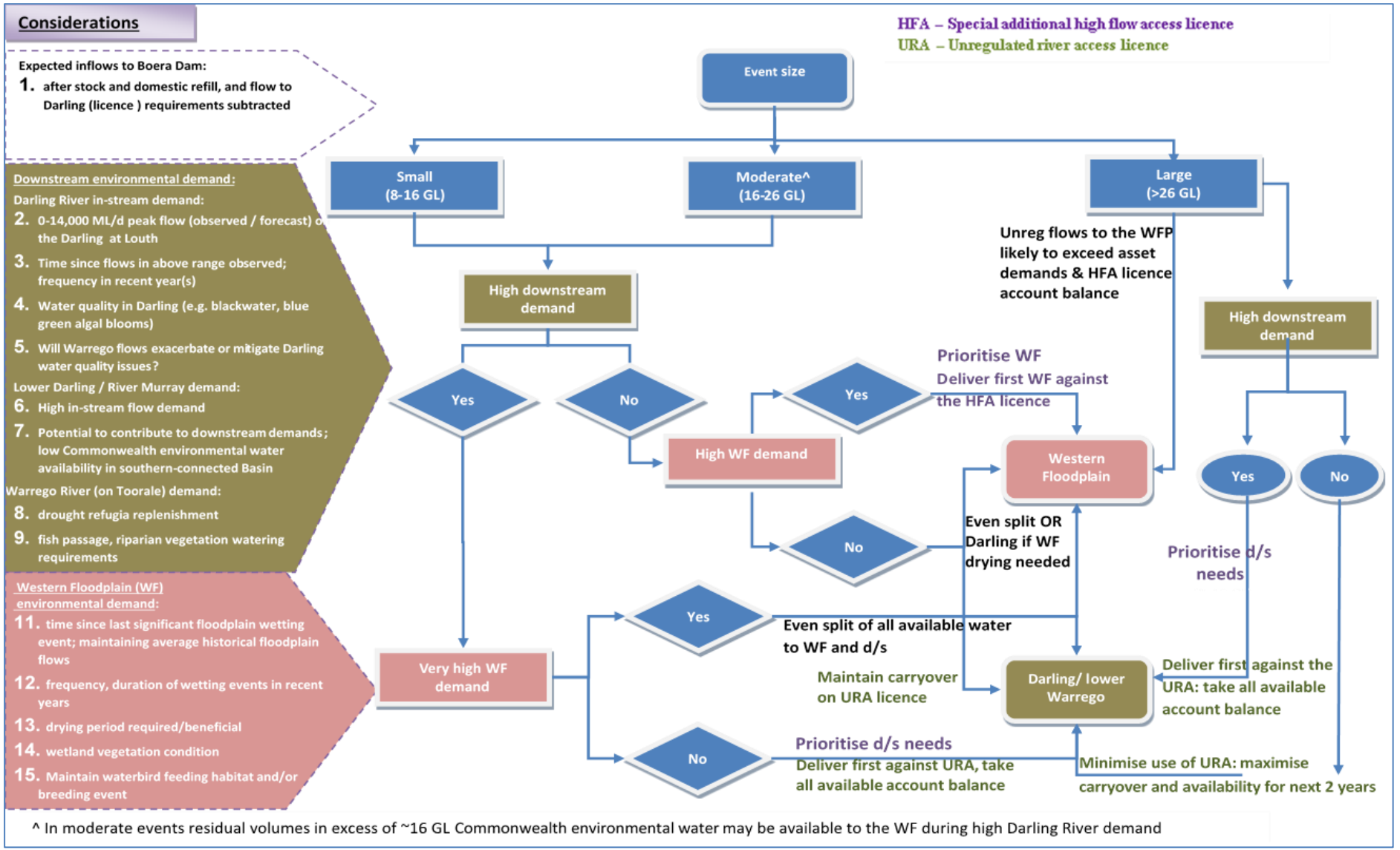
5.5 Water delivery in 2021–22

Commonwealth environmental water entitlements in the Warrego and Moonie are unregulated (or 'unsupplemented' in the Queensland portion of each Valley) and are left instream to contribute to environmental outcomes. In 2021-22, the volumes of Commonwealth environmental water that reach the NSW border will be recorded by Queensland DRDMW on a daily basis. It is expected that the portion of these flows that reaches the Barwon-Darling River will then be protected from extraction by WaterNSW using active management.

The Commonwealth's unregulated holdings on the Warrego River at Toorale are managed in accordance with the management strategy for use of these licences at Boera Dam (Figure WMV1) to meet environmental demands outlined in Table WMV2. The CEWO will have access to the Toorale Warrego River licences in 2021–22. Operation of the Toorale infrastructure will continue to be managed by the NSW National Parks and Wildlife Service and DPIE, in consultation with the Toorale Joint Management Committee and the CEWO. The management strategy will be revised in 2022 upon completion of the Toorale Water Infrastructure project (NSW DPIE 2021).

Further information on environmental demands in the Barwon–Darling is provided in the CEWO Water Management Plan 2021–22: Chapter 9 Barwon–Darling.

Figure WMV1 Management strategy for Commonwealth environmental water at Toorale



5.6 Monitoring and lessons learned

5.6.1 Monitoring

Operational monitoring is undertaken for all Commonwealth environmental watering actions and involves collecting on-ground data about Commonwealth environmental watering such as volumes used, impact on the river systems hydrograph, area of inundation and river levels. It can also include observations of environmental outcomes.

In the Warrego Valley, the five-year Long-Term Intervention Monitoring (LTIM) Project (2013–2014 to 2018–19) included the junction of the Warrego and Darling Rivers as a focus area. It aimed to understand the environmental response from Commonwealth environmental watering with respect to the targeted objectives by carrying out monitoring of site condition over many years.

This monitoring is being continued under the CEWO Monitoring, Evaluation and Research three-year program from 2019–20 to mid-2022.

The CEWO has also co-funded a short-term intervention monitoring project with Queensland DES to better understand native fish resilience following severe drought in the Northern Murray-Darling Basin, including the upper Warrego. Results from this project will be available in early 2022. The CEWO does not currently fund any monitoring in the Moonie Valley.

Learn more about monitoring and research funded by the CEWO in the Warrego and Moonie Valleys.

5.6.2 Lessons learned

Outcomes from monitoring and lessons learned in previous years are a critical component for the effective and efficient use of Commonwealth water for the environment. These learnings are incorporated into the way environmental water is managed.

Key findings from fish, aquatic habitat and flow monitoring in the Warrego and Moonie Valleys are summarised in Table WMV3.

Table WMV3 Key lessons learned in the Warrego and Moonie Valleys

Theme	Lessons learned
Native fish and aquatic invertebrates	• Flows in the Warrego River, including environmental water, support breeding and recruitment of many fish species. During 'wetter' times, multiple species have been observed to breed, recruit and maintain their population structure, e.g. golden perch, spangled perch, bony herring, Hyrtl's tandan (ELA 2019; UNE & 2 Rog Consulting 2020a; Marshall & Lobegeiger 2021). • Golden perch spawn on river rises in the Warrego River, and recruits from within this river system are likely to be contributing to the wider Murray–Darling Basin golden perch population (UNE & 2 Rog Consulting 2020a). The upper Warrego River supports a strong golden perch population, supported by natural spawning and recruitment events. Murray cod are also present in the upper Warrego River, with relatively low carp presence (Marshall & Lobegeiger 2020). • The fish community in the Warrego River are highly resilient and can survive highly variable flow conditions, including drying down. Fish communities were able to recolonise and recruit following larger flow events. Golden perch, spangled perch and bony herring have demonstrated an ability to move, colonise and opportunistically recruit in the Warrego River in response to increased flows (ELA 2019; Marshall & Lobegeiger 2021).

Theme	Lessons learned
	• Retaining water at all times in at least some of the five main waterholes on the Warrego River will ensure that when the system is reconnected, there are populations present that can distribute and recolonise across the lower sections of the Warrego. This helps prepare native fish populations for the next drying phase (ELA 2019; Marshall & Lobegeiger 2021). • The Moonie has relatively long and deep waterholes that have been shown to be critical refugia for sustaining native fish populations in the often-long periods between flows in the system. Species including golden perch, bony bream, eel tailed catfish and smelt moved significant distances (up to 70 kilometres) in response to waterhole reconnecting flows, enabling recolonisation of the system and genetic mixing (Marshall et al. 2016). • The Moonie has also been identified as a source population for golden perch in the Northern Murray–Darling Basin (along with the Condamine–Balonne and Border Rivers) with consistent recruitment over the past decade (Price et al. 2019; Greg Ringwood [Murray–Darling Basin Authority] 2021, pers. comm., 20 May).
Waterbirds	• In the Queensland Warrego River, the Cuttaburra channels represent 10% abundance of each species (one of only four wetlands in the Murray–Darling Basin, with the others being the Lowbidgee, Lower Coorong and Thallon wetlands). The Cuttaburra has been identified as important for waterbirds at a whole-of-Basin scale during wet times (Bino et al. 2015). • Surveys in March 2021 found waterbirds at all sites at Toorale, with the highest bird count at Boera Dam and lower waterbird numbers on the Western Floodplain (UNE & 2 Rog Consulting 2021). Birds detected at Boera included brolgas and the listed migratory species sharp-tailed sandpiper (UNE & 2 Rog Consulting, 2021). Sea eagles were also recorded breeding at Boera Dam in early 2021, unusual in an inland area (UNE & 2 Rog Consulting 2021). • While not recognised as nationally or internationally significant, the Thallon waterholes on the Moonie are important for waterbirds, with representation of 10% abundance for each species between 1983–2012 (only four other wetlands achieved this including the Cuttaburra channels, Lowbidgee and Lower Coorong) (Bino et al. 2015). • Waterbirds tracked by CSIRO Land & Water have been recorded visiting the Moonie Valley in 2020–21 including straw-necked ibis 'Elf' and 'Dani' (CSIRO 2021).
Connectivity	• Environmental water has been observed to successfully increase longitudinal connectivity between the Warrego and Darling rivers, and laterally, with parts of the Western Floodplain (ELA 2019). By increasing connectivity, water for the environment improves water quality, increases available habitat and productivity, and supports native fish movement between rivers (ELA 2019). The resulting productivity booms can also generate an increase in the abundance and diversity of invertebrates, frogs and waterbirds on the floodplain (ELA 2019). • Environmental water can successfully increase the size of flows through the Warrego system, increasing connectivity between the Warrego and Darling rivers (ELA 2019). This is important for improving water quality, increasing productivity and allowing the movement of native fish between rivers for spawning, dispersal and recruitment (ELA 2019). Around 5 gigalitres of water from the Warrego is estimated to have contributed to flows in the downstream Darling in 2020–21 (WaterNSW 2021b). • The Moonie can provide important tributary inflows to the Barwon–Darling during unregulated flow events (around 100 gigalitres in 2020–21) (WaterNSW 2021d). While the Commonwealth's environmental water entitlements in the Moonie are a relatively small proportion of these natural flows, better cross-border accounting arrangements being worked out between Queensland and NSW with input from the Commonwealth will help us track environmental water from the Queensland Moonie into the NSW catchment and downstream to the Barwon–Darling. Active management arrangements in NSW will also provide better protection of the Commonwealth's environmental water in the Moonie and other unregulated Barwon–Darling tributaries.
Water quality	• Water for the environment delivered through the Warrego River consistently helps improve the quality of Darling River water downstream of the confluence (ELA 2019; UNE & 2 Rog Consulting 2020a). Observed improvements include reduced

Theme	Lessons learned
	pH, conductivity, turbidity and algal productivity, and increased nutrient cycling and habitat when compared with periods without environmental water (ELA 2019; UNE & 2 Rog Consulting 2020a).
Food webs/ productivity	• Environmental water that contributes to connection with the floodplain for a long duration (more than six months) stimulates a boom in productivity, which provides food for higher order predators such as waterbirds (ELA 2019; UNE & 2 Rog Consulting 2020a). • The Western Floodplain is important for highly dense and species rich invertebrate communities. More diverse macroinvertebrate communities may offer a wider range of feeding opportunities for higher level consumers such as frogs, fish, waterbirds and other aquatic vertebrates (ELA 2019; UNE & 2 Rog Consulting 2020a). • The Warrego and Western Floodplain are productive systems, species such as shrimps and tadpoles responded quickly to inundation (ELA 2019, UNE & 2 Rog consulting 2020a). Species such as fairy and shield shrimps are known to rely on an egg bank that is desiccation resistant, which may help survival and responsiveness (ELA 2019; UNE & 2 Rog Consulting 2020a; UNE & 2 Rog Consulting 2021).
Vegetation	• The condition of vegetation communities on the Western Floodplain is driven by inundation, which has been enhanced by Commonwealth environmental water (ELA 2019; UNE & 2 Rog Consulting 2020a). Flooding of the Western Floodplain increased the cover and richness of vegetation communities, including annual herbaceous ground cover species (ELA 2019; UNE & 2 Rog Consulting 2020a). Vegetation surveys in early 2021 found groundcover percentage remained low, but most sites had groundcover persistence and relatively high diversity (UNE & 2 Rog Consulting 2021). Floodplain trees were looking healthy in February 2021, with a number of mature river cooba in flower observed along the Western Floodplain (UNE & 2 Rog Consulting 2021). • Lignum condition improved when inundated more frequently. Extended dry periods (greater than two and a half years) on the floodplain resulted in declines in vegetation cover and condition (ELA 2019; UNE & 2 Rog Consulting 2020a), However, lignum condition improved again in response to inundation in 2019 and early 2020 (ELA 2019; UNE & 2 Rog Consulting 2020a). Monitoring of lignum in early 2021 suggested that plant condition decreased as the area dried back following the 2020 flows, however average height and size of plants increased (UNE & 2 Rog Consulting 2021). • Grazing and competition for resources are likely to impact on tree recruitment more than inundation alone (ELA 2019; UNE & 2 Rog Consulting 2020a).
Refuges	• Around 8% of river channels in the Warrego River are estimated as remaining 'wet' during the peak drought of 2018–2020 (Marshall & Lobegeiger 2020). In relation to loss of connectivity, much of the upper Warrego is classed as at 'extreme risk' (100% loss of connectivity flows), with much of the lower part of the catchment at high risk (>70% risk of loss of connectivity flows). Reconnection of these refuge habitats following flows in 2020 and 2021 is likely to allow for movement of native fish (Marshall & Lobegeiger 2020). • Warrego River waterholes act as longer-term refuges for native fish, waterbirds, turtles and frogs (ELA 2019; UNE & 2 Rog Consulting 2020a). Boera and Booka dams provide the most persistent refuges. Environmental water can help replenish and re-connect refuge habitat in the Warrego River and the Darling River near Toorale (ELA 2019; UNE & 2 Rog Consulting 2020a). • The Moonie river has around 8.8% of refuge waterholes that remain wet even during peak drought (for example 2018–2020). This is considerably less than the Border Rivers (at 22%, but more than catchments further west (Warrego and Paroo) (Marshall & Lobegeiger 2020). • Of the 7.6 square kilometres of waterhole habitat that exists in the Moonie River three months after flow (McGregor et al., 2018), only 5% persisted in January 2020 at the peak of the drought, representing 95% habitat loss (Marshall & Lobegeiger 2020).

Theme	Lessons learned
Other aquatic animals	• Surveys in March 2021 found frogs across all sites in the Warrego Selected Area, with Booka Dam having the highest count (mostly desert froglet) (UNE & 2 Rog Consulting 2020b). • Frog species are expected to recover further following the 2020–21 flows in the Warrego catchment. • Large turtles were detected in most dams at Toorale in early 2021. Some turtles exceeded 7 kilograms in weight, which suggests that food resources were still relatively abundant, despite the drier conditions during the first half of the water year (UNE & 2 Rog Consulting 2020b).

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6 Gwydir Valley Water Plan

6.1 Region overview

6.1.1 River valley

Copeton Dam is the major regulated water storage in the system (with a capacity of 1,364 gigalitres). Copeton Dam regulates on a long-term average of approximately 55% of system inflows (MDBA 2012), however, this is highly variable from year to year. Several unregulated tributaries flow into the Gwydir River below Copeton Dam, including the Horton River. These unregulated tributaries can provide significant unregulated flows into the Gwydir River.

In the lower sections of the Gwydir system, reregulating structures at Tareelaroi, Boolooroo and Tyreel manage low to medium flows from the Gwydir River into the Mehi River, Carole Creek and the Lower Gwydir River/Gingham Watercourse. There are also reregulating structures on the Mehi River at Combadello and Gundare, which control low to medium flows between the Mehi and the Moomin and Mallowa creeks.

6.1.2 Traditional Owners

The rivers and wetlands of the Gwydir Valley hold significant spiritual and cultural importance for Aboriginal people. Most of the Gwydir system falls within the traditional lands of the Gomeroi/Kamilaroi people. The Gomeroi is a large Nation, which extends from around Singleton in the Hunter Valley through to the Warrumbungles in the west, and through the Namoi and Gwydir valleys to just over the Queensland border. The eastern headwater around Guyra, Uralla and Tenterfield is the traditional lands of the Anaiwan people. The Commonwealth Environmental Water Office (CEWO) respectfully acknowledges these Nations, their Elders past and present, as the Traditional Custodians of the lands on which this chapter is focused.

6.1.3 Important sites and values

The Gwydir Wetlands (Map GV1) is a terminal wetland in the lower reaches of the Gwydir River and Gingham Watercourse and provide habitat for waterbird species listed under international migratory agreements (JAMBA, ROKAMBA, and CAMBA). Four subsites within the wetlands are listed as a Wetland of International Importance under the Ramsar Convention: Old Dromana on the Lower Gwydir Watercourse and Goddard's Lease; Windella; and Crinolyn on the Gingham Watercourse. The Ramsar subsites contain a range of habitats including large areas of coolibah woodland, water couch, and part of the largest stand of marsh club rush in New South Wales (NSW) (MDBA 2012). These vegetation types have been identified as critical components of the Ramsar subsites that help support its ecological character. The Ramsar subsites were recognised for their important habitat value for waterbirds. In combination with the mosaic of wetlands and floodplain vegetation communities spread across lower Gwydir floodplain, the four Ramsar subsites help sustain up to hundreds of thousands of breeding colonial waterbirds when flooded (MDBA 2012).

Another key asset in the Gwydir River Valley is the Mallowa Wetlands. While it is not Ramsar-listed or as extensive as the Gwydir Wetlands, the Mallowa Wetlands have less lippia (weed) and support a diverse range of wetland and floodplain vegetation, which is representative of the Gwydir River valley's native vegetation (Torrible et al. 2009). The native vegetation of Mallowa

Creek also provides valuable habitat for waterbirds, woodland birds, and other fauna; and prior to river regulation supported large scale waterbird breeding events (Torrible et al. 2009).

The Gwydir River system supports several native fish species identified as threatened in NSW and/or Commonwealth legislation. These include silver perch (critically endangered) and Murray cod (vulnerable) listed under the *Environment Protection and Biodiversity Conservation Act 1999*, and olive perchlet and freshwater catfish (endangered populations), and purple spotted gudgeon (endangered species), listed under the *NSW Fisheries Management Act 1994*.

The Mehi River and Carole Creek connect the network of rivers and creeks within the Gwydir valley to the Barwon-Darling river system. Maintaining connection between these two river networks is important for native fish movement and recruitment. Flows from the Mehi and Carole systems into the Barwon River can provide critical low flows to downstream reaches, which can minimise the length of cease to flow periods. These flows help the survival of native fish and other river dependent fauna species by reconnecting the larger persistent pools and waterholes along the Barwon and Darling rivers. Following the recent drought, connection between the Barwon–Darling river system and its tributaries will be important to ensure the recovery of native fish communities across the northern Basin.

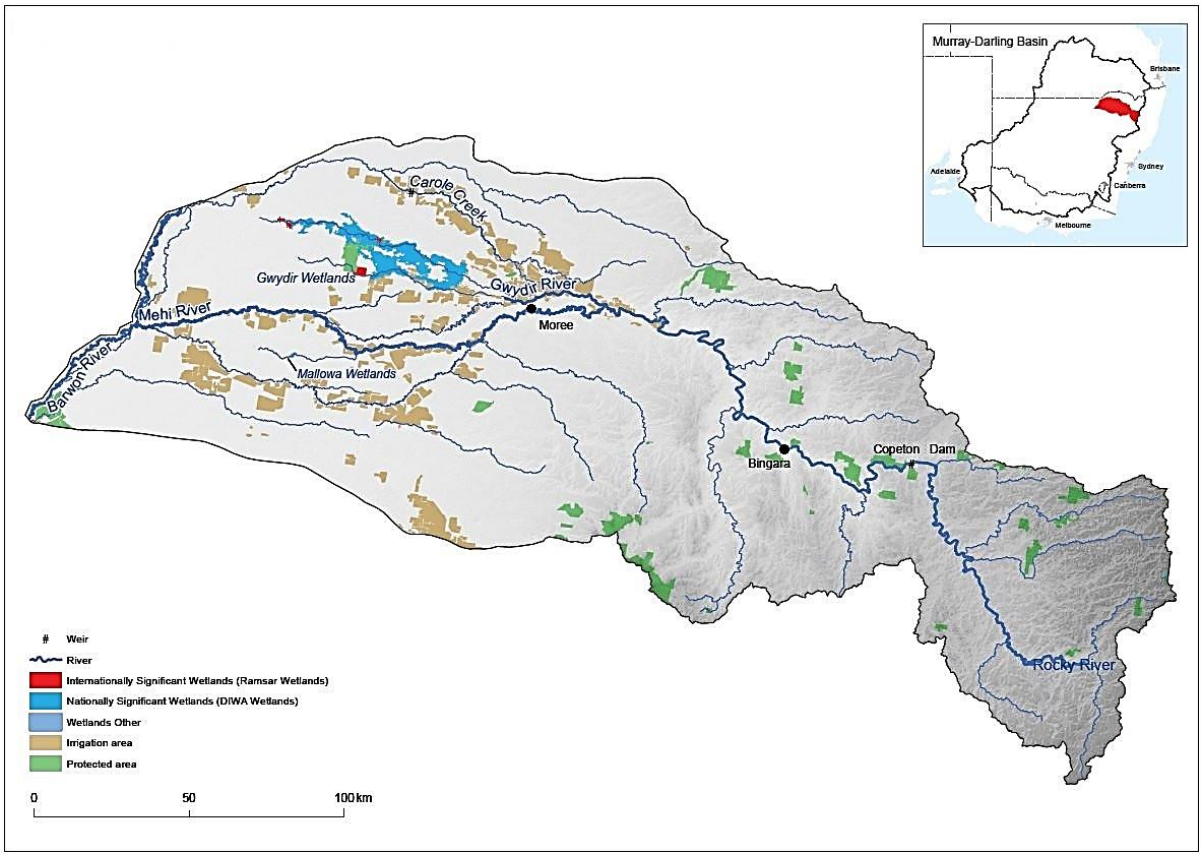
6.1.4 Stakeholder engagement

In the Gwydir River Valley, the planning, management, and delivery of Commonwealth water for the environment is undertaken in conjunction with a range of partners and stakeholder groups. Key stakeholders in the Gwydir include the NSW Department of Planning, Industry, and Environment (DPIE)–Environment, Energy and Science (EES), DPIE–Water, WaterNSW, and the Gwydir Environmental Water Advisory Group (EWAG).

The EWAG provides advice to water managers on priorities for water use and includes representatives from local landholders, Gwydir Valley Irrigators, the local Aboriginal community, independent scientists, and environmental representatives, as well as Government organisations involved in water and environmental management (DPIE–Water, National Parks and Wildlife Service, DPIE–EES, North West Local Land Services, NSW DPI–Fisheries, and WaterNSW).

Local Engagement Officers (LEOs) from the Commonwealth Environmental Water Office (CEWO) also work with a range of stakeholders as part of a broader program of engagement around the management of the Commonwealth's portfolio of environmental water entitlements. As part of this work, CEWO's LEOs engage directly with members of the local Aboriginal community, Local Aboriginal Land Councils (LALCs), and other Aboriginal community groups. This includes working with community around environmental water, to learn and improve on how environmental water may be able to support the local Aboriginal communities' objectives for sites, values, and species significant to the Gomeroi/Kamilaroi Nation in the Gwydir catchment. Engagement with the local Aboriginal community is also being undertaken as part of the current CEWO Monitoring Evaluation and Reporting (MER) Program, which is being undertaken in the Gwydir by the University of New England (UNE) and 2rog (CEWO MER 2020).

Map GV1 Gwydir River Valley



Source: Department of Agriculture, Water and the Environment (2015)

6.2 Environmental objectives

Based on long-term environmental objectives in the Basin Plan, draft state long-term watering plans, site management plans, and best available knowledge, the following objectives are relevant for environmental watering in the Gwydir River Valley.

The objectives that are targeted in a particular year may vary, depending on available water, catchment conditions, operational feasibility, and demand for environmental water. These objectives will continue to be revised as part of the CEWO's commitment to adaptive management. The objectives are:

- Vegetation – Maintain the condition, diversity and extent of riparian, floodplain and wetland vegetation.
- Waterbirds – Increase waterbird abundance and maintain species diversity, and support waterbird breeding events (reproduction and fledging) through to completion.
- Native fish – Support viable populations of threatened native fish and maximise opportunities for range expansion and the establishment of new populations.
- Macroinvertebrates – Support recruitment and maintain macroinvertebrate diversity and habitat.
- Connectivity – Improve flow regimes and increase connectivity in the Gwydir River system, including with the Barwon River, and lateral connectivity between rivers and floodplain.

- Processes/water quality/resilience – Support key ecosystem functions including primary production, decomposition, nutrient and carbon cycling, and the mobilisation and dispersal of biotic/abiotic material; maintain water quality in channels and pools; and maintain drought refuge habitat.

6.3 First Nations environmental watering objectives

The CEWO is committed to working with First Nations groups to better understand their objectives. The CEWO will use environmental flows to contribute to these objectives where possible and where this is consistent with the Commonwealth Environmental Water Holder's statutory responsibility of protecting and restoring environmental assets in the Basin.

As the next steps, CEWO will develop and implement a work program to work with First Nations groups in the northern Basin. The work program will refine and build on the work already undertaken by the Northern LEOs through engagement with members of the local Aboriginal community as part of the Gwydir Case Study (Table GV1). This work program will be developed in collaboration with First Nations groups and will be integral in continuing to build relationships and capacity within First Nations groups. It will also ensure First Nations groups actively participate in the planning and management of environmental flows. Key elements of the program will include:

- Completion of a seasonal calendar in collaboration with Traditional Owners from the Gomeroi nation.
- Working with representatives from the Gomeroi Nation to build on and refine objectives and values identified through the Gwydir Case Study.

Sharing the outcomes from environmental flows with First Nations Groups will be a key step in this process and will include a two-way exchange of knowledge. This information exchange and collaboration will improve the outcomes achieved from providing water for the environment, whilst also ensuring First Nations values are part of the environmental water decision-making and management processes.

Table GV1 First Nations environmental objectives for the Gwydir system

Category	Priority sites and indicator species
River flows and connectivity	Water is life and connects all things, and all things are interconnected; rivers and wetlands need water, need flows; need to care for Country in a physical and spiritual sense; need to look after country and to fulfil cultural obligations; need to look after own mob and for downstream mobs.
Native vegetation	Vegetation species that are resources growing in and along rivers and in wetlands and billabongs, and on floodplains – bush tucker, medicines and cultural practices.
Native birds	Important local indicator species include Brolga, ducks, magpie geese.
Native animals	Look after native fish, both own importance and resource for community; look after the critters, everything needs water, make sure things can survive and live; need to look after critters, care for all as part of whole picture, and to look after totem species and significant species.
Connecting with Country	Sharing stories and knowledge are important to the Gomeroi people and the following assist in doing this: being able to go out on Country to reconnect and share knowledge about landscape and resources, about spiritual and creation stories, and educate the younger generations; connecting to and Caring for Country – opportunities to go out on Country, and obligations to care for

Category	Priority sites and indicator species
	Country. Important values include modified trees, burial sites, scar trees, stone artefacts and a midden site.
Other notable water-dependent sites	Gwydir Wetlands, including the Gingham and Lower Gwydir watercourses and wetlands and significant places in and along these wetlands including Gingham Waterhole, Bunnor Lagoon, Wandoona (Troy) Waterhole and Gin Holes. The Mallowa Creek and its wetlands, including Valetta swamps and wetlands. Moomin Creek sites. Mehi River sites (especially Top and Bottom Camps). Mid-section of the Gwydir River include Gravesend, Elcombe, and Gum Flat. Other lagoons and billabongs including Tillaloo, Baroona Waterholes, the Glen Swamp; Poison Gate (Derra) Billabong; Whittaker's Lagoon and Collymungle.

Source: Heritage Concepts (2009), Hudson Consulting and Woodlots & Wetlands (2009), NSW DECCW (2010) and NSW DPIE 2018). Identified through the Gwydir Case Study.

6.4 Recent conditions and seasonal outlook

6.4.1 Recent conditions and environmental water use

The 2019–20 water year in the Gwydir system began very dry and finished quite wet. Very low falls occurred between July and December 2019. The 2019 calendar year was the driest recorded since 1965. Above average rainfall occurred in January to April 2020, which saw several flows through the full length of the river system. Very heavy rainfall resulted in localised inundation of wetland areas along the lower Gwydir, Ginghams and Mallowa systems in February and March 2020 (BoM 2021c).

Monitoring of refuge pools during spring and summer 2019–20 showed that during no flow periods, water quality and depth within pools declines significantly. Maintaining water quality and depth is important within larger refuge pools to provide native fish species with the best chance of survival during dry times.

Results from monitoring undertaken along the Gwydir River between May to July 2020 showed most native fish species had spawned and recruited in the 2019–20 water year. Whilst the overall numbers of native fish were modest, most individuals sampled appeared in good health. (CEWO MER 2020).

Between April and October 2020, flows across the Gwydir system decreased, with some channels within the lower parts of the system ceasing to flow during September 2020. These cease to flow periods were broken by unregulated flows during mid-October 2020, these flows originating mainly from the Horton River (WaterNSW 2021a).

Over the summer of 2020–21, water for the environment was provided across the Lower Gwydir, Gingham and Mallowa Creek systems, the Mehi and the Barwon River via Carole/Gil Gil creeks. This water complemented natural inflows following widespread rainfall and supported the recovery of wetland areas including the Gwydir Wetlands Ramsar subsites located on 'Old Dromana' and 'Goddard's Lease'. Flows also provided habitat for a range of waterbirds, fish, frogs and turtles. Natural flows in early summer triggered a small waterbird nesting event. Water for the environment was used to help several colonial nesting species finish their breeding.

Waterbird surveys were conducted in February in collaboration with NSW Department of Planning, Industry and Environment (DPIE), NSW National Parks and Wildlife Service (NPWS) and the University of New England (UNE). These surveys recorded around 1,000 magpie geese

in the Gingham watercourse gathering in flocks of 80 to 100, with some establishing nests in the area (DAWE 2021).

In late March 2021, the Gwydir Valley received significant inflows from widespread rainfall. This led to major flooding across much of the Lower Gwydir Floodplain with flows peaking at 10.43 on the Mehi River at Moree and 7.35 metres on the Gwydir River at Yarraman on 25 March 2021. These flows a had a significant impact on communities across the valley. Although supplementary water was available, environmental water managers chose not to participate to minimise further flooding impacts to communities (DAWE 2021).

Following the floods, NPWS and DPIE EES staff observed several large (100+) groups of straw-necked and white ibis, great egrets, intermediate and little egrets, mixed flocks of ducks and lots of cootes and grebes (DAWE 2021).

Learn more about previous Commonwealth environmental water use in the Gwydir catchment.

6.4.2 Seasonal outlook

According to the Bureau of Meteorology outlook in May, above median rainfall is forecast across the Gwydir River Valley from July to September (BoM 2021b). Maximum temperatures are also forecast to remain above average over the coming months (BoM 2021e).

These forecasts suggest weather patterns may help improve the condition of rivers and wetlands in the Gwydir. However, it is also possible that dry conditions may re eventuate over coming months, which may hinder recovery.

6.4.3 Water availability

Commonwealth environmental water is managed in conjunction with other held and planned environmental water managed by NSW. Other flows such as tributary flows, consumptive water and other water orders may also support environmental demands in the Gwydir Valley. As of 30 April 2021, there was 36.8 gigalitres in the Environmental Contingency Allowance (ECA) and 70.6 gigalitres of general and high security Held Environmental Water available out of the 548 gigalitres of active volume in Copeton Dam (NSW DPIE 2021).

The volume of Commonwealth environmental water carried over in the Gwydir River Valley for use in 2021–22 is 59.9 gigalitres. Full (100%) allocation for high security entitlements is expected to be announced at the commencement of the 2021–22 water year, which would add an additional 4.5 gigalitres of water for the environment. As of 20 May 2021, Copeton Dam was at 41% capacity (WaterNSW 2021b).

Based on the expected available volume of environmental water held by the Commonwealth and NSW, as well as recent and forecast catchment conditions, it is expected that the overall resource availability will be moderate in 2021–22. Forecast allocation of regulated (surface water) Commonwealth environmental water in 2021–22 under different water availability scenarios is provided in table 4 of Chapter 2.

Due to the combination of recent flows, moderate storage levels and volumes of environmental water, environmental managers will provide water for the environment in response to natural flow triggers in the 2021–22 water year.

6.4.4 Environmental demands

Considering the prolonged drought conditions and the need to build resilience, and support the recovery of key assets in the Gwydir Valley, there are a number of environmental demands that require water urgently in 2020–21. The environmental water demands for assets in the Gwydir Catchment in 2021–22, are shown in Table GV2.

Table GV2 Environmental demands and watering priorities, 2021–22, and outlook for coming year, Gwydir Valley

Environmental assets	Target values	Indicative demand (for all sources of water in the system)[c]		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	Required frequency (maximum dry interval)		Environmental demands for water (all sources)	Potential Commonwealth environmental water contribution?	Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22
Gwydir Wetlands Areas of Ramsar listed wetlands[a] Nationally significant wetlands Waterbird breeding and habitat Habitat and breeding ground for frogs Native fish habitat Endangered ecological communities Lagoons and wetlands which have important values for the Gomeroi local Aboriginal community. Key sites include: • Old Dromana Wetland • Bunnor Wetland • Gingham Waterhole • Gin Holes	Core wetland inundation Refuge habitat for native fish, waterbirds, frogs and other aquatic species Maintenance and Regeneration of Wetlands Ecosystem function	Small wetland (WL) inundation: WL1 (Protect Core Wetland)[b]: • >6 GL event over 3 to 6 months (Gwydir at Millewa) at any time. • >15 GL event over 1 to 3 months (Gingham at Teralba) at any time. • >15 GL event over 2 to 6 months (Gingham at Tillaloo) at any time. • >3 GL event 1 to 4 months (Gingham at Gingham Bridge) at any time. WL2 (Maintenance and Regeneration of Wetlands)[b]: • >36 GL over 3 to 6 months (Gwydir at Allambie) in Sept to Mar (but can occur at any time). • >30 GL over 1 to 3 months (Gingham at Teralba). • >30 GL over 2 to 6 months (Gingham at Tillaloo) in Sept to Mar (but can occur at any time). • > 15 GL over 1to 4 months (this should have been 2 to 6 months) (at Gingham Bridge).	WL1: 9 to 10 in 10 years (Max. interval: 1 year) WL2: 8 to 9 in 10 years (Max. interval: 2 years)	The Gingham and Lower Gwydir systems experienced moderate flow conditions during 2017–18 with WL1 flow targets at the Millewa in the Lower Gwydir and Teralba, Tillaloo and Gingham Bridge in the Gingham gauges met. During 2018–19 an extended environmental watering event (based on a proactive water delivery strategy) met all WL1 flow targets to be. This inundated most of the core wetlands across both the Gingham and Gwydir systems. Natural flows occurred during Feb–Mar 2020 meeting WL1 flow targets, at Millewa and Teralba. Large parts of core wetlands in the Upper and Central Gingham were inundated, but only a limited area in the Lower Gingham and for a limited duration in areas downstream from Gingham Waterhole. The Goddard's Lease part of the Ramsar site was inundated but flows did not reach the Crinolyn or Windella Ramsar site areas. Most of the Old Dromana Ramsar area and most of the marsh club-rush areas received inundation. The inundation was supported by significant rainfall which fell across much of the lower Gwydir system during February and March 2020. Natural flows occurred over summer and early autumn of 2020–21 completely inundating floodplain areas across the Lower Gwydir and Gingham system. These flows met all wetland demands. Flows necessary to protect core wetlands have occurred 3 to 5 times in the last 5 years, while the flows required to maintain and regenerate wetlands have occurred only 1-2 times in the last 5 years. Therefore the environmental demand has been assessed as high.	High	A high priority for CEW under moderate water resource availability scenarios, subject to occurrence of unregulated flow event and water availability. A combination of entitlements may be used to respond to unregulated flow events, to protect (supplementary) and potentially restore (regulated) parts of a natural flow. Use of supplementary water to protect natural flow. Use will be assessed based on the likelihood of third part impacts.	High
Maintenance and regeneration of floodplain vegetation (including lignum) Waterbird habitat and potential breeding Maintain native fish habitat Ecosystem function	**Large wetland (WL) inundation[b]:** WL3 (Regeneration of Floodplain Vegetation): • >45 GL over 3 to 6 months (Gwydir at Allambie) in Oct to Apr. • >45GL over 1 to 3 months) Gingham at Teralba. • >40 GL over 2 to 6 months (Gingham at Tillaloo) in Oct to Apr. • >20 GL over 1 to 4 months (at Gingham Bridge). **WL4 (Maintenance of Floodplain Vegetation)[b]:** • >65 GL over 2 to 6 months (Gwydir at Allambie) in Aug to Feb (but can occur at any time). • >60 GL over 2 to 6 months (Gingham at Tillaloo) in Aug to Feb (but can occur at any time). • >30 GL over 1 to 4 months (Gingham at Gingham Bridge) in Aug to Feb (but can occur at any time).	WL3: 5–8 in 10 years (Max. interval: 3 years) WL4: 3–5 in 10 years (Max. interval: 5 years)	Dry to very dry conditions persisted during most of the 2017–18, 2018–19 and 2019–20 water years. Flows necessary to support regeneration and maintenance of floodplain flows did not occur. The condition of floodplain vegetation was improved by widespread rainfall, which occurred across the Gingham and Lower Gwydir systems in early 2020. The condition of floodplain vegetation was further enhanced by natural flows which occurred between summer and early autumn of 2020. Flows necessary to support the regeneration and maintenance of floodplain vegetation have only occurred in 1 to 2 of the 5 years. Therefore the environmental demand has been assessed as high.	High	System constraints (identified as part of the package of adopted 'Northern Basin Toolkit measures') will need to be addressed before Commonwealth environmental water can contribute to these demands.	High

Environmental assets	Target values	Indicative demand (for all sources of water in the system)[c]		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	Required frequency (maximum dry interval)		Environmental demands for water (all sources)	Potential Commonwealth environmental water contribution?	Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22
Mallowa Wetlands Waterbird breeding and habitat Habitat and breeding ground for frogs Endangered ecological communities Lagoons and wetlands which have important values for the Gomeroi local Aboriginal community. Key sites include Valetta swamps and surrounding wetlands.	Core wetland inundation Maintain wetland and riparian vegetation condition Ecosystem function	**Small wetland (WL) inundation:** **WL1 (Protect Core Wetland):** >3 GL over 2 to 4 months at the Mallowa Regulator in Oct to Mar (but can occur at any time). **WL2 (Maintenance and Regeneration of Wetlands):** >8 GL over 2 to 4 months at the Mallowa Regulator in Sept to Mar (but can occur at any time).	WL1: 9 to 10 in 10 years (Max. interval: 1.5 years) WL2: 7 to 9 in 10 years (Max. interval: 2 years)	The Mallowa wetlands experienced dry conditions during 2017–18. During 2018–19 an extended environmental watering event (based on a proactive water delivery strategy) met both flow targets, helping to protect, maintain and regenerate core wetland areas. The Mallowa wetlands experienced dry conditions again during 2019–20, with no significant inflows entering the system from the Mehi River. However, several intense high rainfall events across most of the Mehi, Mallowa and Moomin systems in early 2020 provided flows along and into the Mallowa Creek, improving the condition of wetlands across the Mallowa system. High flows and use of Commonwealth supplementary entitlements during summer and early autumn met both flow targets during the 2020–21 water year. Flows necessary to protect core wetlands have occurred 3 times in the last 5 years, while the flows required to maintain and regenerate wetlands have occurred only 2 times in the last 5 years. Therefore the environmental demand has been assessed as high.	High	A high priority for CEW under moderate water resource availability scenarios, subject to occurrence of unregulated flow event and water availability. A combination of entitlements may be used to respond to unregulated flow events, to protect (supplementary) and potentially restore (regulated) parts of a natural flow. Use of supplementary water to protect natural flow. Use will be assessed based on the likelihood of third part impacts.	High
	Maintain native vegetation condition (including lignum) Waterbird habitat and potential breeding Native fish Ecosystem function	**Large wetland (WL) inundation:** WL3 (Regeneration of Floodplain Vegetation): >15 GL over 2 to 4 months at the Mallowa Regulator in Oct to Apr. **WL4 (Maintenance of Floodplain Vegetation):** >22 GL over 2 to 6 months at the Mallowa Regulator in Aug to Feb (but can occur at any time).	WL3: 5 to 7 years in 10 (Max. interval: 3 years) WL4: 3 to 5 years in 10 (Max. interval: 5 years)	Like wetland systems, floodplain areas within the Mallowa system experienced dry conditions during 2017–18. During 2018–19 an extended environmental watering event (based on a proactive water delivery strategy) met the flow target for regeneration of floodplain vegetation. As noted above, dry conditions in 2019–20 resulted in no significant inflows entering the Mallowa system. However, widespread rainfall across the Mallowa Creek system in early 2020 improved the condition of floodplain vegetation communities. Heavy local rainfall and high flows along the Mehi River helped to inundate large sections of the Mallowa floodplain, however the duration of floodplain inundation was shorter than required to assist in the regeneration and maintence of floodplain vegetation. Flows to support the regeneration of floodplain vegetation have only occurred once in the last three years but have not reached the maximum interval between events. Flows to support the maintenance of floodplain vegetation require natural flow events to occur to enable it to be achieved. This demand has not been met in the last 5 years. Therefore the environmental demand has been assessed as high.	High	Use of Commonwealth supplementary water to protect natural flow. Use will be assessed based on demands and the likelihood of third party impacts	High

Environmental assets	Target values	Indicative demand (for all sources of water in the system)[c]		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	Required frequency (maximum dry interval)		Environmental demands for water (all sources)	Potential Commonwealth environmental water contribution?	Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22
Carole Creek Waterbird habitat and refuge Habitat and refuge for frogs Native fish habitat, breeding, recruitment and refuge Aquatic communities	Native fish dispersal and condition Native fish spawning (in-channel specialists and generalists, e.g. Murray cod) Maintain native vegetation condition Aquatic ecosystem function	**Small fresh (SF):** SF1: >200 ML/d for at least 10 days on the Carole near Garah, in Oct to Apr (but can occur at any time) (native fish condition and dispersal). SF2: 200 to 900 ML/d for at least 14 days on the Carole near Garah, in Sept to Apr (spawning of in-channel specialists and generalists)	SF1: Annually (Max. interval: 1 year). SF2: 5 to 10 in 10 years (Max. interval: 2 years).	The Carole Creek system experienced dry conditions during both 2018–19 and the initial parts of the 2019–20 water years, with no significant inflows entering the system for extended periods. During this period environmental water delivery focused on low flows to maintain drought refuges. Natural flows occurred during Feb and Mar 2020 and met the small fresh 1 flow target, but were insufficient to meet the small fresh 2 flow target. High flows and use of Commonwealth entitlements during summer and early autumn enabled both flow targets to be met during the 2020–21 water year. The small fresh 1 flow target has been met in 4 of the last 5 years, while the small fresh 2 flow target has been met in 3 of the last 5 years. Therefore the environmental demand has been assessed as low to moderate.	Low to Moderate	A secondary priority for CEW under moderate water resource availability scenarios. Use of supplementary water to protect natural flow may be considered. Use will be assessed based on the likelihood of third party impacts.	Low to Moderate
		Small fresh (SF3): SF3:> 45 ML/d for at least 10 days on the Gil Gil at Galloway, in Oct to Apr (but can occur at any time) (native fish condition and dispersal).	Within 12 months of a flow >750 ML/day on the Gil Gil at Galloway (end of system gauge) for at least 5 days.	This flow target is closely aligned to the occurrence of large natural flows. The combination of a large natural flows followed by a small fresh only occurred in 2 of the last 5 years (2019–20 and 2020–21). Natural flows along the Gil Gil Creek during Mar 2021 achieved a flow of 750 ML/d for more than 5 days at Galloway. Provision of a small fresh during spring to summer in 2021–22 would provide native fish with an opportunity to move between the Gwydir and Barwon Rivers. This environmental demand has been assessed as moderate.	Moderate	Use of Commonwealth supplementary water to protect natural flow. Use will be assessed based on demands and the likelihood of third party impacts.	Low to Moderate
		Large fresh (LF): LF1: >900 ML/d for at least 5 days on the Carole near Garah, in Jul to Sept (but can occur at any time) (native fish condition and dispersal). LF2: >900 ML/d for at least 5 days on the Carole near Garah, in Oct to Apr.	LF1: 5–10 years in 10 (Max. interval: 2 years). LF2: 3–5 years in 10 (Max. interval: 4 years).	Flow targets for large freshes along Carole Creek require large unregulated flows. Flows occurring in February 2020 and March 2021met both targets, however these targets have not been met outside these two periods. Therefore the environmental demand is still low to moderate.	Low to Moderate	A secondary priority for CEW under moderate water resource availability scenarios. Use of Commonwealth supplementary water to protect natural flow may be considered. Use will be assessed based on the demands and the likelihood of third party impacts.	Low to Moderate
Mehi River Waterbird habitat and refuge Habitat and refuge for frogs Native fish habitat, breeding, recruitment and refuge Aquatic Communities Reaches within the system contain important values for the Gomeroi local Aboriginal community	Native fish dispersal and condition Native fish spawning (in-channel specialists and generalists, e.g. Murray cod) Maintain native vegetation condition Aquatic ecosystem function	**Small fresh (SF):** SF1: for at least 10 days in Oct–Apr (but can occur at any time) for native fish condition and dispersal • >345 ML/d at Moree • >220 ML/d d/s Combadello • >100 ML/d d/s Gundare SF2: in Sept–Apr (spawning of in-channel specialists and generalists) • 345 to 2 800 ML/d at Moree for at least 10 days • 220 to 1 500 ML/d d/s Combadello for at least 14 days • 100 to 850 ML/d d/s Gundare for at least 14 days	SF1: Annually (Max. interval: 1 year). SF2: 5 to 10 in 10 years (Max. interval: 2 years).	Flow targets for small fresh flows (both SF1 and SF2) were met at Moree in each of the last 5 water years. Flow targets to support native fish condition and dispersal (SF1) have also been met downstream of Combardello and Gundare weirs in each of the last 5 water years. Flows required to support spawning of in-channel specialists and generalists (SF2) have been met downstream of Combardello and Gundare weirs in 4 of the last 5 years. Therefore the environmental demands is assessed as low.	Low	A secondary priority for CEW under moderate water resource availability scenarios. Use of Commonwealth supplementary water to protect natural flow may be considered. Use will be assessed based on the demands and the likelihood of third party impacts.	Low

Environmental assets	Target values	Indicative demand (for all sources of water in the system)[c]		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	**Required frequency (maximum dry interval)**		**Environmental demands for water (all sources)**	**Potential Commonwealth environmental water contribution?**	**Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22**
Gwydir River Downstream of Copeton Dam Native fish habitat, spawning and recruitment In-stream aquatic ecosystems Reaches within the system contain important values for the Gomeroi local Aboriginal community		**Small fresh (SF):** SF3: >90 ML/ Mehi near Collarenebri for at least 10 days in Oct to Apr (but can occur at any time) (native fish condition and dispersal).	Within 12 months of a flow >800 ML/day near Collarenebri for at least 5 days.	This flow target is closely aligned to the occurrence of large natural flows. The combination of a large natural flows followed by a small fresh only occurred in 3 of the last 5 years (2016–17, 2019–20 and 2020–21). Natural flows along the Mehi River during Mar 2021 achieved a flow of 800 ML/d for more than 5 days near Collarenebri. Provision of a small fresh during spring to summer 2021–22 would provide native fish with an opportunity to move between the Gwydir and Barwon Rivers. This environmental demand has been assessed as moderate.	Moderate	Use of Commonwealth supplementary water to protect natural flow. Use will be assessed based on the demand and likelihood of third party impacts.	Low to Moderate
	Native fish dispersal and condition Native fish spawning (flow specialists, e.g. golden perch) Maintain native vegetation condition Frog breeding Aquatic ecosystem function	**Large fresh (LF):** LF1: for at least 5 days in Jul–Sept (but can occur at any time) for native fish condition and dispersal. >1 500 ML/d d/s Combadello >850 ML/d d/s Gundare LF2: for at least 5 days in Oct to Apr for spawning of flow specialists >1 500 ML/d d/s Combadello >850 ML/d d/s Gundare	LF1: 5 to 10 in 10 years (Max. interval: 2 years). LF2: 3 to 5 in 10 years (Max. interval: 4 years).	Flow targets for large fresh flows for native fish condition and dispersal were met downstream of Combardello and Gundare weirs in 3 of the last 5 years. Flow targets for large fresh flows for spawning of flow specialists were met downstream of Combardello and Gundare weirs in 2 of the last 5 years. The environmental demand has been assessed as low to moderate.	Low to Moderate	A secondary priority for CEW under moderate water resource availability scenarios. Use of Commonwealth supplementary water to protect natural flow may be considered. Use will be assessed based on the demand and likelihood of third party impacts.	Low to Moderate
	Maintain refuge habitat Native fish survival Aquatic ecosystem function	**Very low flow:** >30 ML/d for at least 200 days at Gravesend. May occur at any time.	Annually (Max. interval: 1 year).	The very low flow target is generally met by water delivered for a variety of purposes and has been met in 4 out of the last 5 years. Therefore the environmental demand has been assessed as low to moderate.	Low to Moderate	Environmental water for other actions could contribute to these demands.	Low to Moderate
	Native fish movement, condition and recruitment (in-channel specialists and generalists, e.g. Murray cod) Native vegetation Aquatic ecosystem function	**Baseflow (BF):** BF1: >440 ML/d for at least 160 days at Gravesend, at any time (native fish movement and condition). BF2: >440 ML/d at Gravesend for at least 100 days in Sept to Mar (recruitment of in-channel specialist and generalists).	BF1: Annually (Max. interval: 1 year). BF2: 5 to 10 in 10 years (Max. interval: 2 years).	The combination of timing and duration of required flows means that water for consumptive and environmental use as well as operational flows is required to meet the baseflow target. Recent drought conditions mean that baseflow targets have only been met 2 out of the last 5 years. Therefore the environmental demand is assessed as moderate.	Moderate	Copeton Dam can regulate a high proportion flows from upstream systems. Demand unable to be met at desired frequency.	Moderate
	Native fish dispersal and condition Native fish spawning (in-channel specialists and generalists, e.g. Murray cod) Native vegetation Aquatic ecosystem function	**Small fresh (SF):** SF1: >990 ML/d at Gravesend for at least 10 days in Oct–Apr (but may occur at any time) (native fish condition and dispersal). SF2: 990–8 600 ML/d at Gravesend for at least 14 days in Sept–Apr (spawning of in-channel specialists and generalists)	SF1: Annually (Max. interval: 1 year) SF2: 5–10 in 10 years (Max. interval 2 years)	Flow targets for small fresh flows to support native fish condition and dispersal (SF1) were met in each of the last 5 water years. Flows required to support spawning of in-channel specialists and generalists (SF2) have been met in 4 of the last 5 years. Therefore the environmental demands is assessed as low.	Low	Environmental water for other actions could contribute to these demands.	Low

Table GV3 Contingency Watering Actions

Refuge pools along the Gwydir and upper Mehi Rivers as well Carole Creek Refuge habitat Native fish Water quality	Maintain critical drought refuge habitat Native fish maintenance and survival	Up to 14 GL **Triggers** 0 ML/d on the Gwydir River at Yarraman **Mehi River** 0 ML/d on the Mehi River at Moree **Carole Creek** 0 ML/d on Carole Creek near Garah	Cease to flow period should not exceed: 30 to 60 days (depending on conditions) on the Gwydir at Yarraman 40 to 80 days (depending on conditions) on the Mehi River at Moree 40 to 80 days (depending on conditions) on Carole Creek near Garah	The Northern Connectivity Event in April–May 2018 and the Northern Fish Flow April to June 2019 contributed to meeting this demand in key reaches (mainly in the Mehi and to a lesser extent in the Carole). Reflecting the extremely dry conditions that persisted through most of 2018–19 and 2019–20, environmental water was delivered to protect critical aquatic and fish refuge habitat in the Gwydir, Carole and Mehi systems to help meet this demand between Oct 2019 and Jan 2020. Late winter and early spring 2021 received below average to very much below average rainfall leading to a number of river reaches across the lower Gwydir ceasing to flow. Cease to flow periods were broken by natural flows originating from unregulated tributaries. This environmental demand is assessed as moderate.	Moderate	Environmental water for other actions could contribute to these demands. Using regulated environmental water entitlements, respond to extended dry periods to protect critical refuge habitat.	Moderate
Gwydir, and Gingham, and Mallowa systems Bird breeding	Support waterbird breeding events	5–15 GL	Respond to naturally triggered bird breeding, if required	Colonial waterbird breeding action has not been triggered in the past 7 years and requires large scale natural flows event to trigger. This environmental demand is assessed as moderate.	Moderate	Using regulated environmental water entitlements, respond to extended period of floodplain inundation to sustain bird breeding.	Moderate
Lower Gwydir, Gingham, Mehi and Carole Water Quality	Native fish maintenance and survival Maintain water quality within acceptable limits	Up to 5 GL	Respond to declining water quality following extended dry periods	This action has not been implemented over the last 5 years.	Moderate	Using regulated environmental water entitlements, respond to declining water quality.	Moderate
Barwon-Darling Connectivity Events	Maintain water quality within acceptable limits Native fish maintenance and survival	5 -25 GL	Respond to declining water quality following extended dry periods	The Northern Connectivity Event in April–May 2018, the Northern Fish Flow in April–June 2019 and the Northern Waterhole Top-up in January–February contributed to meeting this requirement. This environmental demand is still assessed as moderate as water may be needed this year or next.	Moderate	Using regulated environmental water entitlements, respond to declining water quality.	Moderate
Ballin Boora Riparian Areas In-channel and riparian habitat Aquatic communities	Water bird habitat and refuge Habitat and breeding ground for frogs Native fish habitat	600–1 200 ML event delivered at 10–50 ML/d (via infrastructure) for 12–120 days	Frequency subject to further examination Est. Max. interval: 3 years	Environmental flows were delivered for the first time to the Ballin Boora system during 2018–19. The Ballin Boora ran from local runoff following localised intense heavy rainfall several times in Feb–March 2020 (local landholder feedback as per Mallowa). Heavy local rainfall and high flows along the Mehi River in March 2021 helped to inundate large sections of the Ballin Bora system. Therefore this environmental demand is assessed as low.	Low	A low priority for CEW under given recent flows.	Low

Note: Data and information from NSW Department of Planning, Industry and Environment and WaterNSW realtimedata website (WaterNSW 2021a) has informed the watering history in this table. A) Four sites in the Lower Gwydir and Gingham are internationally recognised under the Ramsar Convention and other international agreements for migratory species and for their special habitat value for waterbirds. These are Old Dromana on the Lower Gwydir system as well as Goddard's Lease, Windella and Crinolyn on the Gingham Watercourse. The primary ecological features of the wetlands include large areas of coolibah woodland, water couch and marsh club-rush. By maintaining this wetland vegetation, other critical components of the Ramsar site may be supported, including waterbird breeding and foraging habitat. B) The Gwydir Long-Term Water Plan (NSW DPIE 2020a) describes the environmental water requirements (EWRs) needed to achieve the specified ecological objectives. The EWR's defined within the Gwydir Long Term Water Plan have been used to inform indicative environmental demands for key assets located within the Gwydir system. C) Volumes are net of any irrigation deliveries

Key

Potential watering in 2021–22

- High priority for Commonwealth environmental watering (likely to receive water even under low water availability)
- Secondary priority for Commonwealth environmental watering (watering to occur only if natural trigger is met, or under moderate – high water resource availability); or water demand likely to be met via other means
- Low priority for Commonwealth environmental watering (under high – very high water resource availability); or unable to provide water because of constraints or insufficient water

Environmental demands (demand is considered at a generalised scale; there may be specific requirements that are more or less urgent within the flow regime)

- High to critical demand for water (needed in that particular year or urgent in that particular year to manage risk of irretrievable loss or damage)
- Moderate demand for water (water needed in that particular year, the next year, or both)
- Low demand for water (water generally not needed in that particular year)

6.5 Water delivery in 2021–22

It is preferred to use natural flow triggers for a 'reactive' or responsive use of environmental water in the Gwydir system. Reactive use of environmental water can be in response to dry flow patterns leading to extended cease to flow periods or in response to rainfall and unregulated (natural) flow events.

Where a 'reactive' approach is insufficient to achieve inundation of a priority wetland and floodplain system in a three-year period, a 'proactive' approach is applied. Proactive environmental watering involves the delivery of a larger volume of environmental water to support the continued health of the wetlands. A proactive approach reflects the available water, constraints, and modifications of the system.

Based on the demand for water for the environment, water availability (supply), and catchment conditions, the overall purpose for managing Commonwealth water for the environment in the Gwydir River Valley in 2021–22 is to:

- Maintain the long-term condition of core wetland and riparian areas.
- Enhance connection between the Barwon and Gwydir systems.
- Protect the health and resilience of aquatic ecosystems.
- Avoid damage or loss of significant communities and species.

Consistent with the demands and purpose identified, the CEWO is considering supplying water for the environment for the following actions in 2021–22.

Within the confines of environmental water availability during 2020–21, deliver water in the following ways:

- Commonwealth water for the environment is likely to be provided to restore the condition of core wetland and riparian areas along Mallowa Creek.
- Should unregulated tributary flows enter the Gwydir River upstream of Pallamallawa, NSW and Commonwealth water for the environment may be used to restore the condition of core wetland and riparian areas in the lower parts of the Gwydir system, including along the Lower Gwydir and Gingham watercourses and Carole Creeks.

  Four sites in the Lower Gwydir and Gingham are internationally recognised under the Ramsar Convention, these are Old Dromana on the Lower Gwydir as well as Goddard's Lease, Windella and Crinolyn on the Gingham Watercourse. This watering action would seek to support the values of the Ramsar site by maintaining condition of wetland communities, including water couch and marsh club-rush communities within the Old Dromana and Goddard's Lease sites.
- Should unregulated tributary flows enter the Mehi River and Carole Creek, Commonwealth supplementary entitlements may be used to enhance connection between the Barwon and Gwydir systems. Use will be assessed based on the environmental demands and the likelihood of third party impacts.
- Should dry conditions return and rivers and creeks across the lower part of the system stop flowing, NSW and Commonwealth water for the environment would be used to maintain the

condition of drought refuges across the lower Gwydir system pools. Refuges along the Gwydir River between Tareelaroi weir and Brageen Crossing as wells as the Mehi River upstream of Combadello and Carole Creek upstream of the Garah gauge would be the focus of this watering action.

As in previous years, the use of Commonwealth and NSW environmental water in the Gwydir River Valley will be adaptively managed throughout 2021–22, in response to changing water resource availability and environmental conditions and demands.

6.6 Monitoring and lessons learned

6.6.1 Monitoring

Monitoring and evaluation are key elements of the CEWO's response to the requirements of the Water Act and Basin Plan. They support improved decision-making through the application of adaptive management principles. Monitoring and evaluation are critical steps in the management of Commonwealth environmental water; supporting the efficient and effective use of Commonwealth environmental water within the planning framework and demonstrating the achievement of environmental objectives.

The Monitoring, Evaluation and Research (MER) Program (previously the Long-Term Intervention Monitoring Project 2014–2019) has sites in the Gwydir River Valley. In particular, the program focuses on the Lower Gwydir and Gingham Watercourse wetlands, sections of the Mehi River, the Mallowa Creek and wetlands, and the Gwydir River downstream of Copeton Dam. The MER program is completed jointly with NSW DPIE – EES with support from NPWS for the monitoring of vegetation and waterbirds. The MER program aims to understand the environmental response to Commonwealth environmental watering over a number of years, to help inform future water management.

Learn more about monitoring activities funded by the CEWO in the Gwydir Catchment.

Monitoring information is also provided by NSW agencies, including NSW DPIE – EES (vegetation, waterbirds and frogs), NSW DPI – Fisheries (native fish), and WaterNSW (hydrology and flow delivery data) (WaterNSW 2021a).

6.6.2 Lessons learned

Outcomes from monitoring and lessons learned in previous years are a critical component for the effective and efficient use of Commonwealth water for the environment. These learnings are incorporated into the way environmental water is managed.

Key findings from water delivery and monitoring in the Gwydir Catchment are summarised in Table GV4.

Table GV4 Key lessons learned in the Gwydir River Valley

Theme	Lessons learned
Native fish	• The fish population in the Gwydir River system remains under stress, with many native species and endangered species in low abundance. This may reflect the carrying capacity of the system in its current state. While some species appear to be breeding and recruiting, others, especially some of the more iconic species such as golden perch, freshwater catfish and Murray cod, are not recruiting sufficiently to improve their populations. • Flow events delivered earlier in the water year (winter/spring) improve water quality, stimulate fish to move through the system and encourage the development of diverse invertebrate communities. Primary and secondary production during flows at this time of year are limited by colder water temperatures. • Along with providing environmental flows, other options such as habitat rehabilitation, restocking and barrier remediation should be considered to improve fish community condition.
Vegetation	• Delivery of water for the environment, in combination with natural inflows, has been effective in improving the extent and condition of wetland vegetation. In particular, water couch-spike rush meadows, cumbungi and marsh club-rush tall sedgelands and wetland areas of coolibah woodlands have benefited from watering. These areas are key to maintaining the ecological character of Ramsar sites within the Gwydir.
Wetlands	• Providing flows to wetlands in the Gwydir system promotes invertebrate production and supports waterbird populations and vegetation condition. • While small frequent flows to the Gingham and Lower Gwydir wetlands can occur both from protected portions of natural flows and small deliveries of water for the environment, these small flows tend to only reach into the more eastern portions, and do not result in effective inundation of the central and western portions of wetlands in the Gingham and Lower Gwydir. A larger volume event, be it by natural flooding or a larger delivered volume from dam accounts is required at least once every three years to preserve and conserve the water dependent assets over time. The Mallowa wetlands rely almost solely on environmental water deliveries for all inflows except for inflows that occur from the larger natural flooding events. • While it is preferred to use natural flow triggers for a 'reactive' use of water for the environment to inundate the east, central and western portions of the wetlands in the western Gwydir catchment, it is important to ensure that the wetlands within valley receive water across their entire length at least once every three years. Where a 'reactive' approach is insufficient to achieve inundation in the three-year period, a 'proactive' approach, involving the use of a larger delivered volume from dam accounts into the wetlands, is then undertaken to ensure the continued health of the wetlands. This proactive approach reflects the available water, constraints and modifications of the system. Larger scale proactive environmental watering in 2014–15 and 2018–19 successfully contributed to the recovery of wetland vegetation in the Lower Gwydir and Gingham Watercourses. The Old Dromana and Goddard's Lease Ramsar sites, can be successfully inundated with a large-scale proactive watering action (60 gigalitres with around 30 gigalitres each to the Gingham and Lower Gwydir), helping to support areas of coolibah woodland, water couch, cumbungi and marsh club-rush.
Ramsar sites	• Four sites within the wetlands are listed as a Wetland of International Importance under the Ramsar Convention: Old Dromana on the Lower Gwydir Watercourse, and Goddard's Lease, Windella and Crinolyn on the Gingham Watercourse. The inundation extent achieved by environmental water deliveries varies between the four Ramsar parcels. • Environmental water deliveries during the 2018–19 water year effectively inundated the two upstream Ramsar parcels on Old Dromana and Goddard's Lease. However, environmental water deliveries did not spill into the wetland areas located on Crinolyn and Windella but continued past these sites and reached Morialta Road downstream. These deliveries have demonstrated that while the upstream Ramsar parcels can be watered relatively easily, the two downstream sites require higher flow rates and/or remediation works are required to enable environmental water to flow out onto the wetlands at the Crinolyn and Windella parcels.
Productivity	• Flows delivered over the summer/autumn period tend to improve water quality and promote primary and secondary production. This supports animals further up the food chain such as fish, frogs and waterbirds.

Theme	Lessons learned
Connectivity	• Connectivity between Gwydir and Barwon rivers can be achieved using water for the environment, and is important for supporting native fish habitat, and allowing the movement of native fish between rivers for spawning, dispersal and recruitment. • The Northern Connectivity Event, Northern Fish Flow and Northern Waterhole Top-up delivered from the Gwydir via the Mehi River and/or Carole Creek systems into the Barwon-Darling system during the 2017–18 and 2018–19 and 2020–21 water years were critical actions. These events reconnected channel habitats and promoted fish movement among the channels of the lower Gwydir system via the Mehi and Carole and between the Gwydir and Baron Darling systems. Protecting environmental water delivered in these events from extraction was essential for success. During the 2020–21 water year active management arrangements were implemented in the Barwon–Darling for the first time. These arrangements enabled held environmental water delivered from the Gwydir and Border Rivers systems (as part of the Northern Waterhole Top-up) to be protected from extraction as it flowed along the Barwon–Darling.
Other	• The principle management strategies employed in the lower sections of the Gwydir system of multi-year wetting and drying and using multiple flow types to target a range of wetland and channel outcomes, is helping to sustain the ecology of the system.

Source: CEWO MER (2020) & Eco Logical (2019)

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7 Namoi Valley Water Plan

7.1 Region overview

7.1.1 River system

The Namoi River Valley is located in northern New South Wales (NSW), extending from the Great Dividing Range near Tamworth west to the low-lying alluvial floodplains that connect to the Barwon–Darling River near Walgett (Map NV1). River flows are heavily influenced by rainfall in the upper catchment, which can be highly variable between years.

The Namoi River is the primary riverine asset in the Valley and a major tributary of the Barwon River. Major tributaries of the Namoi River include Cox's Creek and the Mooki, Manilla, McDonald and the Peel Rivers, which join the Namoi River upstream of Boggabri. Baradine and Bohena Creeks join downstream of Boggabri. Flows are confined in-channel until the floodplain begins to broaden at Gunnedah. Major distributary channels on the alluvial plains include Narrabri, Pian and Gunidgera Creeks. Two major storages, Keepit Dam (capacity 425 GL) on the Namoi River (WaterNSW 2021a), and Split Rock Dam (capacity 397 GL) on the Manilla River (WaterNSW 2021b), regulate streamflow in the Namoi River Valley. A number of smaller weirs downstream of Keepit Dam on the Namoi River also regulate catchment water supplies.

The Peel River is a major regulated tributary to the Namoi River, joining slightly downstream of Keepit Dam. Major tributaries of the Peel River are Goonoo Goonoo Creek, the Cockburn River and Dungowan Creek. Flows in the Peel River are regulated out of Chaffey Dam (capacity 100 GL) (WaterNSW 2021c).

7.1.2 Traditional Owners

The rivers of the Namoi River Valley hold significant spiritual and cultural importance for Aboriginal people. The Namoi and Peel rivers are within the traditional lands of the Gomeroi/Kamilaroi people (MDBA 2021). The Commonwealth Environmental Water Office (CEWO) respectfully acknowledges these Nations, their Elders past and present, as the Traditional Custodians of the lands on which this chapter is focused.

7.1.3 Important sites and values

The Peel and Namoi rivers support numerous species listed as vulnerable, endangered or critically endangered under the *Environment Protection and Biodiversity Conservation Act 1999*, including Murray cod, silver perch, freshwater catfish, purple spotted gudgeon, olive perchlet, (NSW DPI 2021). Freshwater mussels are also present in the Namoi River Valley (Murphy & Shea 2013). Riverine vegetation in the Namoi River Valley includes river red gums, coolibah black box endangered ecological community, rough-barked apple, river oaks and emergent aquatic plants (NSW DPIE 2020a).

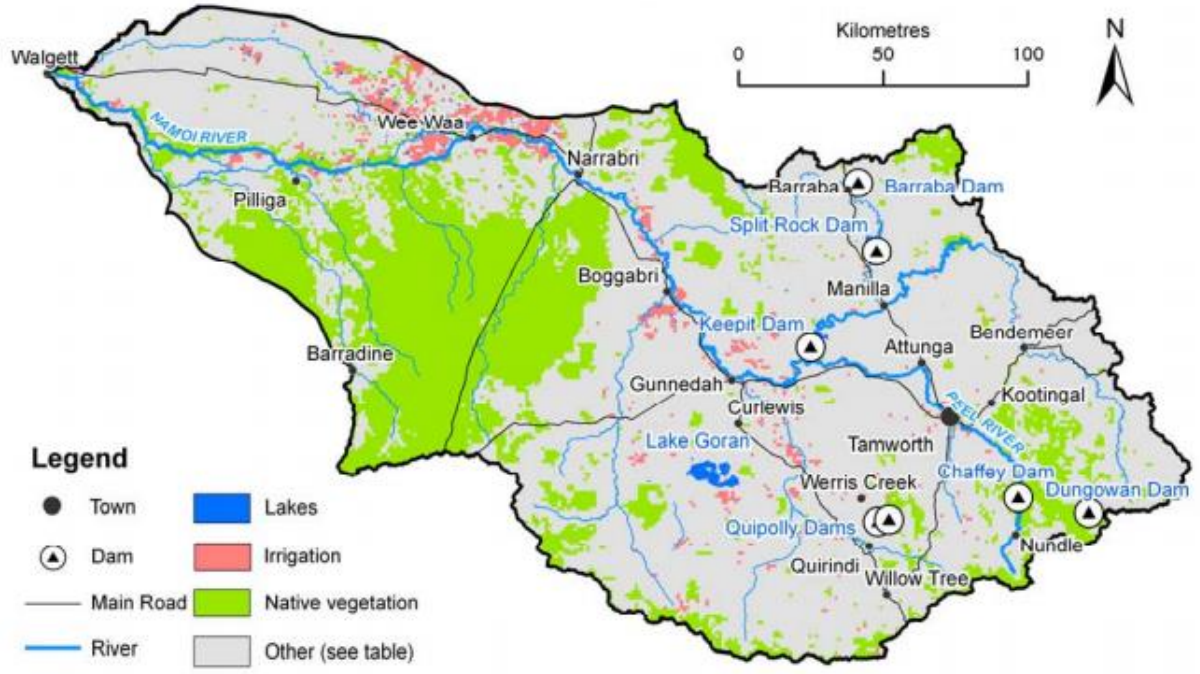
The Namoi, Peel and Manilla rivers form part of the *Lowland Darling River aquatic ecological community*, which is listed as an endangered community under the *NSW Fisheries Management Act 1994* (NSW DPI 2021). This community includes 21 native fish species and hundreds of native invertebrate species that are found within the Darling River and its associated streams, wetlands and anabranches within NSW (Green et al. 2011).

7.1.4 Stakeholder engagement

In the Namoi River Valley, the planning, management, and delivery of Commonwealth water for the environment is undertaken in conjunction with a range of partners and stakeholder groups. Key stakeholders in the Namoi River Valley include the NSW Department of Planning, Industry and Environment (DPIE), the Department of Primary Industries (DPI) – Fisheries, and WaterNSW.

Local Engagement Officers from the CEWO also work with different stakeholders as part a broader program of engagement around the management of the Commonwealth environmental water entitlements. As part of this work, Local Engagement Officers have been engaging directly with members of the local Aboriginal community.

Map NV1 Namoi Valley



Source: CSIRO (2007)

7.2 Environmental objectives

Based on long-term environmental objectives in the Basin Plan, state long-term watering plans, and best available knowledge, the following objectives are relevant for environmental watering in the Namoi Valley.

The objectives that are targeted in a particular year may vary, depending on available water, catchment conditions, operational feasibility, and demand for environmental water. These objectives will continue to be revised as part of the CEWO's commitment to adaptive management.

The objectives are:

- Vegetation – Maintain the condition, growth and survival of riparian, in channel, anabranch and wetland vegetation.
- Waterbirds – Provide drought refuge for waterbirds and support waterbird habitat.
- Native fish – Prevent loss of native fish species by supporting opportunities for movement, dispersal, reproduction, and recruitment, and providing in-channel refuge and aquatic habitat.
- Other vertebrates and invertebrates – Support opportunities for the reproduction and recruitment of other native aquatic species, including frogs and turtles.
- Connectivity – Support longitudinal connectivity, including with the Lower Namoi and the Barwon River, and lateral connectivity between the river and floodplains.
- Processes/water quality/resilience – Support key ecosystem functions and promote productivity and nutrient cycling; maintain water quality in channels and pools; and maintain drought refuge habitat.

7.3 First Nations environmental watering objectives

The CEWO is committed to working with First Nations groups to better understand their objectives. The CEWO will use environmental flows to contribute to these objectives where possible and where this is consistent with the Commonwealth Environmental Water Holder's statutory responsibility of protecting and restoring environmental assets in the Basin (see Chapter 2).

As the next steps, CEWO will develop and implement a work program to work with First Nations groups in the northern Basin. This work program will be developed in collaboration with First Nations groups and will be integral in continuing to build relationships and our capacity with First Nations groups. It will also ensure First Nations groups actively participate in the planning and management of environmental flows.

7.4 Recent conditions and seasonal outlook

7.4.1 Recent conditions and environmental water use

The Namoi Valley experienced extreme drought conditions between 2017–2020, with lowest on record rainfall and highest on record temperatures. Inflows to storage were extremely low during this time with no releases made from Keepit Dam between December 2018 and March 2020. No water for the environment was delivered in 2019–20 as drought conditions continued.

The extreme drought conditions and lack of available water for the environment affected the condition of the Namoi and Peel rivers. In the Namoi River, extended cease to flow conditions resulted in the drying of refuge pools, fish deaths (including Murray cod, golden perch, silver perch, and eel tailed catfish) and stressed vegetation. Very little flow occurred in the Peel River, with flows being restricted downstream of Dungowan to help secure town water supply.

Conditions began to improve later in 2019–20 with late summer and autumn rainfall providing much needed water to parts of the Lower Namoi and Peel rivers. However, the recovery of water storages was slow, with low run off from the dry catchment. Allocations against General Security entitlements were not received until September 2020 in the Namoi and January 2021 in the Peel.

Autumn rainfall also provided good inflows from tributaries to parts of both the lower Namoi and Peel rivers. However, flows remained low directly downstream of Keepit and Chaffey dams, with inflows being captured by the storages.

The summer and autumn rainfall and inflows increased storage levels and water availability. As of 8 June 2021, Keepit Dam was at 67.9% (WaterNSW 2021d) and Chaffey Dam was at 58.1% (WaterNSW 2021e). Allocations of General Security entitlements were increased to 90.5% in the Lower Namoi, and to 84% in the Peel River on 7 June and 9 June 2021, respectively (NSW DPIE – Water 2021a and 2021b).

While no Commonwealth water for the environment was delivered in the Namoi River in 2020– 21, a small volume (395 ML) was delivered in the Peel River in autumn, in combination with 1,170 ML of the NSW Environmental Contingency Allowance. This water contributed to a small baseflow downstream of Chaffey Dam to improve water quality, food and habitat availability, to support native fish and platypus.

Learn more about previous Commonwealth environmental water use in the Namoi Valley.

7.4.2 Seasonal outlook

The La Niña climate pattern that was bringing more rainfall has now ended. However, other climate drivers may provide conditions over coming months that are conducive to above average rainfall. According to the Bureau of Meteorology outlook, the forecast is for above average rainfall between June and August, and between July and September across the Namoi Valley (BoM 2021a). While this forecast indicates that the recent increase in rainfall may continue over winter, conditions can change quickly in the northern Basin.

Maximum temperatures are forecast to be average between June and August, and between July and September (BoM 2021b).

7.4.3 Water availability

Commonwealth environmental water in the Namoi Valley is managed in conjunction with other planned environmental water in the Peel managed by NSW. Other flows such as tributary flows, consumptive water, planned environmental water and other water orders may also support environmental demands in the Namoi Valley.

The Commonwealth holds 13.5 gigalitres of general security entitlements in the Lower Namoi. With the current allocations, the volume of Commonwealth water for the environment carried over into 2021–22 in the Lower Namoi is approximately 12.9 gigalitres.

The Commonwealth holds 1.26 gigalitres of entitlements in the Peel River. NSW manages 5 gigalitres of Environmental Contingency Allowance in the Peel River. However, carryover is not available in the Peel River, so the availability of water for the environment in 2021–22 will be dependent on the announcement of new allocations from 1 July 2021.

Based on the expected available volume of water held by the Commonwealth and other water holders, as well as recent and forecast catchment conditions, it is expected that the overall resource availability will be moderate to high in 2021–22. Forecast allocation of regulated (surface water) Commonwealth environmental water in 2021–22 under different water availability scenarios is provided in table 4 of Chapter 2.

7.4.4 Environmental demands

The environmental water demands for assets in the Namoi Valley Catchment in 2021–22 are shown in Table NV1. The capacity to contribute to these environmental demands is contingent on water availability and conditions in the catchment throughout the year.

Table NV1 Environmental demands and watering priorities, 2021–22, and outlook for coming year, Namoi Valley

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	Required frequency (maximum dry interval)		Environmental demands for water (all sources)	Potential Commonwealth environmental water contribution?	Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22
Lower Namoi River channel: d/s Keepit Dam to Boggabri, Boggabri to Mollee, Mollee to Bugilbone, Bugilbone to Walgett Native fish habitat, dispersal and spawning Instream aquatic ecosystems Riparian vegetation Threatened species, e.g. silver perch, eel tailed catfish.	Drought refuge habitat Water quality Fish maintenance and survival (all groups)	**Very low flows** **d/s Keepit Dam:** 5 to 200 ML/day for minimum 365 days **Gunnedah:** 1 to 200 ML/day for minimum 365 days **Boggabri:** 1 to 150 ML/day for minimum 356 days **Mollee:** 1 to 200 ML/day for minimum 343 days **Bugilbone:** 1 to 150 ML/day for minimum 336 days **Goangra:** 1 to 25 ML/day for minimum 323 days	Ideally: Annually Can occur at any time of year	Very low flows were last met in 2017–18 in the Namoi River between Keepit Dam and Mollee, and in 2016– 17 between Mollee and Walgett. With extended periods of cease to flow conditions, very low flows were not achieved downstream of Keepit Dam to Gunnedah, or between Bugilbone and Walgett, and only partially met between Gunnedah and Mollee in 2020–21. Very low flows are required annually and for most of the year. Therefore, the demand for water in 2021–22 in the lower Namoi River between Keepit and Walgett has been assessed as critical.	**Critical**	High priority for CEW under very low to low scenarios, subject to water availability. Would be met by other water in moderate to very high scenarios. The reaches downstream of Keepit Dam to Gunnedah, and downstream Bugilbone to the Barwon River may be a particularly important target for CEW.	High
	Water quality Habitat maintenance Connectivity Fish maintenance and survival (all groups) Fish recruitment (generalists + in-channel specialists)	**Baseflows** **d/s Keepit Dam:** 200 to 500 ML/day for minimum 209 days for survival; 119 days for recruitment **Gunnedah:** 200 to 600 ML/day for minimum 240 days for survival; 140 days for recruitment **Boggabri:** 150 to 350 ML/day for minimum 274 days for survival; 154 days for recruitment **Mollee:** 200 to 600 ML/day for minimum 267 days for survival; 154 days for recruitment **Bugilbone:** 150 to 350 ML/day for minimum 277 days for survival; 158 days for recruitment **Goangra** 25 to 65 ML/day for minimum 335 days for survival; 195 days for recruitment	Ideally: 1 in 1 to 2 years (Max interval: 2 years for fish recruitment) Can occur at any time for native fish maintenance and survival, or Sept to Mar for native fish recruitment.	Baseflows have generally only been partially or not met in the Lower Namoi River over at least the past six years, except at Goangra, which was met in 2016–17. In 2020–21, intermittent periods of cease to flow conditions meant that baseflows were not achieved for the required duration in the lower Namoi River. The maximum time between baseflow events has been exceeded, and the required frequency to support native fish has not been achieved. Considering baseflows are required once every one to two years, and they have not been adequately met for a number of years, the demand for these flows in 2021–22 has been assessed as critical.	**Critical**	High priority for CEW under very low to moderate scenarios, subject to water availability. May be met by other water in high to very high scenarios.	High
	Longitudinal connectivity Low level bank and bar wetting Pool maintenance Fish movement, productivity and condition Fish spawning (generalists + in-channel specialists)	**Small freshes** **d/s Keepit Dam:** 500 to 1,400 ML/day **Gunnedah:** 600 to 5,400 ML/day **Boggabri:** 350 to 3,600 ML/day **Mollee:** 500 to 6,000 ML/day **Bugilbone:** 350 to 3,200 ML/day **Goangra:** 65 to 1,000 ML/day	Ideally: Annually for fish dispersal and productivity/condition (Max interval: 1 year) 1 in 1 to 2 years for fish spawning (Max interval 2 years) Fish dispersal and condition/ productivity: ideally occurs Oct to Apr (but can occur any time) for minimum of 10 days Fish spawning: Sept to Apr for a minimum of 14 days.	Small freshes have been met each year in the Namoi River between Keepit Dam and Mollee between 2015–16 and 2020–21, except in 2019–20, when they were not met below Keepit Dam and only partially met at Gunnedah. Small freshes are ideally met each year, particularly for native fish dispersal and condition. The maximum interval for these flows will be exceeded if small freshes are not consistently provided across years. Therefore the demand for small freshes has been assessed as high for 2021–22.	High	High priority for CEW under low to moderate water resource scenarios, subject to water availability and being delivered in conjunction with other water. May be met by other water under a high or very high scenario.	High
	Longitudinal connectivity Increase ecosystem function Bench and bank wetting Access to habitat Nutrient cycling	**Large freshes** **d/s Keepit Dam:** 1,400 to 3,500 ML/day **Gunnedah:** 5,400 to 32,700 ML/day **Boggabri:** 3,600 to 17,750 ML/day **Mollee:** 6,000 to 18,750 ML/day	Ideally: 1 in 1 to 2 years for fish dispersal and productivity/condition (Max interval 2 years);	Large freshes were achieved in the lower Namoi River between Gunnedah and Walgett in 2020–21, following rainfall and tributary inflows. These flows were previously met between Mollee and Walgett in 2019– 20, but large freshes between Gunnedah and Boggabri had not been adequately met since 2013–14	**Critical** (d/s Keepit)	Possible use of CEW only if there is an increase in available water under high to very high water resource availability scenarios. Would need to be delivered in conjunction with other flows.	High to Critical

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	**Required frequency (maximum dry interval)**		**Environmental demands for water (all sources)**	**Potential Commonwealth environmental water contribution?**	**Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22**
	Fish dispersal and productivity/condition (all groups) Fish spawning (flow specialists)	**Bugilbone:** 3,200 to 9,900 ML/day **Goangra:** 1,000 to 5,800 ML/day	1 in 2 to 3 years for fish spawning (Max interval 4 years) Fish dispersal and condition/ productivity: ideally occurs July to Sept (but can occur any time) for minimum of 5 days Flow specialist spawning: Oct to Apr for a minimum of 5 days.	or longer. Downstream of Keepit Dam large freshes have not been achieved since 2017–18. Large freshes are required in 2021–22 downstream of Keepit Dam, particularly for native fish dispersal and condition, which is required once every one to two years. The demand at this location has been assessed as critical. From Gunnedah to Boggabri large freshes were met in 2020–21, however, had not been met for multiple years before that, so require water again in 2021–22. Therefore the demand at these locations has been assessed as high to critical. From Mollee to Goangra, large freshes were met in both of the last two years. Therefore the demand at these locations has been assessed as moderate to high for 2021–22.	High to Critical (Gunnedah to Boggabri) Moderate to High (Mollee to Goangra)	Downstream of Keepit to Boggabri would be a particular priority.	
	Lateral and longitudinal connectivity Riparian vegetation in low commence to flow anabranch channels Increase ecosystem function Nutrient cycling Access to habitat Fish spawning (floodplain specialists) Fish dispersal and productivity/condition (all groups)	**Bankfull and overbank flows** **d/s Keepit Dam:** 3,500 to 6,150 ML/day **Gunnedah:** 32,700 to 40,000+ ML/day **Boggabri:** 17,750 to 22,000+ ML/day **Mollee:** 18,7500 to 21,750+ ML/day **Bugilbone:** 9,900 to 13,400+ ML/day **Goangra:** 5,800 to 8,200+ ML/day	Ideally: 1 in 2 years for fish spawning (Max interval 4 years); 1 in 3 to 5 years for fish dispersal and productivity/condition (Max interval 5 years). Fish dispersal and condition/ productivity: ideally Sept to Feb (but can occur at any time) for a minimum of 5 days. Floodplain specialist spawning: Oct to Apr for a minimum of 10 days.	Bankfull and overbank flows have not been met in the Lower Namoi River between Keepit Dam and Walgett in the last three years, and during the past seven years, these flows have only been met at Goangra and Walgett in 2016–17. The maximum interval for these flows has been exceeded between Keepit Dam and Bugilbone for both spawning and dispersal/conditioning flows for native fish, and for fish spawning between Goangra and Walgett. Therefore, the demand for 2021–22 has been assessed as critical overall, particularly between Keepit and Bugilbone.	**Critical**	Commonwealth environmental water unlikely to contribute to this demand because of insufficient water and system constraints.	**Critical**
Peel River channel (d/s Chaffey Dam to Piallamore, Piallamore to Carrol Gap) Native fish habitat and spawning Instream aquatic ecosystems Riparian vegetation	Drought refuge habitat Water quality Fish maintenance and survival (all groups)	**Very low flows** **d/s Chaffey Dam:** 1 to 100 ML/day **Piallamore:** 1 to 100 ML/day **Carrol Gap:** 1to 100 ML/day	Ideally: Annually Very low flows may occur at any time.	Very low flows were met in the Peel River downstream of Chaffey Dam to Carrol Gap in every year between 2012–13 and 2018–19. However, these flows were only partially met at Piallamore and Carrol Gap in 2019–20, with flows being <1 ML/day for part of the year. In 2020–21, very low flows were met at Piallamore and Carrol Gap, following rainfall and tributary inflows, but only partially met downstream of Chaffey Dam. Very low flows are required annually, so the demand for water in 2021–22 has been assessed as high between Piallamore and Carrol Gap. However, the demand has been assessed as high to critical downstream of Chaffey Dam, where these flows were not sufficiently achieved in 2020–21.	High to Critical (d/s Chaffey) High (Piallamore to Carrol Gap)	High priority for CEW under very low to low water resource scenarios, subject to water availability. Expected to be met by other water under moderate to very high scenarios.	High
	Water quality Habitat maintenance Connectivity Fish maintenance and survival (all groups) Fish recruitment (generalists + in-channel specialists)	**Baseflows** **d/s Chaffey Dam:** 100 to 250 ML/day **Piallamore:** 100 to 250 ML/day **Carrol Gap:** 100 to 300 ML/day	Ideally: 1 in 1 to years for fish recruitment (Max interval 2 years) Native fish maintenance and survival: anytime Native fish recruitment: Sept to Mar.	Baseflows were last met downstream of Chaffey and at Piallamore in 2018–19, but have not been sufficiently met for at least the past eight years at Carrol Gap (partially met in 2012–13 and 2016–17). In 2020–21, baseflows were not met in the Peel River downstream of Chaffey Dam, and were only partially met at Piallamore and Carrol Gap. These flows are required once in every 1–2 years, with a maximum interval of 2 years for native fish recruitment. Therefore, the demand for water in 2021–22 has been assessed as critical.	**Critical**	High priority for CEW under very low to moderate water resource scenarios, subject to water availability. May be met by other water under high to very high scenarios.	High

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	Required frequency (maximum dry interval)		Environmental demands for water (all sources)	Potential Commonwealth environmental water contribution?	Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22
	Longitudinal connectivity Low level bank and bar wetting Pool maintenance Fish movement, productivity and condition Fish spawning (generalists + in-channel specialists)	**Small freshes** **d/s Chaffey Dam:** 250 to 900 ML/day **Piallamore:** 250 to 1,350 ML/day **Carrol Gap:** 300 to 3,900 ML/day	Ideally: Annually for fish dispersal and productivity/ condition (Max interval 1 year); 1 in 1 to 2 years for fish spawning (Max interval 2 years). Fish dispersal and condition/ productivity: ideally Oct to Apr (but can occur any time) for a minimum of 10 days Fish spawning: Sept to Apr for a minimum of 14 days.	Small freshes were not met downstream of Chaffey Dam in 2020–21. However, these flows were achieved at Piallamore and Carrol Gap following rainfall and tributary inflows. Before this, small freshes were last met downstream of Chaffey and at Piallamore in 2016–17 and at Carrol Gap in 2019–20. These flows are required annually for native fish dispersal and condition, and the maximum interval has been exceeded downstream of Chaffey Dam. Therefore, this demand for water in 2020–21 has been assessed as critical downstream of Chaffey Dam and high at Piallamore and Carrol Gap.	Critical (d/s Chaffey) High (Piallamore to Carrol Gap)	High priority for CEW in conjunction with other water under low to high scenarios, particularly downstream of Chaffey Dam. Would likely be met by other water in very high scenarios.	High
	Longitudinal connectivity Increase ecosystem function Bench and bank wetting Access to habitat Nutrient cycling Fish dispersal and productivity/condition (all groups) Fish spawning (flow specialists)	**Large freshes** **d/s Chaffey Dam:** 900 to 2,900 ML/day **Piallamore:** 1,350 to 5,150 ML/day **Carrol Gap:** 3,900 to 13,500 ML/day	Ideally: 1 in 1 to 2 years for fish dispersal and productivity/condition (Max interval 2 years); 1 in 2 to 3 years for fish spawning (Max interval 4 years). Fish dispersal and condition/ productivity: ideally Jul to Sept (but can occur any time) for a minimum of 5 days.	Large freshes have not been achieved in the Peel River between Chaffey Dam and Carrol Gap in the period assessed since 2012–13. During that time, large freshes have only been partially met (for a dispersal flow) in 2016–17 at Piallamore and Carrol Gap, and have otherwise not been met. Large freshes are ideally required every 1–2 years for native fish dispersal and once in every 2–3 years for spawning. The maximum intervals for both flows have been exceeded in this reach. Therefore, the demand for water in 2021–22 has been assessed as critical.	**Critical**	Commonwealth environmental water unlikely to contribute to this demand because of insufficient water and system constraints.	**Critical**
	Lateral and longitudinal connectivity Riparian vegetation in low commence to flow anabranch channels Increase ecosystem function Nutrient cycling Access to habitat Fish spawning (floodplain specialists) Fish dispersal and productivity/condition (all groups)	**Bankfull and overbank flows** **d/s Chaffey Dam:** 2,900 to 6,400+ ML/day **Piallamore:** 5,150 to 13,400+ ML/day **Carrol Gap:** 13,500 to 40,000+ ML/day	Ideally: 1 in 2 years for fish spawning (Max interval 4 years); 1 in 3 to 5 years for fish dispersal and productivity/ condition (Max interval 5 years) Floodplain specialist spawning: Oct to Apr for a minimum of 10 days. Fish dispersal and condition/ productivity: can occur any time for a minimum of 5 days.	Bankfull and overbank flows have not been met in the Peel River between Chaffey Dam and Carrol Gap during the period assessed since 2012–13. These flows are ideally required 1 in 2 years for native fish flow spawning, and the maximum intervals for both spawning and dispersal flows have been exceeded. Therefore, this demand has been assessed as critical, with water being required in 2021–22.	**Critical**	Commonwealth environmental water unlikely to contribute to this demand because of insufficient water and system constraints.	**Critical**

Note: Contributions to meet Barwon–Darling environmental requirements may be considered subject to water availability, antecedent conditions and environmental demands (see chapter 9 of the CEWO Water Management Plan 2021–22).
Flow releases in the lower Namoi and Peel rivers are constrained by the outlet capacity of Keepit Dam (4,000 ML/day) and Chaffey Dam (1,100 ML/day) respectively.
Information on environmental demands has been sourced from the Namoi Long-Term Water Plan (NSW DPIE 2020a and b), Green et al. (2011), MDBA (2012), Barma Water Resources et al. (2012), Foster (1999), in conjunction with advice from NSW DPIE – EES and NSW DPI – Fisheries.
All watering history sourced from NSW DPIE – EES and NSW DPI – Fisheries, and data from the following gauges (WaterNSW 2021f) – 419007 Namoi River d/s Keepit, 419001 Namoi River at Gunnedah, 419012 Namoi River at Boggabri, 419039 Namoi River at Mollee, 419021 Namoi River at Bugilbone, 419026 Namoi River at Goangra, 419045 Peel River d/s Chaffey Dam, 419015 Peel River at Piallamore, 419006 Peel River at Carrol Gap.

Key

Potential watering in 2021–22

- High priority for Commonwealth environmental watering (likely to receive water even under low water availability)
- Secondary priority for Commonwealth environmental watering (watering to occur only if natural trigger is met, or under moderate – high water resource availability); or water demand likely to be met via other means
- Low priority for Commonwealth environmental watering (under high – very high water resource availability); or unable to provide water because of constraints or insufficient water

Environmental demands (demand is considered at a generalised scale; there may be specific requirements that are more or less urgent within the flow regime)

- High to critical demand for water (needed in that particular year or urgent in that particular year to manage risk of irretrievable loss or damage)

Moderate demand for water (water needed in that particular year, the next year, or both)

Low demand for water (water generally not needed in that particular year)

7.5 Water delivery in 2021–22

Based on the demand for water for the environment, water availability (supply), and catchment conditions, the overall purpose for managing Commonwealth water for the environment in the Namoi River Valley in 2021–22 is to protect, maintain and where possible improve, the health and resilience of aquatic ecosystems in the Lower Namoi River and the Peel River, subject to water availability.

Consistent with the demands and purpose identified, the Commonwealth Environmental Water Office is considering supplying water for the environment to the following actions in 2021–22.

There is a critical demand to provide very low flows and baseflows in the lower Namoi River, where prolonged drought conditions have meant these flows have not been for an adequate duration for several years. Targeting these flows in reaches below Keepit Dam may be a particularly high priority, where rainfall and tributary inflows have not recently provided sufficient water. These flows would help provide refuge habitat, improve water quality, increase connectivity, support native fish, and help to build resilience.

Should conditions continue to improve, the priority would be to deliver a small fresh, or continue providing baseflows through spring in the lower Namoi River. Targeting these flows further downstream in the system (e.g. downstream of Gunidgera) would help increase connectivity and movement opportunities for native fish, and help achieve greater connectivity with the Barwon River. These flows may also help to improve productivity and support spawning of more generalist fish species.

In the Peel River, the highest priority would be to deliver a small fresh or contribute to a baseflow during spring particularly in the reach downstream of Chaffey Dam, which has a critical demand for water. Delivering a small fresh or supporting a baseflow would provide increased connectivity and maintain pools, help to build resilience, support native fish movement and condition, and possibly the spawning of some generalist and in-channel native fish species. With no carryover provisions, being able to provide water for the environment in the Peel River will be dependent on new allocations being announced in 2021–22.

While there are also critical demands for water to achieve large freshes and bankfull flows in the Namoi and Peel rivers, the capacity to use Commonwealth environmental water to contribute to these demands is limited. In the Namoi River, an increase in water availability and other water in the system would be required to deliver large freshes. It is unlikely that Commonwealth water would be used to contribute to bankfull flows in the Namoi because of insufficient water and system constraints. Similarly, in the Peel River, environmental water is unlikely to contribute to large freshes and bankfull flows because of system constraints and the relatively small volume of water available to meet demands.

As in previous years, the use of Commonwealth water for the environment in the Namoi River Valley will be adaptively managed throughout 2021–22, in response to changing water resource availability and environmental conditions and demands.

7.6 Monitoring and lessons learned

7.6.1 Monitoring

In the Namoi River Valley, monitoring is primarily undertaken by NSW agencies including NSW DPIE (inundation and photo point monitoring), NSW DPI – Fisheries (native fish), and WaterNSW (hydrology and flow delivery data).

7.6.2 Lessons learned

Outcomes from monitoring and lessons learned in previous years are a critical component for the effective and efficient use of Commonwealth water for the environment. These learnings are incorporated into the way environmental water is managed.

Key findings from fish, aquatic habitat and flow monitoring in the Namoi River Valley are summarised in Table NV2.

Table NV2 Key lessons learned in the Namoi Valley

Theme	Lessons learned
Native fish and aquatic invertebrates	• Providing a small flow to the lower Namoi River during dry conditions can be beneficial for water quality and native fish survival, by increasing water depth and dissolved oxygen levels in refuge pools. • The number of small freshes has been substantially reduced by river regulation downstream of Chaffey Dam. Therefore, providing environmental water may be important for supporting native fish that depend on these flows to maintain healthy condition, and to support dispersal and recruitment, which is needed to maintain native fish populations. • The location, persistence and number of refugia in the lower Namoi and Peel rivers were identified during the height of the 2017–20 drought. This information will help to support the management of drought refugia and native fish in the future.
Connectivity	• A pulse of 750 ML/day is more effective than 500 ML/day in wetting low-level benches in the Peel River. • Flows of 750 ML/day can also result in some fine sediment movement/scouring, however, flows over 1 000 ML/day may be required to effectively mobilise sediment and algae that has accumulated downstream of Chaffey Dam.
Other aquatic animals[a]	• Persistence of health populations of freshwater mussels (particularly *Alathyria jacksoni*, which is endemic to the Murray–Darling Basin) is dependent on permanent river reaches and waterholes. The provision and protection of minimum baseflows is vital to their persistence, and for populations to recover from the significant losses experienced during the 2017–20 drought. • Recolonisation of freshwater mussels is dependent on the recovery and movement of native fish populations through the northern Basin. Therefore, the minimum flow requirements of native fish also need to be provided to support recovery of both fish and mussel populations.

a Sheldon et al. (2020)

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8 Macquarie Valley Water Plan

8.1 Region overview

8.1.1 River system

The Macquarie Valley is located in Central Western New South Wales (NSW) extending from the Blue Mountains to the Barwon River, east of Brewarrina. The Macquarie River forms above Bathurst, where the Campbells and Fish rivers join, and flows into Burrendong Dam, south east of Wellington (Map MV1). Below the dam, tributary flows are provided by the Bell, Little and Talbragar rivers, and Wambangalong and Coolbaggie creeks. As the land flattens further west of Dubbo, the Macquarie River provides flows to distributary creeks, wetlands and rich alluvial river flats associated with braided channels, and provides important connections with the Barwon–Darling River.

Macquarie River flows are heavily influenced by large rainfall events in the upper catchment and flows in tributary systems. Two major storages, Windamere Dam (capacity 368 gigalitres) on the Cudgegong River (WaterNSW 2021a), and Burrendong Dam on the Macquarie River (storage capacity of 1,188 gigalitres, with additional storage capacity of 489 gigalitres in the flood mitigation zone) (WaterNSW 2021b), regulate catchment water supplies.

8.1.2 Traditional Owners

The rivers and wetlands of the Macquarie River Valley hold significant spiritual and cultural importance for Aboriginal people (NSW DECCW 2010). In the upper and middle Macquarie Valley, the Aboriginal people are the Wiradjuri, while on the plains the Bogan River forms the boundary between the Ngemba and Ngiyampaa Nations to the west and the Wayilwan Nation to the east (MDBA 2021). Wayilwan country includes most of the Castlereagh catchment, except the north-east corner, which is the traditional land of the Kamilaroi (MDBA 2021). The Commonwealth Environmental Water Office (CEWO) respectfully acknowledges these Nations, their Elders past and present, as the Traditional Custodians of the lands on which this chapter is focused.

8.1.3 Important sites and values

The valley includes the Macquarie Marshes wetland complex on the lower reaches of the Macquarie River, of which, parts of the northern, southern and eastern Marshes are listed as a Wetland of International Importance under the Ramsar Convention (NSW DECCW 2010). These areas were recognised under the Ramsar Convention for being a unique example of a wetland type in the region in terms of their size and their diversity of wetland types, supporting species of conservation significance and biological diversity, providing refuge during adverse conditions, and regularly supporting large numbers of waterbirds (NSW OEH 2012). This includes those listed under international migratory agreements (JAMBA, ROKAMBA, CAMBA). The Ramsar site contains a range of habitats including core areas of semi-permanent wetlands, such as forests and woodlands, reed beds, marshes, rushlands and open lagoons. These vegetation types have been identified as critical components of the Ramsar site (NSW OEH 2012).

Other assets in the valley downstream of Burrendong Dam, where water for the environment can be delivered, include the Macquarie River channel, the unregulated components of the lower Macquarie River and the distributary creek system to the west of the Marshes.

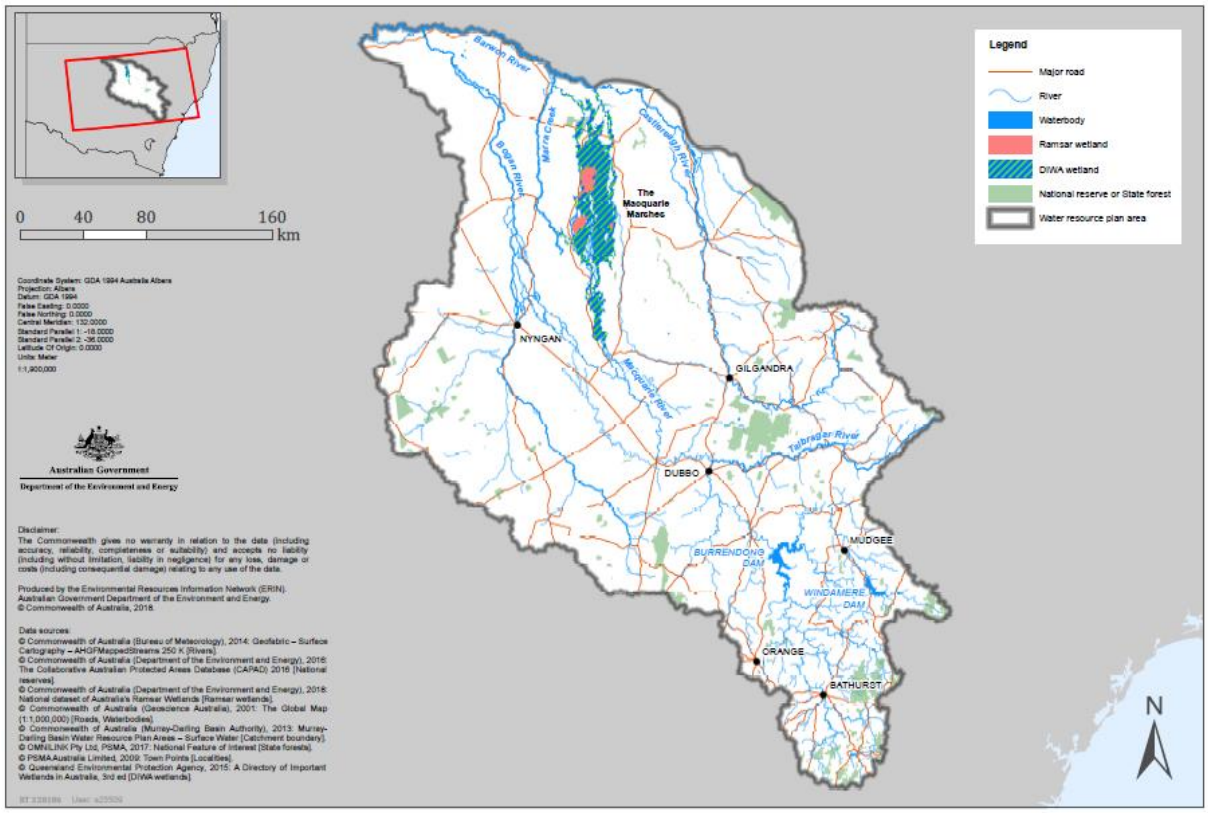
The Macquarie Marshes and Macquarie River support numerous species listed as endangered or vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999*, for example, the Australian painted snipe, Australasian bittern, and Murray cod (NSW OEH 2012). The aquatic community of the Macquarie also forms part of the Lowland Darling River aquatic ecological community, which is listed as endangered under the NSW *Fisheries Management Act 1994* (NSW DPI 2007).

8.1.4 Stakeholder engagement

In the Macquarie River Valley, the planning, management, and delivery of Commonwealth water for the environment is undertaken in conjunction with a range of partners and stakeholder groups. Key stakeholders in the Macquarie include the NSW Department of Planning, Industry and Environment – Environment, Energy and Science (DPIE – EES), the Department of Primary Industries (DPI) – Fisheries, WaterNSW, and the Macquarie Cudgegong Environmental Flow Reference Group (EFRG), who provide advice to water managers on priorities for water use.

Local Engagement Officers from the Commonwealth Environmental Water Office (CEWO) also work with different stakeholders as part a broader program of engagement around the management of the Commonwealth environmental water entitlements. As part of this work, Local Engagement Officers have been engaging directly with members of the local Aboriginal community.

Map MV1 Macquarie Valley



Source: Department of the Environment and Energy (2018)
Note: DIWA refers to the Directory of Important Wetlands in Australia.

8.2 Environmental objectives

Based on long-term environmental objectives in the Basin Plan, state long-term watering plans, site management plans (including Ramsar site ecological character descriptions), and best available knowledge, the following objectives are relevant for environmental watering in the Macquarie Valley.

The objectives that are targeted in a particular year may vary, depending on available water, catchment conditions, operational feasibility, and demand for environmental water. These objectives will continue to be revised as part of the Commonwealth Environmental Water Office's (CEWO) commitment to adaptive management. The objectives are:

- Vegetation – Maintain the condition, growth and survival of riparian, in-channel, floodplain and wetland vegetation.
- Waterbirds – Increase waterbird abundance and maintain species diversity by supporting naturally triggered breeding events, and maintaining suitable refuge, feeding and breeding habitat.
- Native fish – Prevent loss of native fish species and improve population structure and distribution, by supporting opportunities for movement, dispersal, reproduction, and recruitment.
- Other vertebrates – Support opportunities for the reproduction and recruitment of other native aquatic species, including frogs and turtles.
- Connectivity – Support longitudinal connectivity, including with the Barwon River, and lateral connectivity between the river and floodplain.
- Processes/water quality/resilience – Support key ecosystem functions and promote productivity; maintain water quality in channels and pools; and maintain drought refuge habitat.

8.3 First Nations environmental watering objectives

The CEWO is committed to working with First Nations groups to better understand their objectives. The CEWO will use environmental flows to contribute to these objectives where possible and where this is consistent with the Commonwealth Environmental Water Holder's statutory responsibility of protecting and restoring environmental assets in the Basin (see Chapter 2).

As the next steps, CEWO will develop and implement a work program to work with First Nations groups in the northern Basin. This work program will be developed in collaboration with First Nations groups and will be integral in continuing to build relationships and our capacity with First Nations groups. It will also ensure First Nations groups actively participate in the planning and management of environmental flows.

8.4 Recent conditions and seasonal outlook

8.4.1 Recent conditions and environmental water use

The Macquarie Valley experienced its worst drought on record between 2017–18 and 2019–20. During this time rainfall was well below average, with highest on record temperatures, and inflows to Burrendong Dam were just one-third of the previous lowest volume.

Access to general security and planned environmental water accounts was restricted to 70% of the 1 July 2018 carryover balance in 2018–19. Further restrictions were then put in place in 2019–20, with all allocations of water for the environment (along with other general security water) being held in a drought sub-account. Consequently, no water for the environment was able to be delivered at that time.

The mid-Macquarie River was shut off downstream of Warren in late August 2019, resulting in cease to flow conditions, necessitating the rescue of native fish from drying refuge pools over summer. Extended cease to flow conditions resulted in no flows into the Macquarie Marshes for 10 to 12 months. The ongoing very hot and dry conditions affected the condition of vegetation in the Marshes. During the spring and summer large areas had little or no ground cover. A fire in spring 2019 also burnt large areas of the north marsh reedbed (part of the Ramsar site).

Late summer and autumn rainfall and flows in early 2020 provided much needed water to parts of the Macquarie Marshes. Commonwealth and NSW supplementary water entitlements were used to ensure some additional water was left instream to help support recovery in the Macquarie River and Marshes.

Commonwealth and NSW water for the environment was delivered during spring and summer in 2020–21 to the mid-Macquarie River and Macquarie Marshes to support recovery of these systems. This water was designed to support the breeding and recruitment of Murray cod, inundate core areas of the Macquarie Marshes to support wetland vegetation recovery, and maintain breeding and feeding habitat for waterbirds, frogs and other animals. Areas that were inundated, including the burnt north marsh reedbed, responded well to the flows. Areas that did not receive sufficient water remain in poorer condition. Murray cod and water dependent frog species were observed breeding during the delivery of water for the environment. A good diversity of waterbirds was also observed in the Marshes, including Australian painted snipe, Latham's snipe, Australasian bittern, sharp-tailed sandpipers, brolga, ibis, spoonbills, magpie geese and ducks.

Good rainfall and tributary flows in autumn 2021 provided additional water to the mid-Macquarie River and Marshes. As of 8 June 2021, Burrendong Dam was at 57.9%, up from around 39% at the end of January 2021 (WaterNSW 2021c). Allocations of General Security entitlements were increased by another 1% on 10 June 2021, taking the total to 68% of entitlement (NSW DPIE – Water 2021).

Learn more about previous Commonwealth environmental water use in the Macquarie Valley.

8.4.2 Seasonal outlook

The La Niña climate pattern that was bringing more rainfall has now ended. However, other climate drivers may provide conditions over coming months that are conducive to more rainfall. According to the Bureau of Meteorology outlook, the forecast is for above average rainfall between June and August across the Macquarie Valley (BoM 2021a) and between July and September (BoM 2021b). This forecast indicates that the recent increase in rainfall may continue over winter, although conditions can change quickly in the northern Basin. Maximum temperatures across the Macquarie Valley are forecast to be average to below average between June and August (BoM 2021c), and between July and September (BoM 2021d).

8.4.3 Water availability

Commonwealth environmental water is managed in conjunction with other held and planned environmental water managed by NSW. Other flows such as tributary flows, consumptive water and other water orders may also support environmental demands in the Macquarie Valley. As of 10 June 2021, there was 82 gigalitres of planned environmental water and 99 gigalitres of Held Environmental Water available out of the 750 gigalitres of the available resources in the Macquarie (NSW DPIE 2021).

The volume of Commonwealth water for the environment carried over in the Macquarie Valley for use in 2021–22 is 71 gigalitres. The Commonwealth also holds around 8.3 gigalitres of supplementary water in the Macquarie Valley. However, delivery of this water is dependent on access announcements being made by WaterNSW.

Based on the expected available volume of water held by the Commonwealth and other water holders, as well as recent and forecast catchment conditions, it is expected that the overall resource availability will be low to high in 2021–22. Forecast allocation of regulated (surface water) Commonwealth environmental water in 2021–22 under different water availability scenarios is provided in table 4 of Chapter 2.

8.4.4 Environmental demands

The environmental water demands for assets in the Macquarie Valley in 2021–22 are shown in Table MV1. The capacity to contribute to these environmental demands is contingent on water availability and conditions in the catchment throughout the year.

Table MV1 Environmental demands and watering priorities, 2021–22, and outlook for coming year, Macquarie Valley

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)7	2021–22		Implications for future demands
		Flow/volume	Required frequency (maximum dry interval)		Environmental demands for water (all sources)	Potential Commonwealth environmental water contribution?	Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22
Mid-Macquarie River (Burrendong – Marebone Weir) Native fish habitat and spawning including threatened species such as Murray cod, freshwater catfish In-stream aquatic ecosystems Riparian vegetation	Fish refuge: all guilds Aquatic ecosystems	**Baseflows:** small (>200 ML/d), very regular flows through to end of system, wetting waterholes and in-stream storages. Ideally depth >0.3 m above commence to flow level, to allow some movement and prevent pool stratification. Note: Very low flows in the mid-Macquarie River have the same flow rate and requirements as baseflows (>200 ML/day). Cease to flow events should be avoided.	Ideally: continuous flow (Max interval: continuous flow)	Demand expected to be met by essential regulated supplies in all but the most extreme dry years. Minimum baseflows have been achieved in all years, other than in 2019–20 when extreme dry flow conditions meant that the Macquarie River was shut off downstream of Warren Weir in late August 2019 until tributary flows improved conditions in February 2020. Baseflows are ideally required continuously to maintain in-stream habitat, and will be required again in 2021–22. Therefore, the environmental demand has been assessed as high.	High	Expected to be met by essential regulated supply, so a secondary priority for CEW. Potential use of CEW under very low water availability scenario, subject to environmental water being available for delivery.	High
	Fish spawning– flow generalists (e.g. Australian smelt, carp gudgeon) + in-channel specialists (e.g. Murray cod, freshwater catfish)	**Small freshes:** Small fresh 1(SF1) >500 ML/d anytime (but ideally Oct to Apr) for 10 days. Small fresh 2 (SF2) >500 to 6,000 ML/day for at least 14 days at Baroona in Sep to Apr (Sep to Dec for Murray cod spawning); and conditioning flow in winter (July to mid-August).	Ideally: SF1:annually (Max interval: 3 years for large-bodied generalists; 5 years in-channel specialists; 1 year for small-bodied) SF2: 5 to 10 years in 10	Small freshes were achieved in all years between 2015–16 and 2020–21, excluding in 2019–20 when these flows were only partially met. These flows are ideally provided annually, particularly for small bodied fish, so are required again in 2020–21. Therefore, the environmental demand has been assessed as high.	High	High priority for CEW under low to high water resource availability scenarios, subject to natural tributary flows and water temperature.	High
	Flow specialists guild movement and breeding	**Priming flow:** >5 000 ML total flows at Baroona over 3 days with approx. 7 day recession (tributary pulse). **Spawning pulse:** initial peak ≥ 5,000 ML/day at Baroona for >2 days with event lasting for >7 days. (35 to 40 days total event). **Dispersal flow:** Initial pulse >3,000 ML total flows over 3 days at Baroona. Second pulse minimum 2,000 ML/day peak with recession. Approx. 10d duration total events. (Oct to March) Water temperature for all pulses ≥19°C.	Ideally: 3 to 5 years in 10 (up to twice per year) (Max interval: 4 years)	Flows for native fish flow specialists were met in 2020–21, and before that in 2012–13. In 2019–20, tributary flows contributed to priming and dispersal flows. However, spawning flows were not achieved at times that temperatures were suitable, and/or the required flow rates were not achieved along the Macquarie River down to Marebone. Before 2020–21, the maximum interval of 4 years between events for these flows had been exceeded. The required frequency has not been achieved. Considering the extreme drought conditions and fish kills experienced between 2017–18 and 2019–20, it is unlikely that recent improvements in flows have been sufficient to support the longer-term recovery of native fish flow specialists in the mid-Macquarie River. Therefore, the environmental demand for water in 2021–22 has been assessed as critical.	Critical	Although the demand for water is very high, the capacity to target spawning pulses using regulated environmental water is limited in most years. Possible use of CEW (e.g. supplementary) under moderate to high water resource availability scenarios to augment freshes and support movement. Subject to natural tributary flows, water temperature, and significant river rises that will cue movement and possibly spawning of flow specialists.	Moderate
	Fish movement In stream + riparian vegetation	**Large freshes and bankfull:** 10,000 to 20,000 ML/day at Baroona for a minimum of 3 days (to drown out key weirs). (Gin Gin drowns out at 18,000 ML)	Ideally: 2 in 10 years (Max interval: 2 to 4 years)	Large freshes were last achieved in 2016–17, when flows >10,000 ML/day were achieved at Baroona on three occasions, for 6, 3 and 28 days respectively in Sept to Oct 2016, and in 2011–12 before that. These flows were partially met in 2019–20 and 2020–21. To meet the desired frequency of these flows, water is required in 2021–22. Therefore, the environmental demand has been assessed as high.	High	Although the demand for water is high, this is a secondary priority for CEW in 2021–22. Possible use of CEW (e.g. supplementary) under moderate to high water resource availability under certain conditions.	Low
Macquarie Marshes Includes areas of Ramsar listed wetlands Nationally significant wetlands Waterbird breeding and foraging habitat	Blue and Purple inundation zones (4,000 to 9,000 ha)	30 to 60 GL at Marebone over 3 months between June and April to inundate reed beds, lagoons, mixed marsh, and water couch. Volume required to meet demand may vary depending on antecedent conditions.	Ideally: annually (Max interval: 2 years)	Demand has been met in most parts of the Marshes in most years since 2012–13. This demand was met in the Northern, Southern and Eastern Marshes in 2020–21, based on the flow volume, inundation extent and duration. Environmental water deliveries along with rainfall and supplementary events contributed flows to the Marshes. Around 145 GL of water was recorded at Marebone in Aug to Oct, and around 125 GL in Oct to Dec. Flows continued through summer to the Southern and Northern Marshes, with approximately 65.2 GL	High	A high priority for CEW under very low to high water resource availability scenarios.	High

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)7	2021–22		Implications for future demands
		Flow/volume	Required frequency (maximum dry interval)		Environmental demands for water (all sources)	Potential Commonwealth environmental water contribution?	Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22
Habitat and breeding ground for frogs Native fish habitat				reaching Oxley and 56.4 GL reaching Pillicawarrina in Nov to Jan. Overall, the demand for water in 2020–21 has been assessed as high, to continue supporting the recovery and growth of core wetland vegetation, and to provide habitat for a range of aquatic species. This is based on the annual need for water, and the prolonged extreme dry conditions between 2017 and early 2020.			
	Pink inundation zone (19,000 ha)	100 GL at Marebone over 3 months between June and April to inundate reeds, water couch, mixed marsh, river red gum forest, river cooba. Volume required to meet demand may vary depending on antecedent conditions.	Ideally: 8 in 10 years (Max interval: Groundcover – 2 years; trees 4 to 7 years)	Demand met in 2012–13, 2016–17 and again in 2017–18 in all areas of the Marshes, excluding the Eastern Marshes in 2017–18, which was not inundated for the target duration. Demand was either partially met or not met in years in between, including in 2020–21 when it was partially met. Although around 145 GL of water passed Marebone in Aug–Oct, and around 125 GL in Oct to Dec, this demand was not fully met. Extreme dry conditions between 2017 and early 2020 meant that the volume of water was insufficient to achieve the required duration of inundation to support all vegetation types in all areas of the pink zone. Ideally these flows are provided 8 in 10 years but have only been met 3 in the last 9 years. This area requires water in 2021–22 to contribute to 8 in 10 year frequency, avoid damage, and to build resilience, including in Ramsar sites. This environmental demand has been assessed as moderate (for trees) to high (for groundcover).	Moderate to High	A high priority for CEW under moderate to high water resource availability scenarios, subject to water availability and conditions.	Moderate to High
	Red inundation zone (50,000 ha)	250 GL at Marebone over 3 to 5 months between June and April to inundate river red gum woodland, river cooba, inner coolibah woodland. Volume required to meet demand may vary depending on antecedent conditions.	Ideally: 1 in 3 years (Max interval: 4 to 7 years)	Demand met in 2016–17 and 2012–13 in all areas of the Marshes. However, as this flow has now not been met in the last four years the ideal frequency has now been exceeded, and water is needed in 2020–21. Therefore, the demand is considered high to critical.	High to Critical	Possible use under high or very high water resource availability scenarios. Would require other water sources to meet.	Low
	Orange and green inundation zones (81,000 to 145,000 ha)	400 to 700 GL at Marebone over 5 months between June and April to inundate outer river red gum (RRG) woodland, coolibah, and black box. Volume required to meet demand may vary depending on antecedent conditions.	Ideally: 1 in 4 years (RRG), or 1 in 8 years (other veg) (Max interval: 7 years (RRG) 20 years (other veg))	Demand last met in 2016–17 in all areas of the Marshes and previously in 2010–11. Some minor inundation occurred in 2011–12 and 2012–13. The condition of this area may be affected by low inflows and below average rainfall during extreme drought conditions. Demand is considered moderate to high, requiring water in 2021–22, particularly to maintain river red gum woodland, which is approaching the required frequency threshold.	Moderate to High	Low priority for use of CEW in 2021–22 and only able to contribute to this demand when coordinated with major flow event.	High
Lower Macquarie River (Marshes – Barwon River) Native fish habitat and dispersal Provides connectivity between Macquarie and Barwon catchments In-stream aquatic ecosystems and floodplain vegetation	In-stream aquatic ecosystems Fish Connectivity	**In-channel flows:** Minimum 20 ML/day at Bells Bridge for 45 days.	Ideally: annually (Max interval: 1 to 2 years)	Small in-channel flows were met in the lower Macquarie in each year between 2016–17 and 2018–19 (usually between Aug and Jan), and again in 2020–21 (between Jul and Jan). The lower Macquarie has experienced prolonged cease to flow conditions in many other years, particularly in 2019–20. These flows ideally occur annually and are required again in 2021–22. Therefore, the environmental demand has been assessed as high.	High	Possible use under low to moderate water resource availability scenarios, subject to tributary flows. Needs may be partially met by other flows (e.g. environmental water delivered to the Marshes).	High
	Fish Connectivity	System connectivity between the Macquarie and Barwon catchments: for example in-channel flow targeting minimum rates of 140 ML/day at Bells Bridge (minimum depth of 50 cm) to connect the lower	5 years in 10 (Max interval: 4 years)	A suitable connection between the lower Macquarie and Barwon rivers was achieved in 2016–17 and again in 2020–21, resulting from a combination of environmental water, rainfall, and natural flows. Based	High	High priority for CEW under moderate to very high water resource availability scenarios only,	Moderate to High

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)7	2021–22		Implications for future demands
		Flow/volume	Required frequency (maximum dry interval)		Environmental demands for water (all sources)	Potential Commonwealth environmental water contribution?	Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22
		Macquarie River and the Barwon River for a minimum of 28 days.		on flows at Bell's Bridge this demand may also have been partially met in 2017–18 and 2018–19. Ideally these connection flows are achieved 5 years out of 10, however, they have only been met 3 in the last 9 years. Therefore, water is required again in 2021–22, and the environmental demand has been assessed as high.		subject to suitable conditions and operational feasibility.	
	Fish Instream and riparian vegetation Connectivity	**Large freshes:** >700 ML/day at Bells Bridge for 5 days. Can occur at any time for large fresh 1 (LF1) (but ideally Jul to Sep), or Oct to Apr for large fresh 2 (LF2).	Ideally: LF1: 5 to 10 in 10 years (max. interval 2 years) LF2: 3 to 5 in 10 years (max. interval 4 years)	Over the last 9 years assessed, the demand for large freshes in the lower Macquarie has only been met once, in spring 2016–17, and partially met in 2012–13. These flows were not met in any other year over that time. Considering these flows are required more frequently, and the maximum interval for both Large Fresh 1 and 2 have now been exceeded, the environmental demand has been assessed as critical.	Critical	Possible use under high to very high water resource availability scenarios only, subject to suitable conditions and operational feasibility.	High
Unregulated Distributary creeks (Marra Creek Lower Crooked Creek) Native fish habitat In-channel and riparian habitat Connectivity with Barwon–Darling catchment	Fish In channel and riparian vegetation Increased frequency and duration of connectivity to Barwon–Darling	Baseflows and freshes to Marra Creek and/or the lower Crooked Creek. Volumes required dependent on which creeks are targeted. Some connectivity may be provided by replenishment flows.	Required frequency unknown (1 in 1 to 3 years based on key vegetation)	Demand was met in 2016–17 and 2012–13, with stock and domestic replenishment flows partially contributing to demand in some creeks in years in between. Some flows were recorded in Crooked and Marra creeks following rainfall and delivery of stock and domestic water during 2021–22, partially meeting this demand. Marra Creek received flows in August and March/April, but had otherwise minimal flows (total around 12 GL at Carinda and 8.5 GL at Billybingbone to early April). Crooked Creek received more persistent but low flows (average 31 ML/day), with a total of around 10 GL at the Profile Gauge to early May. Considering this demand has not been fully met since 2016–17, water is required in the next 1 to 2 years. Therefore, the environmental demand has been assessed as moderate to high.	Moderate to High	Possible use of CEW under moderate to very high water resource availability scenarios, subject to water availability and operational feasibility.	Moderate
Prioritised critical refuge habitat – various locations as required in exceptional circumstances Refuge habitat Native fish (e.g. olive perchlet), water rat and tortoise survival Water quality	Fish (all guilds) and other aquatic dependent biota refuge Aquatic ecosystems	Baseflows to replenish significant refuge pools at high risk of drying down in exceptionally dry circumstances. Volumes required are likely to be relatively small, but dependent on which refuge pools are targeted.	As required only during extremely dry conditions	Demand expected to be met by essential regulated supplies in all but the most extreme dry years. While extreme dry conditions persisted for much of 2019–20, conditions have continued to improve since, and regulated supplies, rainfall and tributary flows have maintained critical habitat in 2020–21. Therefore, the demand for water to support refuge pools in 2021–22 has been assessed as low.	Low	Expected to be met by essential regulated supplies so a low priority for the use of CEW. Likely only to be used under a very low water availability scenario, subject to environmental water being available for delivery.	Variable depending on climatic conditions: If extreme dry conditions persist, demand may be Critical; Should conditions become significantly wetter, demand may reduce to Low or Very Low

Notes: The Macquarie Marshes Ramsar site includes parts of the northern, southern and eastern areas of the Macquarie Marshes. The Ramsar site contains a range of habitats including core areas of semi-permanent wetlands, such as forests and woodlands, reed beds, marshes, rushlands and open lagoons. These vegetation types have been identified as critical components of the Ramsar site. By maintaining this wetland vegetation, other critical components of the Ramsar site may be supported, including waterbird breeding and foraging habitat.
Contributions to meet Barwon–Darling environmental requirements may be considered subject to water availability, antecedent conditions and environmental demands (see chapter 9 of the CEWO Water Management Plan 2021–22).
Information on environmental demands has been sourced from the Macquarie-Castlereagh Long-Term Water Plan (NSW DPIE 2020), Barma Water Resources et al. (2011), NSW DECCW (2010), MDBA (2012), Thomas et al. (2015), and Torrible et al. (2011), in conjunction with advice from NSW DPIE – EES and NSW DPI – Fisheries.
All watering history sourced from NSW DPIE – EES and NSW DPI – Fisheries, and data from the following gauges (WaterNSW 2021d) – 421090 Macquarie River at d/s Marebone Weir, 421001 Macquarie River at Dubbo, 421147 Macquarie River at Pillicawarrina, 421088 Marebone Break at d/s Regulator, 421107 Marra Creek at Billybingbone Bridge, 421097 Marra Creek at Carinda Road, 421146 Gum Cowal at Bifurcation, 421907 Macquarie River at Brewon, 421127 Macquarie River at Baroona, 421016 Crooked Creek at Profile, 421012 Macquarie River at Carinda (Bells Bridge), 421022 Macquarie River at Oxley Station.

Key

Potential watering in 2021–22

High priority for Commonwealth environmental watering (likely to receive water even under low water availability)

Secondary priority for Commonwealth environmental watering (watering to occur only if natural trigger is met, or under moderate to high water resource availability); or water demand likely to be met via other means

Low priority for Commonwealth environmental watering (under high to very high water resource availability); or unable to provide water because of constraints or insufficient water

Environmental demands (demand is considered at a generalised scale; there may be specific requirements that are more or less urgent within the flow regime)

High to critical demand for water (needed in that particular year or urgent in that particular year to manage risk of irretrievable loss or damage)

Moderate demand for water (water needed in that particular year, the next year, or both)

Low demand for water (water generally not needed in that particular year)

8.5 Water delivery in 2021–22

Based on the demand for water for the environment, water availability (supply), and catchment conditions, the overall purpose for managing Commonwealth water for the environment in the Macquarie River Valley in 2021–22 is to protect, maintain, and where possible improve, the health and resilience of aquatic ecosystems in the Macquarie River and Marshes, and other important sites in the valley as required.

Consistent with the demands and purpose identified, the CEWO is considering supplying water for the environment to the following actions in 2021–22 to build on improvements seen in 2020–21 and continue drought recovery in the Macquarie River and Marshes.

Deliver water to the Macquarie Marshes in late winter and spring to target the inundation of 9,000 to 19,000 ha (blue, purple and some pink inundation zones – Map MV2) of core wetland vegetation (reeds, water couch, mixed marsh, inner river red gum, which are critical components of the Ramsar site). Delivery of water for the environment to the Macquarie Marshes would:

- support further wetland recovery
- maintain the current extent of water couch and mixed marsh in good condition (key foraging areas)
- support and improve numbers of small-bodied native fish (a key food source)
- support vegetation condition and structure at colony sites (where possible) to improve 'event readiness' for future colonial bird breeding.

Deliver water to the mid-Macquarie River in spring 2021 to support the recruitment of native fish and population recovery. Delivery of water for the environment to the mid-Macquarie River would:

- support the breeding of in-channel specialists (e.g. Murray cod)
- support the condition and survival of native fish that were bred in spring 2020.

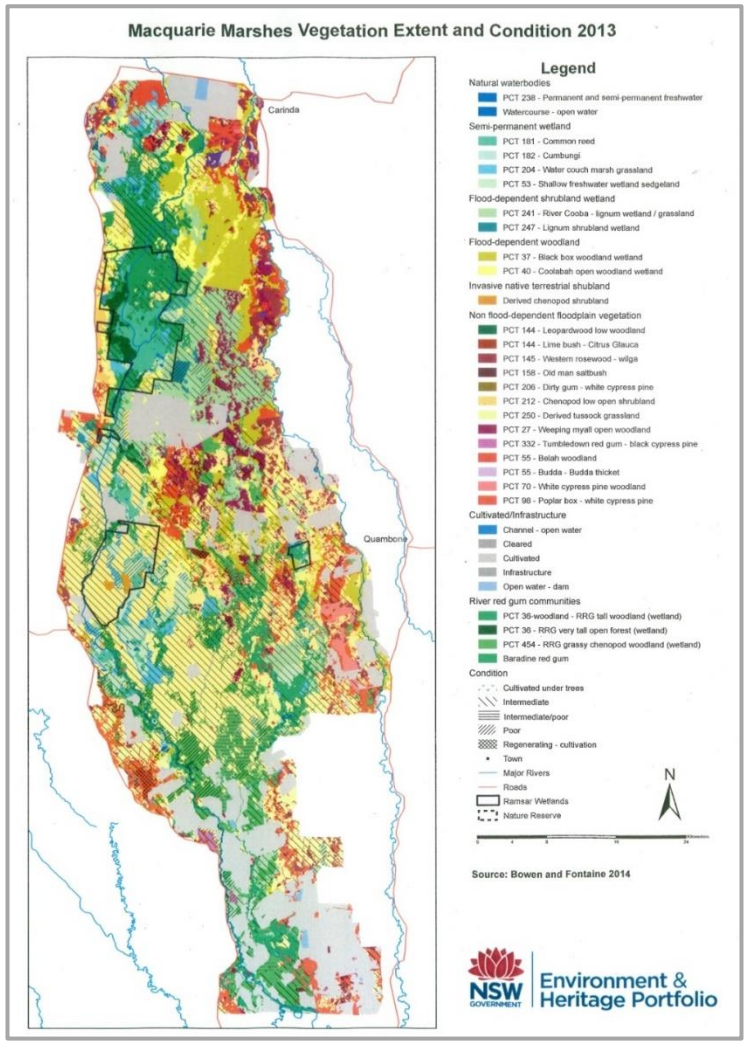
Depending on water availability and conditions, water for the environment may also be delivered to:

- support viable colonial waterbird breeding events, should they occur naturally
- connect the lower Macquarie and Barwon rivers to support the movement and dispersal of native fish (e.g. golden perch) as opportunities arise.

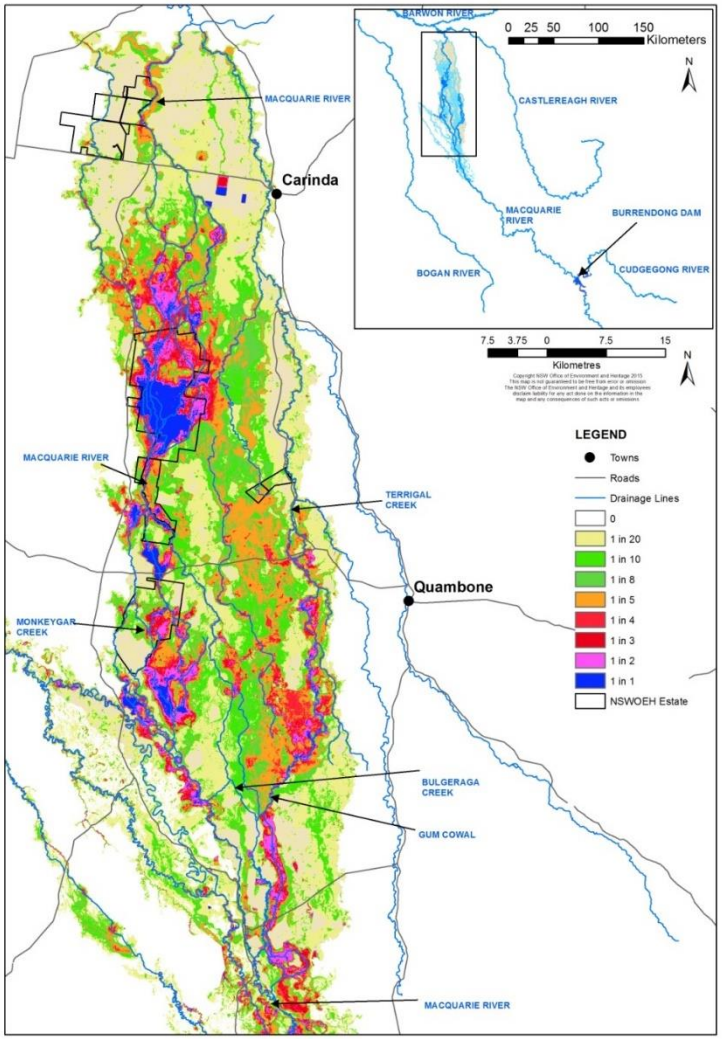
There is a critical demand to provide flows to support native fish flow specialist movement and breeding in the mid-Macquarie River, and large freshes in the lower Macquarie. Similarly, there is a high to critical demand for water to inundate up to 50,000 ha of the Macquarie Marshes. However, there is currently insufficient water for the environment available to meet these demands. The capacity to meet these demands would depend on an increase in water availability and suitable tributary inflows.

As in previous years, the use of Commonwealth and NSW environmental water in the Macquarie Valley will be adaptively managed together throughout 2021–22, in response to changing water resource availability and environmental conditions and demands.

Map MV2 a) Macquarie Marshes vegetation mapping and b) Inundation frequencies, Macquarie Marshes, 1988 to 2008



a) Source: Bowen & Fontaine 2014



b) Source: Thomas et al. 2015

8.6 Monitoring and lessons learned

8.6.1 Monitoring

In the Macquarie River Valley, monitoring is primarily undertaken by NSW agencies including NSW DPIE – EES (vegetation, waterbirds and frogs), NSW DPI – Fisheries (native fish), and WaterNSW (hydrology and flow delivery data). The CEWO has also funded a number of short-term intervention monitoring projects to evaluate the environmental responses of native fish, waterbirds, and freshwater mussels.

Learn more about monitoring activities funded by the CEWO in the Macquarie Valley.

8.6.2 Lessons learned

Outcomes from monitoring and lessons learned in previous years are a critical component for the effective and efficient use of Commonwealth water for the environment. These learnings are incorporated into the way environmental water is managed.

Key findings from fish, flow, frog and waterbird monitoring in the Macquarie Valley are summarised in Table MV2.

Table MV2 Key lessons learned in Macquarie Valley

Theme	Lessons learned
Native fish [a]	• Spring/early summer delivery has been associated with peaks in breeding of some small-bodied opportunistic fish species (e.g. Australian smelt, un-specked hardyhead, Murray-Darling rainbowfish), particularly on the receding tail of flows, or during sustained periods of increased flow. • Spring/early summer delivery is also likely to support recruitment of native species such as Murray cod and freshwater catfish, by increasing flows and boosting in-stream productivity in the river.
Frogs [b]	• High frog abundance reflect patterns of wetland inundation, high aquatic plant growth and warm survey temperatures, which make the conditions highly conducive to frog breeding activity and frog detection. • Local weather and inundation extent influence the activity of some species. Increased inundation increases the number of sites with conditions suitable for breeding, and the calling of flow-responsive species. • Flooding events are very important for increasing overall abundance of flow-responsive species, by supporting breeding and enabling frogs to move between wetlands. • Longer duration of inundation is important for frogs to complete metamorphosis. The highest breeding success has occurred in years with longer wetland duration (2016, 2018 and 2020). Maintaining water levels in the Marshes into late November increases frog recruitment.
Waterbirds [c]	• Delivery in winter/spring (into summer if possible) provides suitable wetland habitat for nationally threatened and internationally recognised migratory species and coincides with warmer temperatures and peak activity for waterbirds and their food supplies. • A slow steady contraction of inundated area is preferable, particularly for wading species. • Delivery to parts of the Marshes during dry conditions supports a diverse range of waterbirds and provides important feeding and refuge habitat.
Connectivity [d]	• Connectivity between Macquarie and Barwon rivers can be achieved using water for the environment and is important for allowing the movement of native fish between rivers for spawning, dispersal and recruitment.
Other aquatic animals [e]	• Persistence of healthy populations of freshwater mussels (particularly *Alathyria jacksoni*, which is endemic to the Murray–Darling Basin) is

Theme	Lessons learned
	dependent on permanent river reaches and waterholes. The provision and protection of minimum baseflows is vital to their persistence, and for populations to recover from the significant losses experienced during the 2017–20 drought. • Recolonisation of freshwater mussels is dependent on the recovery and movement of native fish populations through the northern Basin. Therefore, the minimum flow requirements of native fish also need to be provided to support recovery of both fish and mussel populations.

a Stocks et al. (2015), Davis, Asmus & Stocks (2017). **b** Ocock & Spencer (2017), Ocock & Spencer (2018), Walcott et al. (2019), NSW DPIE – EES (2021). **c** Spencer et al. (2016), McGinness et al. (2017), Brandis (2017), NSW OEH (2019). **d** Davis, Asmus & Stocks (2017), WaterNSW (2017). **e** Sheldon et al. (2020).

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9 Barwon-Darling River Water Plan

9.1 Region overview

9.1.1 River system

The Barwon-Darling River upstream of Menindee Lakes contains a mix of ecosystems including instream habitats, riparian landscapes, and floodplain watercourses. This range of ecosystems help support Commonwealth and NSW-listed threatened ecological communities, threatened, endangered and migratory waterbirds, and threatened native fish species (NSW DPIE 2020a).

The ecology of the Barwon-Darling River is driven by flows that connect the instream benches, cut-off channels, anabranches, floodplains, and wetlands (NSW DPIE 2020a). These flows support nutrient cycling, replenish refuge pools to maintain water quality, and trigger movement and breeding of native fish and waterbirds (NSW DPIE 2020a).

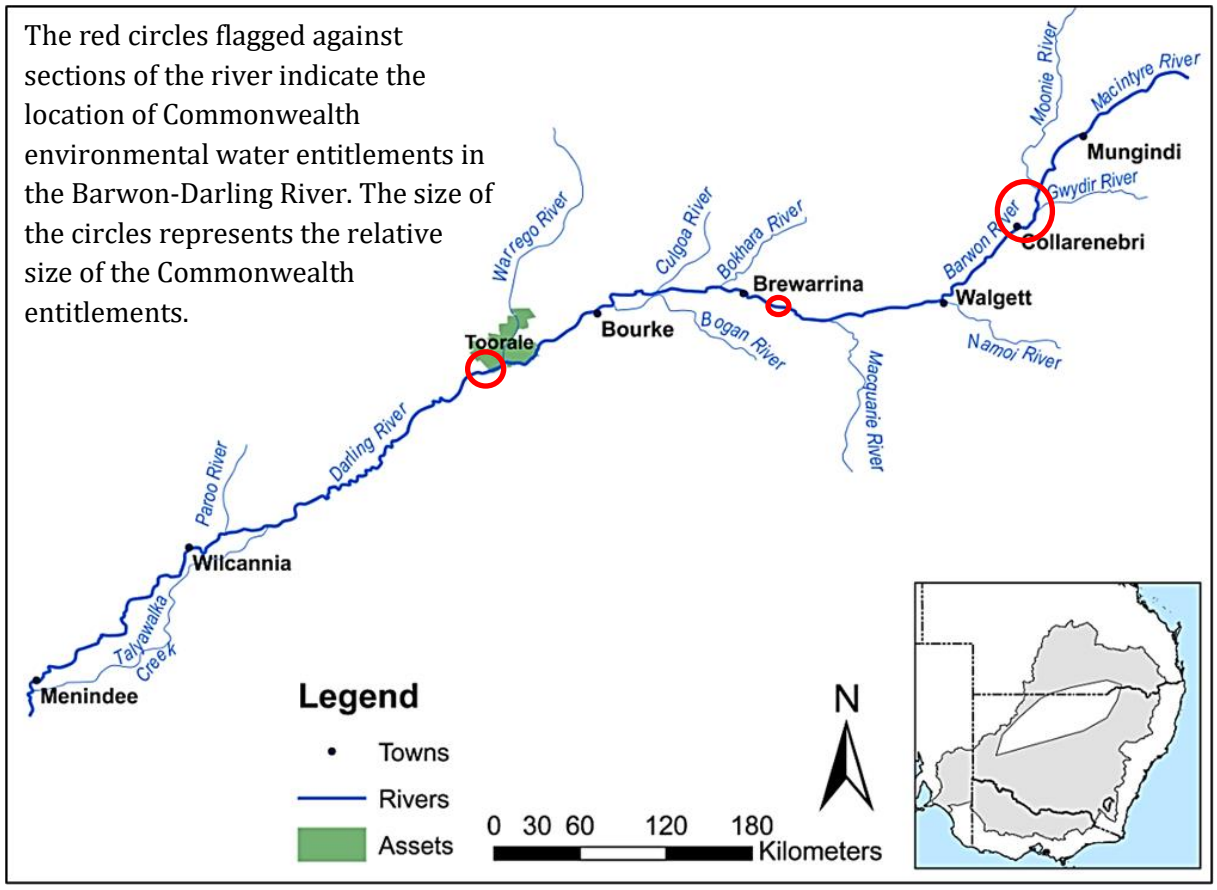
The Barwon-Darling River connects the northern and southern basins. Connection between the two halves of the Basin is critical to maintain and improve the health and condition of native fish (NSW DPIE 2020a). Successful spawning and dispersal of native fish species within and across the Barwon-Darling River enhances the resilience of iconic native fish species such as golden perch (NSW DPIE 2020a).

Commonwealth holdings of water for the environment in the Barwon–Darling are comprised of unregulated entitlements. These entitlements can only be sourced as a share of an unregulated flow event, determined by entitlement conditions and each entitlement's Individual Daily Extraction Component (IDEC). The list of Commonwealth unregulated entitlements held along the Barwon–Darling River is shown in Table BD1, with their location shown in Map BD1.

Table BD1 Unregulated Commonwealth environmental water entitlements along the Barwon–Darling River

Water Access Licence (WAL)	Water Management Zone	Class	Long-term Average Annual Allocation (ML)	Individual Daily Extraction Component (ML)
37810	Boomi River Confluence to Mogil Mogil Weir Pool	B	3,731	307.4
33619	Downstream of Mogil Mogil to Collarenebri	B	9,252	762.2
33798	Downstream of Mogil Mogil to Collarenebri	C	6,963	1247
37461	Boorooma to Brewarrina	B	323	26.6
33701	Bourke to Louth	A	51	2.7
33704	Bourke to Louth	A	22	1.1
33784	Bourke to Louth	B	1,566	129
35944	Bourke to Louth	B	1,188	97.9
35943	Bourke to Louth	C	5,535	991.3

Map BD1 Barwon–Darling catchment



Source: Department of Agriculture, Water and the Environment (n.d.)

There are no major public water storages along the Barwon–Darling River, although large headwater storages exist in several tributaries. There are also large private off-river storages that store water diverted or pumped from the Barwon-Darling River or harvested from floodplain run-off. There are 15 major weirs along the main stem of the Barwon–Darling River from Mungindi to upstream of Menindee Lakes, which create a series of barriers for fish passage (DPIE 2020a). The Brewarrina and Walgett weirs currently contain effective fishways, with plans also progressing for improved fish passage at Wilcannia Weir as part of the proposed upgrade works at the weir. The NSW fish for the Future: Reconnecting the Northern Basin project has commenced as part of the Northern Basin Toolkit and aims to reinstate fish passage at the other barriers along the system in coming years.

9.1.2 Traditional Owners

The rivers and waterholes of the Barwon–Darling River hold significant spiritual and cultural importance for Aboriginal people from several nations including the Barkandji, Murrawarri, Eahlayi, Ngemba, Ngiyampaa and Wailwan peoples. The Commonwealth Environmental Water Office (CEWO) respectfully acknowledges these Nations, their Elders past and present, as the Traditional Custodians of the lands on which this chapter is focused.

9.1.3 Important sites and values

The Barwon–Darling River channel connects the rivers, lakes and wetlands in the northern Murray–Darling Basin as well as providing connectivity with the southern Basin (NSW DPIE

2020a). Connectivity of the Barwon–Darling River has been listed in the Basin environmental watering priorities in recent years. The Barwon–Darling River provides a critical dry period refuge and movement corridor for fish and waterbirds, as well as habitats for other aquatic species including turtles, mussels, river snail and shrimp (NSW DPIE 2020a). Connectivity along the length of the Barwon-Darling River is particularly important for communities of native fish and other aquatic species.

Diverse in-stream habitats including channels, deep pools, riffles, benches, snags, gravel beds and aquatic and riparian vegetation support a significant native fish community (NSW DPIE 2020a). There are more than 1,100 refugial waterholes between Mungindi and Wilcannia (NSW DPI 2015).

The fish community within the Barwon–Darling River includes 15 native species and up to five non-native species (NSW DPIE 2020a). Silver perch is listed as critically endangered and Murray cod as vulnerable under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. The system is likely to contain remnant populations of olive perchlet, purple spotted gudgeon and freshwater catfish, all of which are listed under relevant threatened species legislation within NSW. Other important species found in the Barwon–Darling River that are not widely dispersed across the Basin include Rendahl's tandan, Hyrtl's tandan, spangled perch, Darling River hardyhead and desert rainbowfish (NSW DPIE 2020a).

The Barwon–Darling River also supports several species of river mussels, including *Alathyria jacksoni*, which is highly responsive to changes in low and zero flows (NSW DPIE 2020a).

9.1.4 Stakeholder engagement

The CEWO works with the following organisations and groups to collect and collate relevant monitoring information and evaluation results that facilitates adaptive management and changing our practices where needed:

- NSW agencies in particular the Water group and Environment, Energy and Science group in the Department of Planning, Industry and Environment (DPIE) as well as Department of Primary Industries (DPI) - Fisheries
- the Murray–Darling Basin Authority
- regional organisations, local groups and landholders
- research organisations.

This continual review of information and outcomes is helping to build knowledge about the best way to get positive outcomes across the Barwon–Darling River, based on what does and does not work across the system.

The CEWO funds a Monitoring, Evaluation and Research program, that includes a selected area at the junction of the Warrego and Darling rivers. This provides additional information to inform adaptive management.

9.2 Environmental objectives

Based on long-term environmental objectives in the Basin Plan, state long-term watering plans, site management plans, and best available knowledge, the following objectives are relevant for environmental watering in the Barwon–Darling River.

Because of the unregulated nature of the Barwon–Darling River, the objectives that can be achieved in a particular year may vary and are highly dependent on catchment conditions and rainfall events within the systems tributaries. These objectives will continue to be revised as part of the commitment of the CEWO to adaptive management. The objectives are:

- Connectivity – Support longitudinal connectivity, along the Barwon-Darling River, and lateral connectivity within the river network and between the rivers and their floodplains.
- Vegetation – Maintain the condition, growth and survival of riparian, in-channel, floodplain and wetland vegetation.
- Waterbirds – Increase waterbird abundance and maintain species diversity by supporting naturally triggered breeding events, and maintaining suitable refuge, feeding and breeding habitat.
- Native fish – Prevent loss of native fish species and improve population structure and distribution, by supporting opportunities for movement, dispersal, reproduction, and recruitment.
- Other vertebrates and invertebrates – Support opportunities for the reproduction and recruitment of other native aquatic species, including frogs and turtles.
- Processes/water quality/resilience – Support key ecosystem functions and promote productivity, maintain water quality in channels and pools, and maintain drought refuge habitat.

9.3 First Nations environmental watering objectives

The CEWO is committed to working with First Nations groups to better understand their objectives. The CEWO will use environmental flows to contribute to these objectives where possible and where this is consistent with the Commonwealth Environmental Water Holder's statutory responsibility of protecting and restoring environmental assets in the Basin (see Chapter 2).

Representatives of the First Nations peoples of the Barwon-Darling have identified environmental objectives for their country for 2021-22 (Table BD2). These objectives have been developed through a collaborative process under the Barwon-Darling First Nations Environmental Water Objectives and Guidance Pilot Project. The Project was led by NSW Department for Planning, Industry and Environment: Environment, Energy and Science (DPIE EES) with input co-ordinated by Northern Basin Aboriginal Nations (NBAN) staff. Discussion held through the Project involved:

- NBAN Delegates from the Ngemba, Euahlayi, Murrawarri, Ngiyampaa First Nations
- Staff from NSW DPIE EES and the Commonwealth Environmental Water Office.

These discussions identified objectives across a range of sites and values. These discussions have also identified sites of special significance for First Nations across the Barwon-Darling System.

Some of these objectives are potentially outside the scope of Commonwealth water for the environment because the portfolio is only able to contribute during large infrequent flow events.

For other objectives, the link between water for the environment and the site or issues is not well understood and needs further consultation.

Table BD2 First Nations environmental objectives in the Barwon–Darling, 2021–22

Nation	Site	Objective	Values	Indicator Species
Ngemba	Ngemba (Brewarrina) Fish Traps	To always have flows moving through the site.	Cultural heritage site	N/A
	Yanda Creek,	To have flows moving through the sites during cooler months.	Connection to the Barwon-Darling River	N/A
	Mulga Creek,			
	Gundabooka (National Park) (beside Yanda Creek)		Cultural heritage site	
	Byrock (beside Mulga Creek)		Cultural heritage site	Wedge-tail eagle, kangaroo, crayfish, turtle, black duck, shrimp, crayfish, turtle, echidna, sand goanna, bronzed wing pigeons and mulga trees.
Euahlayi	Collymongle	To always have flows moving through the site.	Ceremonial site, sacred women's site, and scarred trees.	Coolabah, red gum, crayfish, yellowbelly, and Murray cod.
	Eurool	N/A	Woman's site	Red gum, coolabah, black box, ducks, kangaroos, ibis, pelican, crayfish, and mussels
	Fish Holes Lagoon	To always maintain some water in the lagoon	Mussel dreaming site	Mussel, pelican, duck, and shrimp
	Merchadool and riparian areas along the Barwon State Conservation area	To see water flow through at the site during winter and spring	Crayfish breeding site	Ducks, crayfish, tea trees, yellowbelly, and cod
	Area surrounding Yambie Lagoon	To see water flow through at the site during August - October	Site of black swan dreaming story	Waterbirds including swans, ducks, ibis, pelicans, cranes
Murrawarri	May's Bend (Darling River) – floodplain channel connecting the two ends of the bend	To enhance flows through the channel	Spiritual connection to red gums	Red gum, coolabah, blackbox, yellowbelly, cod, catfish, mussels
Ngemba/ Ngiyampaa	North Bourke Bridge lagoon	To ensure that when there is rainfall, that the lagoon has water flowing through it	Vegetation used for toolmaking	Black cockatoo, shrimp, yellowbelly, cod, bream, red gum, coolabah, nardoo, bulrush, and pin rush.

9.4 Recent conditions and seasonal outlook

9.4.1 Recent conditions and environmental water use

Like much of the northern Basin, the Barwon–Darling River experienced very hot and dry conditions in the drought between January 2018 and January 2020. The two highest annual average maximum temperatures at Brewarrina for the 83 years of record occurred in 2018 and 2019. Rainfall was well below average. Flows along the River during this period were also

generally low, with long reaches of the Barwon–Darling ceasing to flow for extended periods. The hot and dry conditions resulted in the Darling River downstream of Bourke not flowing for over 430 days between September 2018 and November 2019. Other river reaches such as downstream of Collarenebri and upstream of Wilcannia experienced low or no flow periods of over 170 days and 200 days respectively. These long periods of low or no flow reduced the number and quality of drought refuge pools within the Barwon–Darling River. This is likely to have had a significant impact on the aquatic communities of the system. Exceptions to these dry conditions were:

- Small flow events moving through the system in autumn 2018, winter 2019 (river reaches downstream of the Warrego/Darling River junction to just downstream of Wilcannia), and late spring 2019.
- Environmental flows from the Northern Connectivity Event along both the Barwon-Darling River to the Menindee Lakes during autumn and winter 2018, and Northern Fish Flow moving along the full-length of the Barwon River during autumn and winter 2019.

During late summer and early autumn 2020 widespread rainfall occurred across most of the northern Basin with the upper parts of northern Basin valleys recording more than 300 mm of rainfall during January and February. This rainfall generated significant flows in most Barwon–Darling tributaries and corresponding inflows into the Barwon-Darling River. The contribution each tributary made to flows along the Barwon-Darling River varied, with the Condamine-Balonne contributing the most (205 gigalitres as measured at the end of system gauges on the Culgoa and Bokhara rivers) (WaterNSW 2021a).

Between September and December 2020, flows across the Barwon–Darling River declined, with most river reaches experiencing extended cease to flow periods. In January 2021, Commonwealth and planned NSW water for the environment was provided to the Barwon–Darling River as part of the Northern Waterhole Top–up. The Northern Waterhole Top–Up originally targeted 230 river kilometres of the Barwon River between Mungindi and Walgett, where refuge habitat was declining in quality. Water for the delivery was sourced from the Gwydir and Border Rivers catchments. Summer rain helped extend the Northern Waterhole Top–Up well beyond its original target range, enabling some of this water to reach the Menindee Lakes. In addition to connecting river reaches along the Barwon-Darling River, the flow provided connectivity benefits between both the Gwydir and Macintyre (Border Rivers) systems and the Barwon River.

During the 2020–21 water year NSW implemented active management arrangements in the Barwon–Darling for the first time. These arrangements enabled held environmental water delivered from the Gwydir and Border Rivers systems, as part of the Northern Waterhole Top-up, to be protected from extraction along the Barwon–Darling.

Following widespread rainfall in March 2021, significant unregulated flows entered the Barwon–Darling River. Consistent with active management arrangements, Commonwealth water for the environment remained instream by activating a range of water licences to enhance flows along the Barwon-Darling River. While Commonwealth water for the environment made up only a part of the overall flows, it helped reconnect parts of the Barwon-Darling River and enabled fish to move and breed. Commonwealth water for the environment also helped connect the Barwon–Darling and Lower Darling systems.

Details of previous Commonwealth environmental water use in the Barwon–Darling are available on the CEWO website.

9.4.2 Seasonal outlook

According to the Bureau of Meteorology outlook in June 2021, above median rainfall is forecast across the Barwon–Darling from July to September 2021(BoM 2021a). Maximum temperatures are forecast to be below average over the coming months (BoM 2021b, c).

This forecast suggests weather patterns may further improve the condition of the Barwon–Darling system. However, given the variability of the climate of the northern Basin, it is also possible that dry conditions may emerge over coming months, which may hinder ecological recovery.

9.4.3 Water availability

Unregulated held environmental water entitlements

The amount of water for the environment from unregulated entitlements within the Barwon–Darling system depends on the nature of flow events that occur. The *Water Sharing Plan for the Barwon–Darling Unregulated and Alluvial Water Sources 2012* outlines the rules around managing unregulated entitlements. These rules provide opportunistic access to unregulated river flows when triggered. Each entitlement will contribute to restoring in-stream flows reflecting its flow class, daily take rates and location.

The amount of water available in each water year varies, with above average volumes of Commonwealth water for the environment available in wet years and very small or no volumes of water available during dry times.

Environmental water entitlements held in tributary systems

In addition to holdings within the Barwon–Darling River, held water for the environment delivered from within tributary systems of the Barwon–Darling can be delivered to the Barwon-Darling River itself to enhance environmental outcomes. During the 2020–21 water year, active management enabled water for the environment delivered from the Border Rivers and Gwydir systems to be protected from extraction and maximise environmental outcomes.

Regulated and supplementary entitlements of water for the environment in tributary systems of the Barwon–Darling can be delivered to increase flows in the Barwon-Darling River. The Northern Connectivity Event, Northern Fish Flow and Northern Waterhole Top-up were examples of this type of use. Moderate resource availability is forecast in several regulated upstream storages. This may provide an opportunity for regulated releases to be used to maintain the condition of environmental assets in the Barwon–Darling should dry conditions return during the 2021–22 watering year.

Policies to support the use of water for the environment

Recent amendments to the *Water Sharing Plan for the Barwon-Darling River Unregulated River Water Source 2012* included a range of new management arrangements put in place for the 2020–21 water year (NSW DPIE 2020b). These elements are important in protecting further ecologically significant elements of the flow regime such as low flows and protecting Commonwealth water for the environment.

One of the new management arrangements put in place for the 2020–21 water year was active management. Between January and June 2021 active management arrangements were operated to ensure Commonwealth held environmental water was protected from downstream extraction. In addition to protecting held environmental water, these arrangements enabled these volumes to be measured daily as flows moved through the Barwon–Darling.

9.4.4 Environmental demands

Prior to the rainfall and flows that occurred over summer and autumn of 2020-21, the preceding four years had been the driest on record for many Barwon-Darling River tributaries. During these extended dry conditions most environmental demands for the Barwon-Darling River were not met.

Rain in December 2020 to January 2021 saw flows move along the Barwon-Darling River replenishing refuge pools and connecting a range of instream habitats. Significant flows into the Barwon-Darling River during March enabled most environmental demands to be met for 2020-21 and helped the river transition from dry to moderate condition.

The environmental water demands for assets in the Barwon–Darling in 2020–21 are represented in Table BD3. These demands are based on the Barwon-Darling Long-Term Watering Plan, prepared by NSW for the Barwon–Darling River.

Table BD3 Environmental demands and watering priorities, 2021–22, and outlook for coming year, Barwon-Darling catchment

Environmental assets	Target values	Indicative demand (for all sources of water in the river)		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	Required frequency (maximum dry interval)		Environmental demands for water (all sources)	Potential Commonwealth environmental water contribution?	Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22
Refuge pools along the Barwon-Darling River Refuge habitat Native fish Water quality Aquatic invertebrate species	Critical drought refuge habitat Native fish maintenance and survival Maintenance and survival of key invertebrate fauna	**Cease-to-flow Triggers** 0 ML/day (Barwon River at Dangar's Bridge, near Walgett) for a maximum of 45 days during very dry conditions 0 ML/day (Darling River at Bourke) for a maximum of 100 days during very dry conditions 0 ML/day (Darling River at Louth) for a maximum of 110 days during very dry conditions 0 ML/day (Darling River at Wilcannia) for a maximum of 120 days during very dry conditions	Cease to flow period should not exceed periods of 45 to 120 days	The Northern Connectivity Event in April–May 2018 assisted in replenishing refuge pools along the entire Barwon–Darling River. With extremely dry conditions during the 2018–19 water year, the Northern Fish Flow in April to June 2019 assisted in replenishing refuge pools along the Barwon River to just downstream of the Culgoa junction. Reflecting the extremely dry conditions that persisted through most of 2017-18, 2018–19 and 2019–20, cease-to-flow triggers were exceeded at Bourke, Louth and Wilcannia. Rainfall events during late summer to early autumn 2020 helped replenish pools along the River. Between September and December 2020, flows across the Barwon–Darling River decreased, with most river reaches experiencing extended cease to flow periods. Cease-to-flow triggers were exceeded in sections of the Barwon River upstream of Dangar's Bridge, near Walgett. In January 2021, water for the environment was provided to the Barwon–Darling River as part of the Northern Waterhole Top–up. The combination of tributary inflows and the Northern Waterhole Top–up event helped break cease to flows periods along most reaches of the Barwon-Darling River.	High	A high priority for CEW under dry to very dry conditions. Protection of natural flow events through activation of unregulated environmental water entitlements held along the Barwon-Darling River is a high priority. Using regulated environmental water entitlements to respond to extended periods of no flow may be an option depending on account volumes in key regulated systems.	High
		Very Low flows >95 ML/day for a total of 230 days in a year at Dangar's Bridge (near Walgett) on the Barwon River >105 ML/day for a total of 180 days in a year at Bourke on the Darling River >70 ML/day for a total of 180 days in a year at Louth on the Darling River >30 ML/day for a total of 175 days in a year at Wilcannia on the Darling River	Every year	These flows help replenish refuge pools along the Barwon–Darling River. Over the last 4 years the requirements for very low flows have been met 2 times. Flow events during late summer and autumn 2021 moved the system to a moderate condition. However, the extremely dry conditions that persisted for most of 2018–19 and 2019–20 mean the requirement for very low flows across the system remains a high priority.	High	A high priority for CEW under dry to very dry conditions. Protection of natural flow events through activation of unregulated environmental water entitlements held along the Barwon-Darling River is a high priority. Using regulated environmental water entitlements to respond to extended periods of no flow may be an option depending on account volumes in key regulated systems.	High
In-stream habitats (pools channels benches, snags, and gravel beds) along the Barwon-Darling River Aquatic habitat Native fish Aquatic invertebrate species Water quality	Enabling native fish to access in-stream habitats Native fish movement Maintaining the condition/quality of in-stream habitat	**Baseflows** >320 ML/day for a total of 150 days in a year at Dangar Bridge (near Walgett) on the Barwon River >500 ML/day for a total of 135 days in a year at Bourke on the Darling River >450 ML/day for a total of 135 days in a year at Louth on the Darling River >350 ML/day for a total of 145 days in a year at Wilcannia on the Darling River	Every year	These flows provide a flow depth to support movement for small and medium bodied fish as well as assist in managing water quality issues (e.g., destratification of waterholes and blue green algal blooms). During dry years like the 2017–18 water year, held environmental water delivered from tributaries systems (through watering actions like the Northern Connectivity Event) can assist in achieving these environmental water requirements. Over the last 4 years, baseflow requirements across the Barwon–Darling River have generally not been met. The exception to this was the 2020-21 water year when all baseflow requirements were met. Due to the extent of dry periods over the last 4 water years the need for baseflows across the Barwon–Darling River is a high priority.	High	A high priority for CEW under dry to very dry conditions. Protection of natural flow events through activation of unregulated environmental water entitlements held along the Barwon-Darling River is a high priority. Using regulated environmental water entitlements to respond to extended periods of no flow may be an option depending on account volumes in key regulated systems	High

Environmental assets	Target values	Indicative demand (for all sources of water in the river)		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	Required frequency (maximum dry interval)		Environmental demands for water (all sources)	Potential Commonwealth environmental water contribution?	Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22
Native fish habitat and aquatic communities along the Barwon-Darling River Aquatic habitat Aquatic invertebrate species Water quality Breeding opportunities for native fish	Providing native fish with spawning and recruitment opportunities	**Small Fresh 1** >700 ML/day for at least 10 days on the Barwon at Dangar's Bridge near Walgett ideally in Oct to April (but can occur at any time). >1,500 ML/day for at least 10 days on the Darling at Louth ideally in Oct to April (but can occur at any time). >1,400 ML/day for at least 10 days on the Darling at Wilcannia ideally in Oct to April (but can occur at any time).	Every year	Small fresh 1 flow along the Barwon-Darling River have occurred 2 out of the last 4 years (2019-20 & 2020-21). Small fresh 1 flow seek to provide opportunities for fish movement across each water year and are a moderate to high priority because native fish communities are still in a recovery phase.	Moderate to High	A high priority for CEW under dry to moderate conditions. Protection of natural flow events through activation of unregulated environmental water entitlements held along the Barwon-Darling River is a moderate to high priority.	Moderate to High
		Small Fresh 2 700 to 6,500 ML/day for at least 14 days on the Barwon at Dangar's Bridge near Walgett in October to April. 1,500 to 15,000 ML/day for at least 14 days on the Darling at Bourke ideally in October to April.	5 to 10 years in 10 (overall, 75% of years)	Small fresh 2 flows seek to support spawning opportunities for native fish - preferred temperature range for fish spawning, >20°C for most native fish and >18°C for Murray cod). Small fresh 2 flows along the Barwon River have occurred 2 out of the last 4 years (2019-20 & 2020-21). Along the Barwon-Darling River the frequency of small fresh 2 events have generally been met within the specified range. However, small fresh 2 flows are moderate priority because native fish communities are still in a recovery phase.	Moderate	A moderate priority for CEW under all water resource availability scenarios. Protection of natural flow events through activation of unregulated environmental water entitlements held along the Barwon-Darling River is a secondary priority.	Moderate

Note: Data and information from NSW Department of Planning, Industry and Environment and WaterNSW real time data website (WaterNSW 2021a, b) has informed the watering history in the above table. The Barwon–Darling Long-Term Water Plan (NSW DPIE 2020a) describes the environmental water requirements (EWRs) needed to achieve the specified ecological objectives. The EWR's defined within the Barwon-Darling River Long-Term Water Plan have been used to inform indicative environmental demands for key assets located within the Barwon-Darling River.

Key

Potential watering in 2021–22

- High priority for Commonwealth environmental watering (likely to receive water even under low water availability)
- Secondary priority for Commonwealth environmental watering (watering to occur only if natural trigger is met, or under moderate – high water resource availability); or water demand likely to be met via other means
- Low priority for Commonwealth environmental watering (under high – very high water resource availability); or unable to provide water because of constraints or insufficient water

Environmental demands (demand is considered at a generalised scale; there may be specific requirements that are more or less urgent within the flow regime)

- High to critical demand for water (needed in that particular year or urgent in that particular year to manage risk of irretrievable loss or damage)
- Moderate demand for water (water needed in that particular year, the next year, or both)
- Low demand for water (water generally not needed in that particular year)

9.5 Water delivery in 2021–22

Environmental water contained within unregulated flows is important in achieving ecological outcomes in the Barwon–Darling River. These flows that are not delivered from dams are particularly important for fish as they contain the natural cues and nutrients fish require for their lifecycles. Unregulated flows through the Barwon–Darling River can be enhanced using Commonwealth holdings both from tributary systems and along the Barwon-Darling.

The focus for Commonwealth environmental water use during the 2021–22 water year will be the protection of unregulated flows along the Barwon–Darling River to meet a range of watering priorities, including:

- supporting longitudinal connectivity and end of system flows
- promoting growth, reproduction, and small-scale recruitment for native fish
- supporting low level lateral connectivity (mainly connection between anabranches and the main channel).

9.5.1 Managing Commonwealth holdings of water for the environment in the Barwon–Darling River

New active management arrangements in the Barwon–Darling came into effect on 1 December 2020. With these arrangements, water users must wait until WaterNSW announce access before they can take water from the river. Under active management arrangements, water access is announced daily and is based on the amount of (actively managed) environmental water in the river at that time. License holders can choose how much water to take on a daily basis up to the IDEC for each entitlement.

In general, the CEWO will maximise the use of Commonwealth entitlements given the opportunistic nature of flows in the Barwon-Darling Rivers. However, there may be some circumstances particularly during large flows (large fresh range) or persistently wet periods where the Commonwealth entitlements are not activated or only partially activated. Broadly this involves maximising environmental outcomes (priority outcomes and supporting strategies are outlined in Table BD4) in consultation with communities, government agencies, First Nations and other stakeholders. However, given how new these arrangements are principles to guide for the use of Commonwealth environmental water entitlements will evolve over time.

9.5.2 Managing Commonwealth holdings of water for the environment in tributaries

Moderate resource availability is forecast in several regulated upstream storages, this may provide an opportunity for regulated releases to be used to maximise outcomes in the Barwon–Darling (Table BD3) should dry conditions return during the 2021–22 watering year.

Table BD4 Watering priorities and supporting strategies

Conditions	Priority Outcomes	Strategies
Dry/very dry conditions	• Avoid critical loss of species, communities, and ecosystems • Maintain refugia	• Use Commonwealth Barwon-Darling unregulated entitlements to support very low and base flows • Use Commonwealth holdings in tributaries to

Conditions	Priority Outcomes	Strategies
	• Avoid irretrievable damage or catastrophic events • Avoid prolonged dry periods between flow events • Support targeted longitudinal connectivity along the Barwon Darling River for functional processes and a range of flora and fauna	provide targeted low flows from tributaries, where possible, to boost water quality and quantity of in-stream refugia. • Use Commonwealth Barwon-Darling unregulated entitlements to protect flows following extended cease-to-flow periods
Moderate/wet conditions	• Enable growth, reproduction, and small-scale recruitment for a diverse range of flora and fauna • Support medium flow river and floodplain functional processes • Support longitudinal connectivity within and between catchments for functional processes and a range of flora and fauna • Support low level lateral connectivity (mainly anabranches and flood runners) and end of system flows	• Use Commonwealth Barwon-Darling unregulated entitlements to support a range of flows • Use Commonwealth holdings in tributaries to provide targeted flows to enhance connection opportunities.

Source: NSW DPIE 2020a

9.6 Monitoring and lessons learned

9.6.1 Monitoring

Operational monitoring about environmental water delivery is undertaken for all Commonwealth environmental watering actions. This monitoring involves collecting on-ground data such as volumes delivered, impact on the river systems hydrograph, area of inundation and river levels. It can also include observations of environmental outcomes.

The Monitoring, Evaluation and Research (MER) Program (previously the Long-Term Intervention Monitoring Project 2014–2019) has the junction of the Darling and Warrego rivers as a focus area. It aims to understand the environmental response from Commonwealth environmental watering with respect to the targeted objectives by carrying out monitoring of site condition over many years.

Information on monitoring activities is available on the CEWO website.

Monitoring information is also provided by state governments and other organisations throughout the Barwon–Darling River.

9.6.2 Lessons learned

Outcomes from monitoring and lessons learned in previous years are a critical component for the effective and efficient use of Commonwealth water for the environment. These learnings are incorporated into the way environmental water is managed.

Key findings from monitoring undertaken across the Barwon–Darling River are summarised in Table BD5.

Table BD5 Key lessons learned in the Barwon-Darling River

Theme	Lessons learned
Native fish and other aquatic species	• Over the last several years, the University of New England with NSW DPI–Fisheries have been monitoring native fish responses to flow as part of the CEWO's MER/LTIM Warrego-Darling selected area projects. • Results from monitoring undertaken in July to August 2020 found reasonable numbers of mature golden perch and bony herring.
Connectivity	• Connectivity between the Barwon–Darling River and its tributaries can be enhanced using water for the environment. Connectivity is important for supporting native fish habitat and allowing the movement of native fish between rivers for spawning, dispersal and recruitment. • The Northern Connectivity, Northern Fish Flow and Northern Waterhole Top-up events delivered from the Gwydir and Border Rivers into the Barwon–Darling River during the 2017–18, 2018–19 and 2020–21 water years were critical actions for survival of native fish. These events reconnected channel habitats and promoted fish movement. Protecting environmental water delivered in these events from extraction was essential for success. In the case of the Northern Waterhole Top-up, protection was provided through active management arrangements. • Active management arrangements are complemented by information shown on the Water Insights Portal (WaterNSW Water Insights 2021). The portal provides key information on how water is being managed and shared within the Barwon–Darling River on a daily basis. Both active management arrangements and the portal are invaluable tools for environmental water managers and community members alike. • Understanding the amount of water required to refill pools and wet up sections of river channel is a key element to estimating the environmental water requirements of the Barwon-Darling River during dry periods. • For the Northern Fish Flow, on a dry riverbed, the volume of water that passed Collarenebri was approximately 15,350 megalitres, of which 2,230 megalitres or about 15% passed Brewarrina. This means about 5,000 megalitres per 100 river kilometres was used to fill pools and wet the dry river channel between Collarenebri and Brewarrina. • For the Northern Connectivity Event, where waterholes were full before the flow, the volume of water that passed Collarenebri was about 19,900 megalitres, of which approximately 15,700 megalitres or about 80% passed Brewarrina. • This means that approximately three times as much water was used to refill pools and wet up sections of the Barwon River channel between Collarenebri and Brewarrina during the Northern Fish Flow as compared to the Northern Connectivity Event.
Water quality	• During summer months refuge pools located along the Barwon-Darling River can stratify, reducing habitat quality and putting native fish at risk. • The primary risk considered before the Northern Connectivity Event and the Northern Fish Flow was the stratification of waterholes. Waterholes can rapidly de-stratify when flow return, resulting in deoxygenation of the waterholes and fish kills. Consultants were used to gather information about water quality risks (Eco Logical Australia 2020). • Samples of dissolved oxygen were collected from refuge pools before, during and after the Northern Fish Flow. If dissolved oxygen falls below 4 mg/L then fish become stressed and may die (Eco Logical Australia 2020). Before the Northern Fish Flow, dissolved oxygen concentrations at the Collarenebri Weir pool were found to be below 4 mg/L in places (Eco Logical Australia 2020). Dissolved oxygen readings show that concentrations increased when the Northern Fish Flow passed (Eco Logical Australia 2020). • The Northern Fish Flow was timed for the flows to reach the Barwon River by late May and early June when temperature was significantly reduced, helping to reduce risks to water quality. • The Northern Waterhole Top-up (NWT) was the first time a connectivity event was delivered during summer. Timing of the event was based on: – extended dry conditions across the Barwon River during winter-spring 2020

Theme	Lessons learned
	– coordinating with regulated block releases to minimise losses. While dissolved oxygen (DO) levels in the Collarenebri Weir pool were below 4 mg/L following initial inflows, no fish deaths were observed. The NWT most likely assisted in diluting low DO tributary inflows. Regular water quality monitoring would assist in determining the origins and potential mitigation of water quality issues. • Commonwealth water for the environment delivered as part of natural flow events can improve water quality, nutrient cycling and provide access to in-channel habitats for other species. Additionally, Commonwealth water delivered as part of small flow events in the Barwon-Darling River may minimise algal productivity and the potential for blooms.

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10 Lower Darling/Baaka Water Plan

10.1 Region overview

10.1.1 River system

Travelling approximately 700 km, the lower Darling/Baaka includes the river channel and adjacent billabongs and wetlands from the Menindee Lakes to the junction of the Murray and the Darling rivers at Wentworth (Map LDR1). The catchment also includes the lakes, floodplains and channel of the Great Darling Anabranch—an ancestral path of the Darling River. The catchment is located on the semi–arid plains of south–western New South Wales.

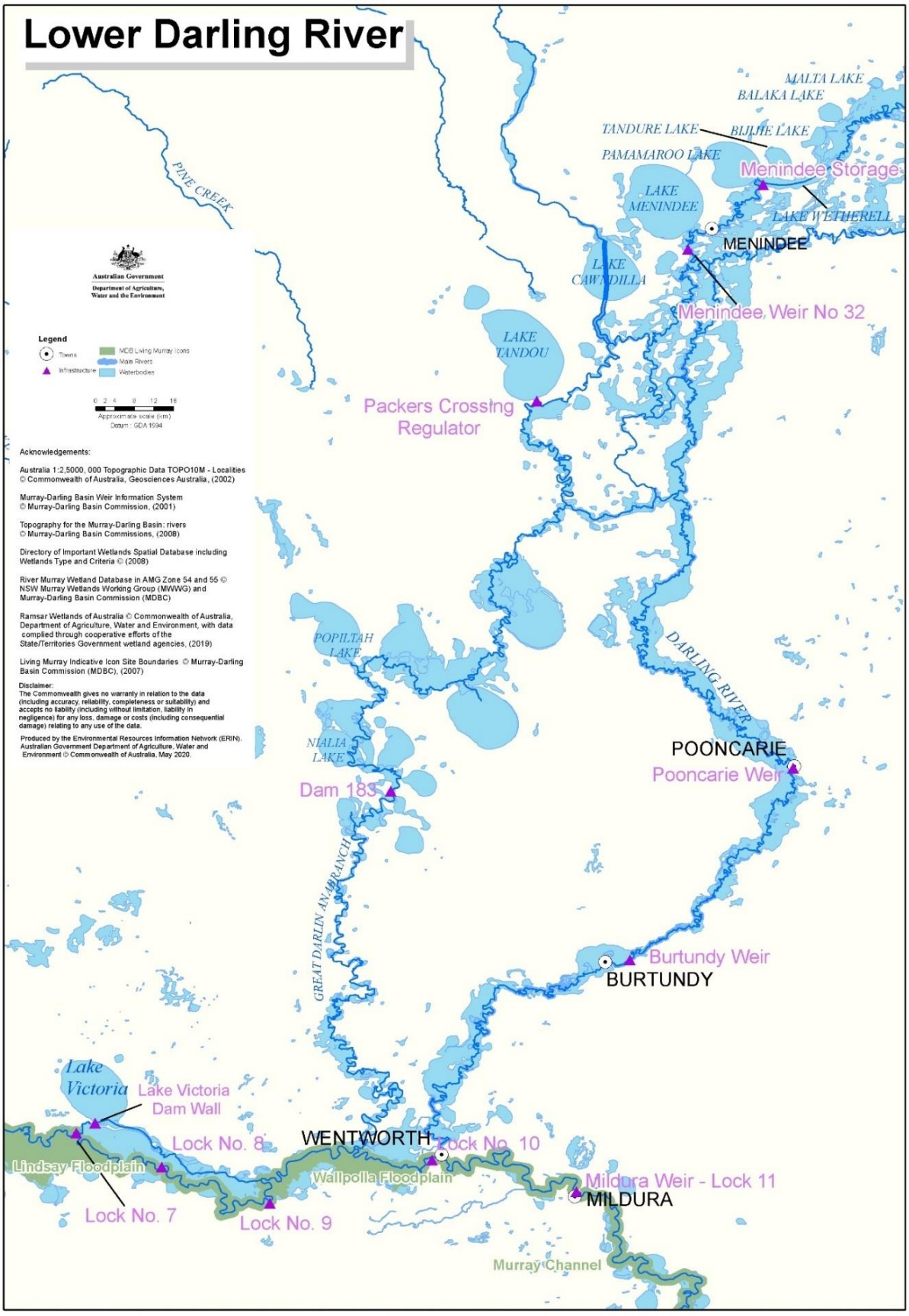
The lower Darling/Baaka valley relies on flows from rivers in southern Queensland and northern New South Wales, including ephemeral systems such as the Warrego, that flow into the Barwon–Darling River. Water is captured in the Menindee Lakes, a series of natural lakes that have been altered to improve water storage. Key storages include lakes Menindee, Pamamaroo Cawndilla and Wetherell (the latter of which incorporates Lakes Tandure, Balaka, Bijiji and Malta, and the floodplains between and adjacent to them). Water is released from lakes Menindee, Wetherell and Pamamaroo to provide flows into the lower Darling/Baaka. Flows to the Great Darling Anabranch can originate from the lower Darling/Baaka (via the Old Anabranch) during elevated flows and floods or delivered from Lake Cawndilla via Tandou and Redbank Creeks. Flows can be provided down the Anabranch from Lakes Menindee, Pamamaroo and Wetherell to supplement flows out of Cawndilla in rare high release rates scenarios.

Land use in the catchment is largely based on pastoral industries, comprising mainly of sheep as well as rangeland goats and beef cattle production. There are also some areas of lakebed cropping and irrigated cropping, horticulture and viticulture. Tourism is vitally important to the local economy, with waterways and national parks supporting widespread recreational activities such as fishing and camping.

10.1.2 Traditional Owners

The river and floodplains of the lower Darling/Baaka have long been important for sustenance and spirituality. In 2015, the Barkindji people received Native Title over much of the Darling/Baaka River valley, extending from the South Australian border to Tilpa in the east, Wentworth in the south and north almost to Wanaaring. The lower Darling/Baaka flows through the traditional land of many other Aboriginal nations including the Maraura, Muthi Muthi, Nyeri Nyeri and Ngintait nations. The region contains many significant spiritual and cultural sites, including Menindee Lakes. The Commonwealth Environmental Water Office (CEWO) respectfully acknowledges these Nations, their Elders past and present, as the Traditional Custodians of the lands on which this chapter is focused.

Map LDR1 Lower Darling/Baaka catchment



10.1.3 Important sites and values

The Menindee Lakes are listed in the Directory of Important Wetlands in Australia as an exceptional example of the Ephemeral Deflation Basin Lakes (EDBL) wetland type within the bioregion. They provide important waterbird habitat with more than 30 species recorded on the main lakes, including threatened species such as freckled duck and migratory waders. They also provide critical habitat for native fish including golden perch and threatened species such as Murray cod, silver perch and freshwater catfish. The ephemeral large shallow lakes are very productive and provide diverse food sources for fish at a range of life-stages. The Menindee Lakes also provide important refuge for wildlife during drought or adverse conditions.

The *Commonwealth Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) lists the Coolibah Black Box community, Menindee nightshade, silver perch, Murray cod and 37 waterbirds as conservation dependent. Eighteen migratory bird species recorded at Menindee Lakes are listed under international agreements (JAMBA and CAMBA). The *Fisheries Management Act NSW 1994* lists the Menindee Lakes, including lakes Cawndilla and Menindee, lower Darling/Baaka and Great Darling Anabranch as an Endangered Ecological Community.

The Menindee Lakes and lower Darling/Baaka support a diverse native fish community. The natural flow variability of the lower Darling/Baaka River promotes and supports fish breeding, recruitment and dispersal of native fish (particularly by Murray cod and golden perch) which contribute to native fish communities throughout the Northern and Southern Basin (Stuart and Sharpe 2020, Sharpe and Stuart 2018b, Zampatti et al 2018, Price et al 2019). The Menindee Lakes are the only EDBL floodplain lake system in the Murray–Darling Basin in which mass golden perch recruitment events have been demonstrated (Sharpe and Stuart 2018a, Stuart and Sharpe 2020). The Menindee Lakes are considered among the last, functional EDBL golden perch nursery habitat remaining in the Murray–Darling Basin and are listed in Directory of Important Wetlands in Australia (Stuart and Sharpe 2020).

The Great Darling Anabranch is an ancestral path of the Darling/Baaka with its own system of ephemeral lakes. The Anabranch is highly significant in terms of its contribution to terrestrial and biodiversity value through natural wetting and drying cycles and diverse habitats and the Anabranch Lakes are listed in the Directory of Important Wetlands in Australia. Other wetlands, creeks and anabranches in the Lower Darling/Baaka catchment also offer considerable ecological value.

Lake Cawndilla is an important fish nursery habitat. As part of the Menindee Lakes Scheme a channel was cut linking Lake Cawndilla to the Darling Anabranch. Environmental flows have been delivered to the Anabranch from Lake Cawndilla with monitoring indicating a dispersal by native fish, such as golden perch from Lake Cawndilla along the Anabranch to the Murray River.

Flows in the lower Darling/Baaka also transport propagules and nutrients that support food webs and fish communities in the lower Murray. In recent decades, protracted cease–to–flow and low–flow conditions have significantly impacted many of the lower Darling/Baaka values, including fish deaths events in 2004, 2008, 2015–16 and more recently in 2018–19 (NSW DPI Fisheries 2020).

Both the lower Darling/Baaka River and the Great Darling Anabranch are identified in the Basin–wide environmental watering strategy (MDBA 2019) as wetlands of Basin significance for native fish and waterbirds.

10.1.4 Stakeholder engagement

In the lower Darling/Baaka, Commonwealth environmental water is managed in partnership with the NSW Department of Planning, Infrastructure and Environment– Environment, Energy and Science (DPIE EES). It is coordinated with other sources of water, including environmental water available through The Living Murray program (TLM), and operational flows managed by WaterNSW and/or the Murray–Darling Basin Authority (depending on who has operational control of Menindee Lakes at the time in accordance with the Murray–Darling Basin Agreement).

In addition to the above agencies, advice is regularly received from the NSW Department of Primary Industries—Fisheries (DPI—Fisheries) regarding watering requirements to support native fish and other aquatic species, as well as the Lower Darling Technical Advisory Group (convened by DPIE EES) and the Lower Darling Regional Operations Stakeholder Consultation Committee (LD ROSCCo), who provide advice to water managers to address stakeholder concerns and share river operation information. Advice and guidance are also sought from representatives of the Barkindji Traditional Owners, Murray Lower Darling Rivers Indigenous Nations (MLDRIN), recreational fishers, landholders and irrigators. Local council and community members with an interest in environmental water management in the lower Darling/Baaka are consulted at key planning and decision points during the year.

10.2 Environmental objectives

Based on long–term environmental objectives in the Basin Plan, state long–term watering plans, site management plans, and best available knowledge, the following objectives are relevant for environmental watering in the lower Darling/Baaka region.

The objectives that are targeted in a particular year may vary, depending on available water, catchment conditions, operational feasibility and demand for environmental water. These objectives will continue to be revised as part of CEWO's commitment to adaptive management.

The objectives are:

- Native fish – provide flows to support habitat and food resources and promote increased spawning and movement, recruitment and survival/condition of native fish.
- Vegetation – maintain riparian and in–channel vegetation condition. Increase periods of growth for non–woody vegetation communities that closely fringe or occur within river channels.
- Waterbirds – provide habitat and food sources to support waterbird survival and recruitment and maintain condition and current species diversity.
- Invertebrates – provide habitat to support increased microinvertebrate and macroinvertebrate survival, diversity, abundance and condition.
- Other vertebrates – provide habitat to support survival, maintain condition and provide recruitment opportunities for frogs and turtles.
- Connectivity – maintain longitudinal connectivity along the lower Darling/Baaka and with the Murray River, to support important environmental functions (see next objective). Support intermittent connectivity through the Great Darling Anabranch to the River Murray. Provide lateral connectivity between the channels of the lower Darling/Baaka and Great Darling Anabranch with low-lying wetlands. Where feasible, provide lateral

connectivity with wetlands in Kinchega National Park that connect with the Menindee Lakes.

- Processes/water quality/resilience – increase primary productivity, nutrient and carbon cycling, biotic dispersal and movement; maintain suitable water quality for native plants and animals; and provide refuge from adverse water quality events (for example hypoxic blackwater in the Murray). Maintain drought refuge habitat and maintenance/condition of native biota (for example fish and other aquatic fauna).

10.3 First Nations environmental watering objectives

The CEWO and DPIE EES have been participating in workshops run by the Barkandji Native Title Group Aboriginal Corporation to develop their Healthy Country Plan. Both organisations are committed to working with the Barkindji people to incorporate objectives and values identified in this plan into where and when we may deliver water to the Baaka (where this is consistent with our statutory responsibilities). This could include the possibility of delivering water for the environmental to a small number of wetlands in Kinchega National Park in 2021–22, subject to further discussions, feasibility investigations and approvals. The NSW National Parks and Wildlife Service is working with Traditional Owners via the Kinchega Co-Management Committee to align ecological and cultural objectives for the potential watering of the wetlands.

10.4 Recent conditions and seasonal outlook

10.4.1 Recent conditions and environmental water use

In the past 20 years, the lower Darling/Baaka River has experienced increased frequency and duration of low flow. The Millennium drought saw record low inflows and river flows that led to some major fish deaths.

A series of wet years from 2009–13 saw a breaking of the Millennium drought and high flows/floods through the Barwon-Darling and lower Darling/Baaka to the Murray, including the Great Darling Anabranch. These events boosted fish communities in the lower Darling/Baaka and provided timely dispersal of a strong cohort of golden perch from the Darling to the southern Basin (Zampatti et al 2018, Price et al 2019), which had heightened importance in the wake of hypoxic blackwater fish kills in the southern Basin (Murray and Murrumbidgee rivers).

From 2013–16, dry conditions saw low inflows to the lower Darling/Baaka before a small flood delivered much needed inflows to Menindee Lakes, which filled the lakes from less than 5% to over 90% capacity (Burrell et al 2018).

These inflows enabled environmental releases in spring of 2016 and again in 2017 that supported Murray cod spawning and recruitment in the lower Darling/Baaka. A population census in winter 2018 found that the resulting cohorts represented 28% of the overall population structure, with around 14% from each cohort (Sharpe and Stuart 2018a). Subsequent water releases from the Menindee Lakes and down the lower Darling/Baaka in 2017 to meet consumptive needs were ‘shaped’ by ecologists and environmental water managers in collaboration with the river operators to promote the spawning and dispersal of other large–bodied native fish species such as golden perch and silver perch.

In the Great Darling Anabranch, environmental water releases in 2016–17 contributed to positive responses in river red gum and black box vegetation communities fringing the Anabranch, and facilitated the successful dispersal of native fish, particularly golden perch

juveniles, from Lake Cawndilla, down the Anabranch and ultimately to the River Murray (Sharpe and Stuart 2018a).

From mid-2017 to early 2020 inflows in the Barwon-Darling were extremely low, with Menindee Lakes volumes shrinking to 1%. The return of dry and low flow conditions had catastrophic impacts on the local ecology. Mass deaths of millions of fish occurred in the lower Darling/Baaka adjacent to the town of Menindee in in December 2018 and January 2019. As the lower Darling/Baaka contracted to disconnected pools through 2019, many thousands more fish perished. Small remnant fish populations were supported through intervention such as relocation to more secure waters and use of mechanical aerators at 10 locations in the lower Darling/Baaka and Menindee Lakes region.

A return of inflows to the top Menindee Lakes (Wetherell and Pamamaroo) in early 2020, supported by temporary water restrictions put in place by the NSW Government using Section 324 of the *NSW Water Management Act 2000*, saw total Menindee Lakes storage increase to almost 30% (Burrell et al 2021). This provided an opportunity to 'restart' the lower Darling/Baaka River, with a pulsed flow to reconnect with the River Murray in autumn 2020. During spring 2021–21, environmental flows were released into the lower Darling/Baaka. This was the first opportunity for environmental water to support Murray cod breeding, recruitment and river health since the devastating fish deaths in lower Darling/Baaka 2018 and 2019. Many golden perch that had been spawned in the upper reaches of the Barwon-Darling catchment in response to river flows in early in 2020 were transported downstream to Menindee Lakes with some also able to continue their journey into the lower Darling/Baaka and potentially on to the Murray in managed environmental flows and operational releases.

Through the first half of 2021, additional inflows (with protection of inflows in the northern NSW basin via new 'first flush' rules) resulted in the Menindee Lakes filling to over 1,000 gigalitres total storage (around 63%), including inflows to the bottom lakes (Menindee and Cawndilla). Further environmental water releases have been made in winter 2021 to provide additional food resources and habitat for growing young fish. As discussed in Sections 1.4 and 1.5 below, the recent inflows also provide an opportunity to plan for environmental water releases to improve the health of the lower Darling/Baaka system in 2021–22.

Learn more about previous Commonwealth environmental water use in the Lower Darling/Baaka or about the latest storage and release details for the lower Darling/Baaka and the Menindee Lakes system.

10.4.2 Seasonal outlook

According to the Bureau of Meteorology outlook (BoM 2021) above median rainfall between August and October 2021 is likely in both the lower Darling/Baaka valley, as well as the northern catchments that provide inflows to the lower Darling/Baaka system.

While this forecast indicates that dry conditions have somewhat eased, several months of above average rainfall are needed to see recovery from the drought continue.

10.4.3 Water availability

The Menindee Lakes resource became shared with other States in early May 2021 when the system storage volume reached 640 gigalitres. It will remain administratively connected with the Murray until volumes fall below 480 gigalitres. Inter-valley trade will remain open until this

time, enabling allocations to be transferred between the lower Darling/Baaka and other southern river valleys.

Water resource availability is moderate to high at the start of the 2021–22 water year, given inflows to the Lakes system in autumn 2021. Allocations for both general and high security entitlements have opened at 100%, providing a total of 25.8 gigalitres of Commonwealth environmental water available for use within the valley. Trade–in of additional environmental water may be considered subject to a number of factors.

10.4.4 Environmental demands

For the environmental water demands for assets in the lower Darling/Baaka in 2021–22 (Table LDR1). The extent to which these environmental demands can be contributed to is contingent on several factors described in the table.

Table LDR1 Environmental demands and watering priorities, 2021–22, and outlook for coming year, lower Darling/Baaka catchment

Environmental assets	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
	Flow/volume	**Required frequency (maximum dry interval)**		**Environmental demands for water (all sources)**	**Potential Commonwealth environmental water contribution?**	**Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22**
Menindee Lakes • Native fish: survival, dispersal & recruitment of flow pulse specialists in Lakes and dispersal downstream • Vegetation: non–woody wetland, lignum, fringing river red gum, low–lying black box and coolibah • Waterbirds: maintain habitat, potential breeding • Ecosystems: refuge, productivity	**Lake Menindee**: 60 GL (1.5 m, 56 m AHD) **Lake Cawndilla**: 50 GL (1.5 m, 53.8 m AHD) Timing: anytime of year, filling to be triggered by upstream flows in the Barwon–Darling River system Min duration: 3–5 months Max duration: 3 years	6–8 years in 10 (**Menindee**: 2 years) (**Cawndilla**: 3 years)	The lakes last refilled in 2016–17 (total storage around 1,730 GL). Inflows in autumn and winter 2021 saw Lake Menindee reach 26% (205 GL) and Lake Cawndilla reach 44% (326 GL).	Low (assuming storage level remains above the identified thresholds for at least 3–5 months)	Lake levels primarily rely on upstream inflows and larger natural events. Commonwealth environmental water deliveries will consider environmental needs in both the Lakes and lower Darling/Baaka system and will look to where the most effective use of available environmental water.	Moderate (if no subsequent re-fill during 2021–22)
	Lake Menindee: 116 GL (1.8 m, 56.5 m AHD) **Lake Cawndilla**: 84 GL (2.2 m, 54.5 m AHD) Timing: anytime of year, filling to be triggered by upstream flows in the Barwon–Darling River system Min duration: 3–5 months Max duration: 1–2 years	3–5 years in 10 (4 years)		Low (assuming storage level remains above the identified thresholds for at least 3–5 months)		Moderate (if no subsequent re-fill during 2021–22)
	Lake Menindee: 57.5 m AHD **Lake Cawndilla:** 57.5 m AHD Timing: anytime of year, filling to be triggered by upstream flows in the Barwon–Darling River system Min duration: 3–5 months Max duration: 1 year	1.5 year in 10 (8 years)	The lakes last refilled in 2016–17 (total storage around 1,730 GL). This indicator was not met by the autumn/winter 2021 inflows.	Moderate		Moderate
Lower Darling/Baaka River • Native fish: spawning, nesting and recruitment (riverine specialists, generalists) • Ecosystem functions: longitudinal connectivity, refuge habitat, small–scale productivity	Elevated baseflows above minimum releases through to River Murray for water quality and fish habitat requirements (400 ML/d at Weir 32).	Continuous (if limited water, focus on baseflows during spring and summer).	Very low and cease–to–flow conditions in 2014–15 and 2015–16. Small to moderate spring pulse was achieved in 2016–17 and, to a lesser extent, in 2017–18. Cease–to–flow conditions commenced in 2018–19 and persisted for most of 2019–20. Resumption of flows in March and April 2020. Elevated baseflows in spring 2021, including a short pulse of 1,500 ML/day. Small operational pulse up to 4,000 ML/d in late May 2021, followed by elevated baseflows of 500 ML/d.	**Critical**	Each of these demands are a high priority for Commonwealth environmental watering 2021–22. Capacity to deliver a large fresh will depend upon availability of allocations held by all Lower Darling environmental water holders and becomes more feasible if an opportunity to 'piggy-back' on operational releases arises.	**Critical**
	Small to moderate river pulse (up to 800 ML/d at Weir 32 in spring and summer).	1–2 in 5 years (max interval unknown)		High		Moderate
	Small fresh (up to 2,000 ML/d at Weir 32 for around 60 days in summer) for Murray cod breeding.	2–4 years in 10 (5 years)				Moderate
	Large fresh (up to 7,000 ML/d at Weir 32 for around at least 5 days for dispersal of flow pulse specialists, especially important following mass golden/silver perch recruitment in Menindee Lakes.	3–5 years in 10 (4 years)				Low
Floodrunners and fringing lakes • Native fish: spawning (flow pulse specialists), dispersal (all species), • Waterbirds: foraging habitat, support natural breeding events • Ecosystem functions: lateral connectivity, dispersal of biota, channel maintenance,	10,000 – 12,000 ML/d at Weir 32, ideally August–October or January–April (or anytime) for a minimum of 14 days (to achieve 2–6 months of wetland inundation)	5–8 years in 10 (2 years) Annual event for 2–3 consecutive years for recovery of wetland vegetation	Small overbank flow in 2011 and 2012. Flows since that time have remained within channel.	High	Reliant on large, unregulated flows.	High

Environmental assets	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
	Flow/volume	Required frequency (maximum dry interval)		Environmental demands for water (all sources)	Potential Commonwealth environmental water contribution?	Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22
productivity, nutrient/carbon exchange • Frog habitat and breeding						
Great Darling Anabranch • Native fish: recruitment and dispersal of flow pulse specialists • Native vegetation: non–woody, fringing river red gum, black box, lignum • Waterbirds: habitat and potential breeding • Ecosystem functions: refuge; productivity	> 800 ML/day (800–2 000 ML/day) from Menindee Lakes for minimum 21 days.	2–3 in 10 years (4 years)	Environmental releases to the Great Darling Anabranch last occurred in summer of 2017, allowing for dispersal of large bodied native fish and improved water quality and vegetation condition. No flows have been provided down the Anabranch since then.	High	High priority for Commonwealth environmental water use in 2021–22, given recent inflows into Lake Cawndilla	Low

Source: DPIE–Water 2020

Key

Potential watering in 2021–22

- High priority for Commonwealth environmental watering (likely to receive water even under low water availability)
- Secondary priority for Commonwealth environmental watering (watering to occur only if natural trigger is met, or under moderate – high water resource availability); or water demand likely to be met via other means
- Low priority for Commonwealth environmental watering (under high – very high water resource availability); or unable to provide water because of constraints or insufficient water

Environmental demands (demand is considered at a generalised scale; there may be specific requirements that are more or less urgent within the flow regime)

- High to critical demand for water (needed in that particular year or urgent in that particular year to manage risk of irretrievable loss or damage)
- Moderate demand for water (water needed in that particular year, the next year, or both)
- Low demand for water (water generally not needed in that particular year)

10.5 Water delivery in 2021–22

Based on the demand for water for the environment, water availability (supply), and catchment conditions, the overall purpose for managing Commonwealth water for the environment in the lower Darling/Baaka in 2021–22 is to support recovery of the system and improve ecological health and resilience.

The highest priority will be to provide elevated baseflows and small to moderate pulses/freshes in the lower Darling/Baaka during spring to support Murray cod and golden and silver perch breeding and recovery of a variety of other aquatic biota (e.g. mussels). A large spring fresh is also a high priority depending on availability of environmental allocations across all water holders and an opportunity to 'piggy-back' operational releases in the lower Darling/Baaka.

Golden perch spawning has again been reported upstream in northern basin in response to flow in the Barwon–Darling and its tributaries. Young fish were recorded dispersing with these flows to the Menindee Lakes nursery habitat in 2020, and again with more recent inflows in 2021 (i.e. two juvenile cohorts are now in the lakes). Delivery of environmental water will provide an opportunity for some of these fish to ultimately disperse further into the lower Darling/Baaka and potentially into the River Murray.

Environmental flow to the Great Darling Anabranch is also a high priority for Commonwealth environmental water use, as recent inflow into Lake Cawndilla presents the first opportunity to provide benefits to native fish (including via dispersal from Lake Cawndilla to the Anabranch and ultimately the River Murray), fringing vegetation, waterbirds and frogs for the first time in five years.

Environmental flows will be designed with native fish ecologists in consultation with the local community, including First Nations people. Consideration will also be given to the benefits of water retention in the Menindee Lakes and its associated environmental values (for waterbirds, vegetation and as nursery habitat for fish), as well as potential benefits to the River Murray via contribution of Darling/Baaka flows to productivity and fish populations in the lower Murray. Consideration will be given to coordinating and aligning River Murray and Lower Darling/Baaka watering actions to maximise the dispersal of carbon, nutrients and larval/juvenile fish to the River Murray.

10.6 Monitoring and lessons learned

10.6.1 Monitoring

In the lower Darling/Baaka River, monitoring is primarily undertaken by NSW agencies including NSW DPIE-EES (vegetation, waterbirds and frogs), NSW DPI–Fisheries (native fish), and WaterNSW (hydrology and flow delivery data).

Several short–term intervention monitoring projects were conducted by the CEWO to assess the success of environmental flows in 2016–17, 2017–18 and 2020–21. The monitoring projects demonstrated the success of the flows in achieving outcomes (further described below) and informed real–time adaptive management of the flows.

Technical reports from short term monitoring projects in the lower Darling/Baaka can be found on the departmental website (the final report for 2020–21 will be published on the CEWO website early in 2021–22). Some key reports include:

- Assessment of Murray cod recruitment to the lower Darling River in response to environmental flows throughout 2016–18 (Sharpe and Stuart 2018a).
- Environmental flows in the Darling River to support native fish populations 2016–17 (Sharpe and Stuart 2018b).
- Environmental flows to support Murray cod spawning in the lower Darling River 2017 (Sharpe 2019).

Monitoring under the Darling Anabranch Adaptive Management Monitoring Program may be undertaken in conjunction with flows to the Great Darling Anabranch.

In addition, monitoring in the River Murray may detect outcomes from environmental watering in the Lower Darling/Baaka and Great Darling Anabranch that extend to the lower Murray. For example, monitoring in the lower Murray via the CEWO's Flow-MER program, and implementation of the River Murray Channel Monitoring Plan in 2021–22 is expected to include detection of influences of key tributaries (such as the Lower Darling/Baaka and Great Darling Anabranch) on productivity and fish outcomes in the River Murray.

10.6.2 Lessons learned

Outcomes from monitoring and lessons learned in previous years are a critical component for the effective and efficient use of Commonwealth water for the environment. These learnings are incorporated into the way environmental water is managed.

Monitoring in the lower Darling/Baaka River (2016–17 and 2017–18) and the Great Darling Anabranch (2016–17) showed environmental flows were successful in supporting tangible and significant multi–species outcomes for native fish. Where possible, maintaining the function of the Menindee Lakes and lower Darling/Baaka is critical for Murray cod spawning and recruitment, the dispersal and recruitment of golden perch from their nursery grounds in the Menindee Lakes, and spawning of golden perch and the nationally threatened silver perch in the lower Darling/Baaka River channel (Sharpe and Stuart 2018a and b, Stuart and Sharpe 2020).

Monitoring during 2020–21 spring flow detected a spawning response from Murray cod with strong numbers of larvae and juvenile fish recorded despite a depletion in adult stocks through the 2019 dry period i.e. fish kills (Stuart et. al. 2021). A limited spawning response by golden perch was detected during the flow, however subsequent monitoring in autumn confirmed the presence of young-of-year golden perch in the lower Darling/Baaka (Stuart et. al. 2021). This was likely due to substantial depletion of adults in the lower Darling/Baaka during the 2019 cease to flow period, and subsequent barriers to fish passage which limited replenishment in the lower Darling/Baaka. With connectivity from Wentworth to Menindee having now been restored, the likelihood of golden perch spawning events in the lower Darling/Baaka in response to future freshes is increased.

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11 Lachlan River

11.1 Region overview

11.1.1 Lachlan Valley

The Lachlan River is the fourth longest river in Australia at 1,448 kilometres with a catchment of around 90,000[2] kilometres. The Lachlan runs from the Great Dividing Range in central New South Wales, westwards through to the Great Cumbung Swamp. Flow attenuation in the system is high due to the low gradient of the system and it can take 90 days for a flow event from Wyangala Dam to reach the end of the river system at The Great Cumbung Swamp (Map LR1, Map LR2, Barma Water Resources 2011). Many anabranches and distributary creeks in the Lachlan terminate in wetlands. Not all environmental water is sourced from dam releases – unregulated tributary inflows can be ordered and accounted for as environmental water and allowed to reach assets by bypassing regulating storages. The harvesting of water for consumptive purposes has significantly modified the flow of the Lachlan River (Higgisson et al, 2019).

11.1.2 Traditional Owners

The Lachlan River flows through the lands of the Nari Nari, Ngiyampaa, Wiradjuri and Yita Yita Nations. The Commonwealth Environmental Water Office (CEWO) respectfully acknowledges these people, their Elders past and present, as the Traditional Owners of the land on which this chapter is focused.

11.1.3 Important sites and values

The Lachlan Valley contains eight nationally important wetlands, including the Great Cumbung Swamp, the Lachlan Swamp, Booligal Wetlands, Merrowie Creek Wetlands, Lake Merrimajeel/Murrumbidgil Swamp, Lake Brewster, Cuba Dam and Lake Cowal. Below Wyangala and Carcoar dams, the catchment's lowlands are recognised as an endangered ecological community.

The Great Cumbung Swamp comprises a variety of wetland types that supports one of the largest areas of common reed in NSW, as well as lignum shrublands and river red gums. Booligal Wetlands support some of most extensive areas of lignum in NSW.

The *Basin-wide environmental watering strategy* (MDBA, 2019) identifies the Booligal Wetlands, Great Cumbung Swamp, Lake Brewster and Lake Cowal as being of Basin-wide significance for waterbirds. The valley provides habitat for a number of birds listed under international migratory bird agreements, including great egret, glossy ibis, sharp-tailed sandpiper, common greenshank, Latham's snipe, painted snipe, and white-bellied sea-eagle. The valley also attracts several birds listed as vulnerable, including the Australasian bittern, blue-billed duck and the freckled duck.

The Lachlan River between Condobolin to Booligal is also recognised as being of Basin-wide importance for native fish.

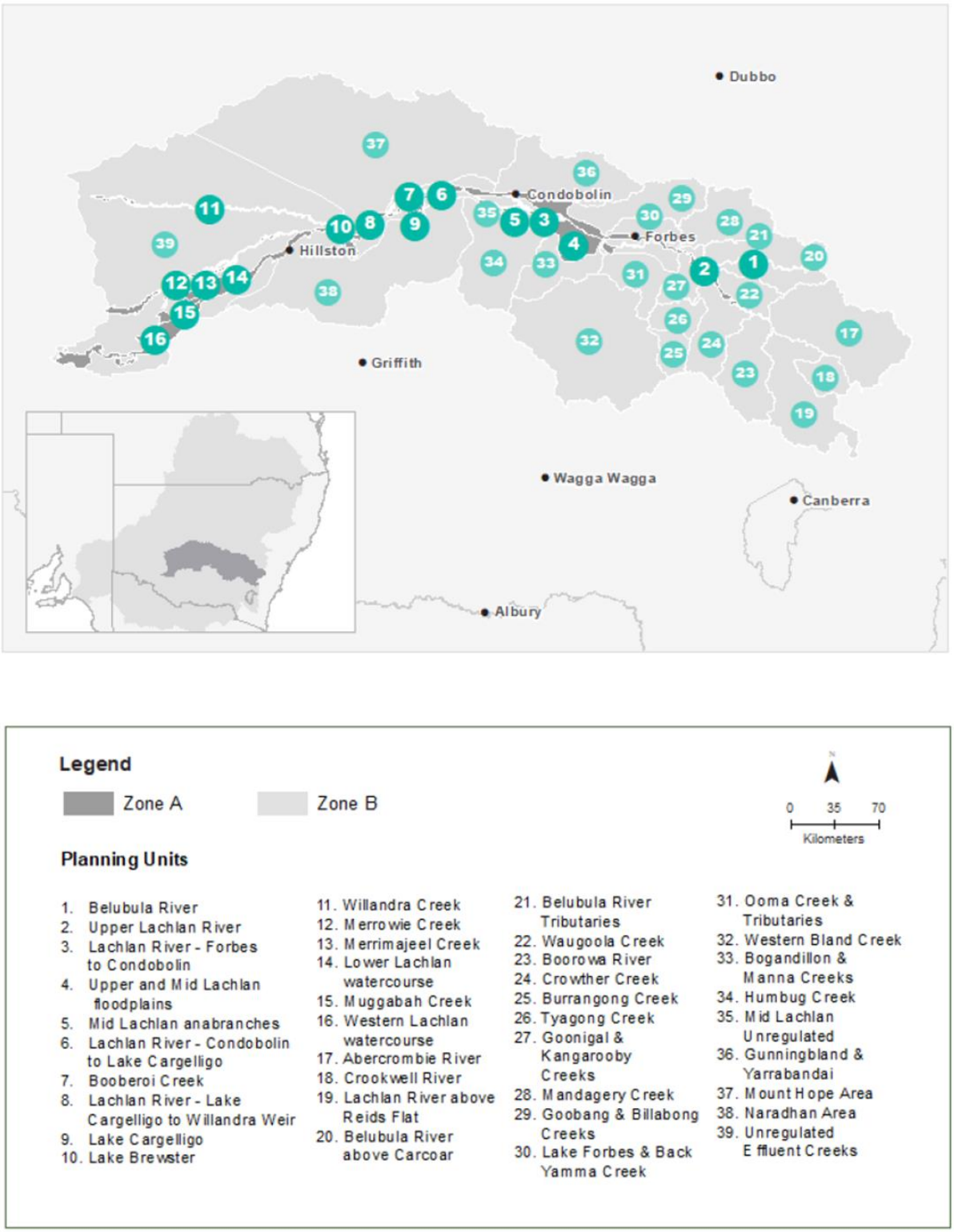
The Long Term Water Plan for the Lachlan Catchment (NSW DPIE 2020a and b) provides greater detail on the environmental assets found in the Lachlan Catchment and their watering requirements.

11.1.4 Stakeholder engagement

The CEWO continues to work with NSW Department of Planning, Industry and Environment, Environment Energy and Science (NSW DPIE-ESS) in reviewing, coordinating, and managing environmental watering actions in the Lachlan Catchment. This work is done in conjunction with the CEWO's Monitoring, Evaluating and Research (MER) Program provider, the University of Canberra, the river operator WaterNSW and the Lachlan Environmental Water Advisory Group (EWAG). This work is further complemented by regular landholder visits and discussion, which includes the work being progressed for the proposed Great Cumbung Region Water Management Plan.

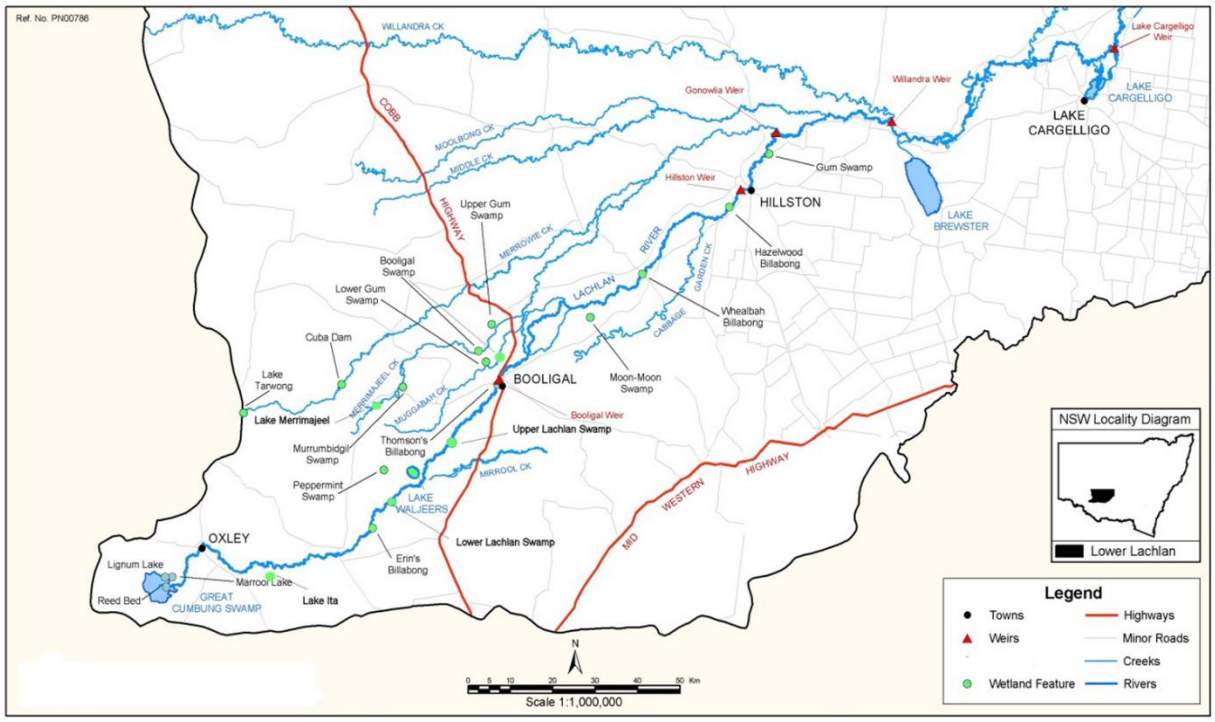
The CEWO will continue to work with NSW agencies, particularly NSW DPIE EES and NSW National Parks and Wildlife Service who have established processes and relationships with First Nations communities in the Lachlan catchment, to undertake watering actions that also contribute to cultural outcomes whenever possible. The CEWO's Monitoring Evaluation and Research (MER) project, led by the University of Canberra, also provides further opportunities to work with and learn alongside First Nations communities in the Lachlan catchment.

Map LR1 Lachlan Valley showing the division of planning units



Note: Planning units divided into Zone A and B as used in the draft Long Term Water Plan for the Lachlan Catchment.
Source: NSW DPIE 2020a

Map LR2 Lower Lachlan Catchment



Source: (Driver et al 2003)

11.2 Environmental objectives

Based on long-term environmental objectives in the Basin Plan, NSW Lachlan long-term watering plans, site management plans, and best available knowledge, the following objectives are relevant for environmental watering in the Lachlan River catchment.

The objectives that are targeted in a particular year may vary, depending on available water, catchment conditions, operational feasibility, and demand for environmental water. These objectives will continue to be revised as part of the Commonwealth Environmental Water Office's (CEWO) commitment to adaptive management. These objectives will also seek to align with the Lachlan Annual Environmental Watering Priorities published by NSW each year. The objectives are:

- Vegetation – Maintain or increase the extent and improve the condition, growth and survival of riparian, in-channel, floodplain, and wetland vegetation.
- Waterbirds – Increase waterbird abundance and maintain species diversity by supporting naturally triggered breeding events, and maintaining suitable refuge, feeding, and breeding habitat at targeted floodplain sites.
- Native fish – Prevent loss of native fish species and increase distribution and abundance, by supporting opportunities for movement, dispersal, reproduction, and recruitment.
- Other vertebrates – Support opportunities for the recruitment of other native aquatic species, including rakali (native water rat), frogs, and turtles.
- Invertebrates – Provide habitat to support increased invertebrate survival, diversity, abundance, and condition.

- Connectivity – Maintain longitudinal & lateral connectivity through contributing to an increase in the frequency of freshes and Maintain latitudinal connectivity (within constraints) to wetlands, floodplains, creeks, and anabranches by contributing an increase in the frequency of lowland floodplain flows.
- Processes/water quality/resilience – Increase primary productivity, nutrient and carbon cycling, biotic dispersal, and movement. Increase transport of organic matter and nutrients downstream. Maintain water quality and provide refuge habitat from adverse water quality events. Provide drought refuge habitat and maintenance/condition of native biota.

11.3 First Nations environmental watering objectives

The CEWO is committed to working with First Nations groups to better understand their objectives. NSW engagement processes, particularly the Lachlan Environmental Water Advisory Group, continue to play an important role for First Nations representatives to influence water use decisions. The Ngiyampaa Nation Plan, prepared by the Ngiyampaa Wangaaypuwan Nation Planning Working Group, notes the objectives and cultural significance of Willandra Creek and Booberoi Creek. Initial discussions have also commenced with NSW National Parks and Wildlife Service and the Mawambul Co-Management Group regarding the potential to deliver water for the environment into Lake Ita within Kalyarr National Park. The CEWO will use environmental flows to contribute to these objectives where possible and where this is consistent with the Commonwealth Environmental Water Holder's statutory responsibility of protecting and restoring environmental assets in the Basin.

11.4 Recent conditions and seasonal outlook

11.4.1 Recent conditions and environmental water use

At the end of 2019-20 the Lachlan catchment was at Stage 3 (severe) drought criticality under the NSW Extreme Events Policy (NSW DPI, 2018). The arrival of La Nina conditions in May-June 2020 brought rainfall across the Lachlan River system. This enabled water that had been set aside under the NSW Extreme Events Policy to be made available for use from August 2020. The rainfall resulted in two translucent flow events (August-September and November-December 2020) which contributed to inundation of the lower Lachlan River floodplain.

Commonwealth and NSW water for the environment was used in partnership to further enhance the environmental outcomes generated by the translucent flow events. This use targeted outcomes relating to connecting the river to floodplain habitats, maintaining native vegetation health, supporting waterbird breeding, and improving flow variability. Water for the environment was provided to Booberoi Creek, the river channel, Lake Brewster, the lower Lachlan wetlands, including the core reed beds of The Great Cumbung Swamp.

As of early May 2021, of the approximately 76 GL of Commonwealth environmental water available for use in 2020-21, about 42 GL has been used with approximately 34 GL to be carried over into 2021-22. Wet conditions have seen the use of translucent flow and air space releases from Wyangala Dam in July to August 2021.

Learn more about previous Commonwealth environmental water use in the Lachlan River catchment.

11.4.2 Seasonal outlook

The Bureau of Meteorology (2021, accessed 5 August) is forecasting median rainfall for much of eastern Australia. The El Niño–Southern Oscillation being neutral but may change to result in an increased chance of above median spring rainfall for much of eastern Australia.

Storage levels as of early August 2021, (WaterNSW, 2021 accessed 5 August) were:

- Wyangala Dam is about 95% full
- Lake Cargelligo is about 79% full
- Lake Brewster is 29% full.

11.4.3 Water availability

Given the wet catchment conditions it is anticipated that water availability will be high for 2021-22. As of early May 2021, of the approximately 76 GL available for use in 2020-21, around 42 GL has been used with the remaining 34 GL to be carried over into 2021-22.

11.4.4 Environmental demands

Environmental demands are moderate as a result of the need to further restore key assets after the drought conditions across the catchment prior to 2020-21.

For the environmental water demands for assets in the Lachlan River catchment in 2021–22 (Table LR1). The capacity to contribute to these environmental demands is dependent on overall water availability in the catchment.

Over the longer term the Commonwealth Environmental Water Office is concerned about the ability of environmental water to maintain the resilience, or prevent further degradation, of key environmental assets in the lower Lachlan catchment due to climate change and potential further impacts of river regulation. Recent modelling by Larkin et. al. (2020) suggests that over the next 50 years and under a drier climate, the Lachlan River system may become a system of disconnected waterholes for long periods. The lower Lachlan wetlands, including The Great Cumbung Swamp, will be much less frequently inundated. This will fundamentally change the dynamics of the Lachlan River ecosystem and the objectives currently being targeted using environmental water.

Table LR1 Environmental demands and watering priorities, 2021–22, and outlook for coming year, Lachlan River catchment

Environmental assets and Long Term Water Plan unit (PU) reference number (see Figure 1 and more detailed description at bottom of table)	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	Required frequency (maximum dry interval)		Environmental demands for water (all sources)	Potential Commonwealth environmental water contribution?	Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22
Lachlan River (PU 2, 3, 6, 8, 14, 16)	Protect tributary inflows (natural trigger) or deliver upon environmental triggers (e.g., timing or temperature) being reached Maintain native vegetation condition Native fish reproduction, conditioning, and maintenance. Maintain in-channel habitats, in-stream productivity, and longitudinal connectivity. Duration and frequency of pulse dependent on outcomes required and potential contribution/linkage to other watering actions.	>300 ML/d in the Lachlan River at Booligal (412005) to also contribute to small scale wetland inundation. If releases are made from Wyangala Dam, will be delivered as part of a small fresh of less than2600 ML/day in the Lachlan River at Forbes (412004).	Timing: September to March (but can occur any time). Usually early Spring and/or early December (at end of cod nesting) Duration: 30 days, 2–8 months of habitat inundation Frequency: 7-8 years in 10 (75% of years). Annual for the maintenance of drought refuge Maximum inter-event period: 2 years	Flow/volume met every year since 2011-12.	High	A high priority for watering in 2021–22.	High
		>650 ML/d in the Lachlan River at Booligal (412005) to also contribute to small scale wetland inundation. Will be delivered as part of a small fresh of around 2600 ML/day in the Lachlan River at Forbes (412004) if releases are made from Wyangala Dam.	Timing: October to April (but can occur any time). Usually early Spring and/or early December (at end of cod nesting) Duration: 30 days, 2–8 months of habitat inundation Frequency: 5-7 years in 10 (60% of years). Annual for the maintenance of drought refuge. Maximum inter-event period: 3 years	Flow/volume met every year except 2014-15 and 2018-19.	High	A high priority for watering in 2021–22.	High
		>1200 ML/d in the Lachlan River at Booligal (412005) to also contribute to large scale wetland inundation. May be delivered to extend duration of translucent flows from Wyangala Dam or Lake Brewster.	Timing: October to April (but can occur any time). Usually early Spring and/or early December (at end of cod nesting) Duration: 60 days, 2–3 months of habitat inundation Frequency: 2–3 years in 10 (25% of years) Maximum inter-event period: 5 years	Flow/volume met in 2012-13, 2013-14, 2015-16, 2016-17 (flood year), and 2020-21.	Moderate	Secondary priority for Commonwealth environmental watering. Will occur only if natural trigger is met, or under moderate to high resource availability.	Low
Booberoi Creek (PU 7)	Maintain populations of native fish, aquatic plants, and connectivity to the Lachlan River. Assist with recovery in upper reach after desilting in 2019-20. Maintain First Nations cultural values associated with Booberoi Creek.	>120 ML/d via the Booberoi Creek at Offtake (412189) to contribute to a large fresh. May be delivered as part of a larger Lachlan River watering action (e.g., spring pulse release from Wyangala Dam).	Timing: July to September (but can occur any time). Duration: 5 days, 2–3 months of habitat inundation Frequency: 5–10 years in 10 (75% of years) Maximum inter-event period: 2 years	Flow/volume met in 2011-12, 2012-13, 2016-17 (flood year), 2018-2019 and 2020-21.	High	A high priority for watering in 2021–22.	High
Mid-Lachlan anabranches (PU 5) **Wallamundry Creek and Wallaroi Creek**	Provide lateral connectivity to anabranch systems, maintain native vegetation and native fish outcomes	>120 ML/d via Wallaroi Creek upstream Worrongorra Weir (412046) to provide a large fresh.	Timing: July to September (but can occur any time). Duration: 5 days Frequency: 5–10 years in 10 (75% of years) Maximum inter-event period: 2 years	Flow/volume met in 2011-12, 2012-13, 2013-14, 2016-17 (flood year), 2019-2020 and 2020-21.	Low	A low priority for watering in 2021–22.	Low
		>200 ML/d Wallamundry Creek at Island Creek (412016)		Flow/volume met every year since 2011-12.	Low	A low priority for watering in 2021–22.	Low
Willandra Creek (PU 11) **Includes Morrison's Lake**	Maintain lateral connectivity to major distributary Maintain riparian vegetation health.	>250 ML/d via Willandra at Road Bridge (412012). Small freshes (>70 ML/day) are provided annually by operational flows.	Timing: July to September (but can occur any time). Duration: 5 days Frequency: 5–10 years in 10 (75% of years) Maximum inter-event period: 2 years	Flow/volume met in 2011-12, 2012-13, 2013-14, 2015-16, 2016-17 (flood year), 2019-2020 and 2020-21.	Low	A low priority for Commonwealth environmental water. Asset receives more water under regulated conditions than would have occurred naturally	Low

Environmental assets and Long Term Water Plan unit (PU) reference number (see Figure 1 and more detailed description at bottom of table)	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	Required frequency (maximum dry interval)		Environmental demands for water (all sources)	Potential Commonwealth environmental water contribution?	Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22
	Maintain foraging and nesting habitat for waterbirds Maintain riparian habitat for other species i.e., frogs Morrison's Lake has significant cultural values.	Morrison's Lake Nature Reserve - 400 to 500 ML to fill but may require up to 3 GL for conveyance and to also target blackbox	Can be completed in conjunction with Willandra replenishment flows.	Received water in 2016-17 (flood year).	Moderate	Secondary priority for Commonwealth environmental watering. Will occur under moderate to high resource availability. Demand may be met by other means.	Low
Lake Cargelligo (PU9)	Maintain lateral connectivity to major distributary Native fish reproduction, conditioning, and maintenance Maintain foraging and nesting habitat for waterbirds	>65% full at Lake Cargelligo at Storage (412107)	Timing: September to March (can occur anytime) Duration: varies depending on objective may include up to 2–6 months of habitat inundation Frequency: 5–7 years in 10 (60% of years) Maximum inter-event period: 3 years	Flow/volume met every year since 2011-12.	Moderate	A high priority for watering in 2021–22. Trial watering action linked to spring pulse in the Lachlan River. Seeks to determine if larval native fish drift from the river on a pulse flow and potentially contribute to native fish recruitment outcomes in Lake Cargelligo.	Moderate
Brewster Weir Pool (PU 8)	Help maintain weir pool height to maintain olive perchlet habitat	Up to 5 GL dependant on the operational level and management requirements of the weir at Lachlan Lake B Weir (412048). May be delivered as part of pulse flows in the Lachlan	5–10 years in 10 (annual for the maintenance of drought refuge)	Flow/volume met every year since 2011-12.	Low	A low priority for watering in 2021–22.	Low
Lake Brewster (PU 10)	Maintain foraging and nesting habitat for waterbirds and pelicans. Maintain aquatic vegetation health.	Flows are managed where possible to avoid inundation of nests if pelican breeding has occurred. 2000 ML use in 2020-21.	As required	Watered in 2020-21 for pelican and aquatic vegetation outcomes.	Moderate	Secondary priority for Commonwealth environmental watering. Will occur only if natural trigger is met, or under moderate to high resource availability. Demand may be met by other means.	Low
Merrowie Creek (PU 12) **While not referenced in LTWP, this system includes Lake Tarwong at end of system (Box Creek)**	Maintain lateral connectivity to major distributaries Maintain riparian vegetation health. Maintain foraging and nesting habitat for waterbirds Maintain riparian habitat for other species i.e., frogs	>150-160 ML/d via Merrowie Ck at Offtake (412163) to provide small fresh and/or small wetland inundation.	Timing: September to March (can occur anytime) Duration: 30 days, 2–8 months of habitat inundation Frequency: 7-8 years in 10 (75% of years) Maximum inter-event period: 2 years	Flow/volume met annually via stock and domestic replenishment flows each winter/early spring.	Low	A low priority for watering in 2021–22.	Low
		>150 ML/d via Merrowie Ck at Offtake (412163) to provide large wetland inundation.	Timing: September to June (can occur anytime) Duration: 60 days, 2–3 months of habitat inundation Frequency: 3-5 years in 10 (40% of years) Maximum inter-event period: 4 years	Duration target only met in 2011-12, 2012-13, and 2016-17. Duration of ~30 days reached during Aug-Sept 2020 translucent flow event (peaked at 575 ML/day) and duration of ~14 days reached in Nov 2020 translucent flow event (peaked at 325 ML/day). Could be delivered in conjunction with stock and domestic replenishment flows. 2020-21 translucent flow event did not reach Lake Tarwong at end of Merrowie-Box Creek system.	Moderate	Secondary priority for Commonwealth environmental watering. Targeting of Lake Tarwong will occur only if natural trigger is met, or under moderate to high resource availability.	Low
Merrimajeel Creek (PU 13) **Includes Lake Merrimajeel, Murrumbidgil**	Maintain lateral connectivity to major distributaries Maintain riparian vegetation health.	>300 ML/d in Lachlan River at Booligal (412005) to contribute to small wetland inundation.	Timing: September to March (can occur anytime) Duration: 30 days Frequency: 7-8 years in 10 (75% of years) Maximum inter-event period: 2 years	Flow/volume met every year since 2011-12. Received translucent flows in 2020-21.	Low	A low priority for watering in 2021–22.	Low

Environmental assets and Long Term Water Plan unit (PU) reference number (see Figure 1 and more detailed description at bottom of table)	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	Required frequency (maximum dry interval)		Environmental demands for water (all sources)	Potential Commonwealth environmental water contribution?	Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22
Swamp and Booligal wetlands. **See also waterbird breeding contingency below.**	Maintain foraging and nesting habitat for waterbirds Maintain riparian habitat for other species i.e., frogs	>650 ML/d in Lachlan River at Booligal (412005) to contribute to small wetland inundation. Note: flows at Booligal do not always translate to flows further into Merrimajeel Creek Cobb Hwy (412122), e.g., 2017-18 flows at Booligal did not register at Cobb Highway gauge.	Timing: October to April (can occur anytime) Duration: 30 days, 2–8 months of habitat inundation Frequency: 5-7 years in 10 (60% of years) Maximum inter-event period: 3 years	Flow/volume met every year at Booligal except for 2014-15 and 2018-19. Received translucent flows in 2020-21.	Low	A low priority for watering in 2021–22.	Low
		>850 ML/d in Lachlan River at Booligal (412005) to contribute to large wetland inundation	Timing: August to February (can occur anytime) Duration: 60 days, 2–6 months of habitat inundation Frequency: 3-5 years in 10 (40% of years) Maximum inter-event period: 4 years	Flow/volume met in 2011-12, 2012-13, 2013-14, 2015-16, 2016-17 (flood year) and 2020-21 (translucent flows).	Moderate	Secondary priority for Commonwealth environmental watering. Will occur only if natural trigger is met, or under moderate to high resource availability.	Low
		>1200 ML/d in Lachlan River at Booligal (412005) to contribute to large wetland inundation	Timing: Any time Duration: 60 days, 2–3 months of habitat inundation Frequency: 2-3 years in 10 (25% of years) Maximum inter-event period: 5 years	Flow/volume met in 2011-12, 2012-13, 2013-14, 2015-16, 2016-17 (flood year) and 2020-21 (translucent flows).	Moderate	Secondary priority for Commonwealth environmental watering. Will occur only if natural trigger is met, or under moderate to high resource availability.	Low
Muggabah Creek (PU15) **See also waterbird breeding contingency below.**	Maintain lateral connectivity to major distributaries Maintain riparian vegetation health. Maintain foraging and nesting habitat for waterbirds Maintain riparian habitat for other species i.e., frogs	>300 ML/d in Lachlan River at Booligal (412005) to contribute to small wetland inundation. Note: flows at Booligal do not always translate to flows further into Muggabah Creek Cobb Hwy (412124), e.g., 2017-18 flows at Booligal did not register at Cobb Highway gauge. Flows rarely reach or go above 250 ML/day and require flood or translucent flows to be achieved.	As per equivalent Merrimajeel action above.	As per equivalent Merrimajeel action above.	Low	A low priority for watering in 2021–22.	Low
		>650 ML/d in Lachlan River at Booligal (412005) to contribute to large wetland inundation.	As per equivalent Merrimajeel action above.	As per equivalent Merrimajeel action above.	Low	A low priority for watering in 2021–22.	Low
		>850 ML/d in Lachlan River at Booligal (412005) to contribute to large wetland inundation	As per equivalent Merrimajeel action above.	As per equivalent Merrimajeel action above.	Moderate	Secondary priority for Commonwealth environmental watering. Will occur only if natural trigger is met, or under moderate to high resource availability.	Low
		>1200 ML/d in Lachlan River at Booligal (412005) to contribute to large wetland inundation	As per equivalent Merrimajeel action above.	As per equivalent Merrimajeel action above.	Moderate	Secondary priority for Commonwealth environmental watering. Will occur only if natural trigger is met, or under moderate to high resource availability.	Low
Western Lachlan watercourse (PU 16) **Includes Lachlan River channel, Great**	Lateral and longitudinal connectivity, support movement, spawning and recruitment of aquatic species. Riparian and wetland vegetation health.	>650 ML/d in Lachlan River at Booligal (412005) to contribute to small wetland inundation.	Timing: September to March (can occur anytime) Duration: 30 days, 2–8 months of habitat inundation Frequency: 7-8 years in 10 (75% of years) Maximum inter-event period: 2 years	Flow/volume met in 2011-12, 2012-13, 2013-14, 2015-16, 2016-17 (flood year) and 2020-21 (translucent flows).	High (to maintain core reed beds of Great Cumbung)	A high priority for watering in 2021–22.	High (to maintain core reed beds of Great Cumbung)

Environmental assets and Long Term Water Plan unit (PU) reference number (see Figure 1 and more detailed description at bottom of table)	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	Required frequency (maximum dry interval)		Environmental demands for water (all sources)	Potential Commonwealth environmental water contribution?	Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22
Cumbung Swamp, Lachlan swamp, Lake Waljeers, Baconian swamp	Nutrient and carbon cycling Maintain refuge for aquatic biota and fish Maintain riparian habitat for other species i.e., water birds	>850 ML/d in Lachlan River at Booligal (412005) to contribute to small wetland inundation.	Timing: October to April (can occur anytime) Duration: 60 days, 2–6 months of habitat inundation Frequency: 5-7 years in 10 (60% of years) Maximum inter-event period: 3 years	Flow/volume met in 2011-12, 2012-13, 2013-14, 2015-16, 2016-17 (flood year) and 2020-21 (translucent flows).	High (to maintain core reed beds of Great Cumbung)	A high priority for watering in 2021–22.	Moderate (to maintain core reed beds of Great Cumbung)
		>1200 ML/d in Lachlan River at Booligal (412005) to contribute to large wetland inundation	Timing: August to February (but can occur any time) Duration: 60 days, 2–3 months of habitat inundation Frequency: 3-5 years in 10 (40% of years) Maximum inter-event period: 4 years	Flow/volume met in 2011-12, 2012-13, 2013-14, 2015-16, 2016-17 (flood year) and 2020-21 (translucent flows).	Moderate	Secondary priority for Commonwealth environmental watering. Will occur only if natural trigger is met, or under moderate to high resource availability.	Low
		>1200 ML/d in Lachlan River at Booligal (412005) to contribute to large wetland inundation	Timing: Any time Duration: 60 days, 2–3 months of habitat inundation Frequency: 2-3 years in 10 (25% of years) Maximum inter-event period: 5 years	Flow/volume met in 2011-12, 2012-13, 2013-14, 2015-16, 2016-17 (flood year) and 2020-21 (translucent flows).	Moderate	Secondary priority for Commonwealth environmental watering. Will occur only if natural trigger is met, or under moderate to high resource availability.	Low
Wetlands, lagoons, and billabongs (various PUs) **Includes, but not limited to, Yarrabandai Lagoon, Noonamah, Comayjong, Fletchers Lake and Lake Ita.**	Maintain off-channel drought refuge habitat for native frogs and waterbirds Support movement, spawning and recruitment of aquatic species. Maintain floodplain vegetation health	Site specific. Delivery may involve the use of regulators and/or pumping.	Will vary from site to site and depending on the outcomes being sought. Likely to be annual to maintain wetland vegetation with a period of drying down followed by re-inundation.	Various and site specific. Several sites have received water frequently in recent years (e.g., Noonamah), some have just commenced receiving water (e.g., Comayjong) and planning is underway for other sites, such as Lake Ita, to be able to be watered in the future.	High	A high priority for watering in 2021–22.	Moderate
Waterbird breeding contingency	Waterbird breeding sites including (but not limited to) Lake Brewster, the Booligal wetlands (Merrimajeel Creek, Muggabah Creek), Lachlan Swamps and Great Cumbung Swamp.	Variable and seeks to provide at least 0.8 metres of depth below nests until chicks have fledged	As required, more likely in very wet/flood years	Water provided during breeding events in 2012, 2015 and 2016. Small pelican rookery supported at Lake Brewster in 2020-21.	High (Contingency: bird breeding)	Depending on timing, option to be considered if breeding event is triggered, however more likely to occur under moderate or high water resource availability	High (Contingency: bird breeding)
Water quality contingency:	River channel and seeks to maintain dissolved oxygen concentration at approximately 4 mg/L.	Variable and may depend on in-channel flow rates (e.g., flood recession).	As required, more likely in very wet/flood years or during very low flow periods and heat waves in summer.	Use of Lachlan Water Quality Allowance would occur before use of Commonwealth environmental water.	High (Fish refuge flows)	Depending on ability to source high quality water and noting potential long travel times from storages to impacted sites in lower Lachlan.	High (Fish refuge flows)

Note: reference numbers in table drawn from Lachlan Long Term Water Plan Part B: Lachlan planning units (NSW DPIE 2020).

Key

Potential watering in 2021–22

- High priority for Commonwealth environmental watering (likely to receive water even under low water availability)
- Secondary priority for Commonwealth environmental watering (watering to occur only if natural trigger is met, or under moderate – high water resource availability); or water demand likely to be met via other means
- Low priority for Commonwealth environmental watering (under high – very high water resource availability); or unable to provide water because of constraints or insufficient water

Environmental demands (demand is considered at a generalised scale; there may be specific requirements that are more or less urgent within the flow regime)

- High to critical demand for water (needed in that particular year or urgent in that particular year to manage risk of irretrievable loss or damage)
- Moderate demand for water (water needed in that particular year, the next year, or both)
- Low demand for water (water generally not needed in that particular year)

11.5 Water delivery in 2021–22

Based on the demand for water for the environment, water availability (supply), and catchment conditions, the overall purpose for managing Commonwealth water for the environment in the Lachlan catchment in 2021–22 is to maintain and protect the health and resilience of aquatic ecosystems and wetland areas.

The planning of watering actions is undertaken in partnership with NSW agencies. A range of scenarios, from very dry to very wet conditions, are planned for so that environmental water managers can respond quickly to changing catchment conditions during the year. In comparison to 2020-21, the return to wetter/average conditions, and related increases in water availability, will provide an ability to deliver a broader range of environmental flows in the Lachlan River catchment during 2021-22.

The inclusion of a spring pulse from Wyangala Dam has demonstrated its value in enabling several watering actions to be efficiently and effectively delivered as part of a larger flow event. A spring pulse potentially includes all the main river channel while also enabling watering actions into Yarrabandai Lagoon, Booberoi Creek, Brewster Weir pool, Noonamah, Comayjong, Fletchers Lake and The Great Cumbung Swamp. The pulse being planned for 2021–22 seeks to expand on this approach with the potential inclusion of Lake Cargelligo as a watering site. The volume of environmental water required would be dependent on the size of any natural flow event which ideally is used as a trigger for delivery (the larger the natural event, the less environmental water required). Depending on the inflow scenario, distributaries such as Willandra, Merrowie, Merrimajeel and Muggabah Creeks would be considered for watering in conjunction with stock and domestic replenishment flows where applicable. Wherever possible Commonwealth environmental water is proposed to be used in conjunction with water provided by NSW.

Should there be substantial rainfall and a significant increase in water availability during 2021– 22, watering actions will be scaled up accordingly. Under very wet conditions, watering actions may seek to compliment other flows in the system to maintain the health of floodplain vegetation, maintain water quality where feasible to do so and/or the need to support waterbird breeding events. Watering actions that contribute to maintaining waterbird habitat within the Lachlan catchment, and potentially link to waterbird habitat in other parts of the Basin (e.g., the Macquarie, Murrumbidgee, and Mid-Murray catchments).

11.6 Monitoring and lessons learned

11.6.1 Monitoring

The CEWO Monitoring, Evaluation and Research (MER) Program (2019–20 to 2021–22) integrates and replaces monitoring and research activities under the Long-Term Intervention Monitoring (LTIM) and Environmental Water Knowledge and Research (EWKR) projects.

The University of Canberra is the lead agency, contracted by the CEWO, to undertake the Lachlan LTIM (Dyer et al 2015, 2016, 2017, 2018, 2019) and MER projects (Dyer et al 2020). A detailed MER Plan has been developed by the University of Canberra for the Lachlan River which sets out the schedule of activities to be undertaken to June 2022. Learn more about the Lachlan MER project.

Additional monitoring is also undertaken by NSW agencies. Landholders and community members play a critical role in providing real-time, on ground advice and observations of conditions in the catchment, including the progress and outcomes from the use of environmental water.

11.6.2 Lessons learned

Outcomes from monitoring and lessons learned in previous years are a critical component for the effective and efficient use of Commonwealth water for the environment. These learnings are incorporated into the way environmental water is managed.

Key findings from monitoring in the Lachlan River Catchment are summarised in Table LR2.

Table LR2 Key lessons learned in the Lachlan River Catchment

Theme	Lessons learned
Native fish	• Dyer et al. (2019) notes evidence that a remnant adult population of Murray cod persists in the lower Lachlan below Lake Brewster after the 2016 hypoxic water event. Monitoring has shown this population to be spawning and will be the most likely recovery pathway for this species. It will be important for future water delivery to continue to provide breeding opportunities, by facilitating the movement of pre-spawning fish and maintaining spawning habitat during nesting periods to prevent rapid water level drops and nest abandonment or desiccation. Dyer et al. (2020) suggests that increased variability during the Murray cod nesting season may improve spawning and recruitment outcomes for Murray cod. • The provision of a 'minimum flow' targets during the spawning season for nesting fish species may also be river reach specific. The decision in 2018–19 to not include a minimum flow target at Hillston (lower Lachlan) appears to have had no impact on cod larvae response in that year. This would suggest that nesting fish species are (a) nesting at sites lower than existing low flow levels, and/or (b) that flows delivered to the upper Lachlan continued to provide benefit to the lower Lachlan in addition to operational base flows. These flows would be better informed/targeted if incorporated with habitat mapping undertaken by NSW and fish movement monitoring (yet to be undertaken in the Lachlan) (Dyer et al. 2019). • Watts et al. (2019) note the learning from the 2015–16 watering action that targeted, but failed to detect, golden perch spawning in the Lachlan River (Dyer et al. 2016). Future watering actions targeting golden perch spawning as an objective, will need to be undertaken in a year of high water availability to be able to provide increasing flows over several days combined with increasing water temperatures (above 23°C). Under such catchment conditions consideration will also have to be given to the likelihood that golden perch may have spawned on earlier high flows (translucent releases or flood flows). This has been shown to be the case in 2020–21 with Golden perch spawning detected for the first time in seven years of monitoring (Dyer, 2021) and linked to 2020–21 translucent flow events. • The integration of eDNA metabarcoding in the 2018–19 monitoring efforts resulted in more robust species richness data for the lower Lachlan River through the detection of freshwater catfish and silver perch. • Monitoring coordinated by NSW continues to show the importance of off-channel habitat, such as Booberoi Creek, to a range of native fish including Freshwater catfish. Monitoring has also shown that Olive perchlet are continuing to persist in Brewster Weir pool (McGrath 2020). • Linked to the theme of stream metabolism below, CEWO (2017) notes the difficulty in the timely provision of water for native fish refuge flows during hypoxic water quality events. Long travel times for the delivery of flows can mean that it is not possible to provide refuge flows in time to prevent or minimise the impacts of fish kills, especially in the lower Lachlan. The recent installation of dissolved oxygen loggers on NSW gauges in the system will help with earlier detection of hypoxic water conditions.
Vegetation	• Dyer et al. (2020) notes the MER research project that focusses on the reed beds of the Cumbung Swamp has shown that environmental water is maintaining the condition of the central reed beds of the Great Cumbung Swamp, promoting growth, cover, and reproduction. • There is a challenge for environmental water managers in maintaining the health of floodplain vegetation, especially at sites that are easier to provide water to (Higgisson et al. 2019). These sites may be prone to river redgum encroachment. Planning of events for vegetation outcomes must include and trial not only the timing of flow events but also the duration and depth of flows to match what is required for the vegetation outcomes being targeted at individual sites.

Theme	Lessons learned
	• Dyer et al. (2019) found that frequently watered sites, such as Nooran Lake, have the greatest number of native amphibious species present and can frequently replenish soil seedbanks. Maintaining flows to these sites may help reduce the number of terrestrial plant species that would be able to invade these sites in the absence of regular watering. A comparison of approaches and results with watering similar wetland sites for vegetation outcomes in the Murrumbidgee Catchment (Wassens 2020) may also help inform such an approach in the Lachlan Catchment.
Connectivity	• Dyer et al. (2020) found that all four of the 2019–20 watering actions provided water to parts of the river system that would otherwise have been dry in 2019–20, thus contributing to the provision of refuge habitat for water dependent species. • Dyer et al. (2019) also notes the increasing influence and importance of these watering actions have as they move downstream. For example, in 2018–19 these flows contributed 4 % of the flow in the mid-Lachlan (at Forbes). In the lower Lachlan (at Booligal) these flows contributed 24 % of the flow, doubled the number of freshes that exceeded 200 ML/day and provided the only fresh to reach 500 ML/day for the watering year. • Based on Sentinel monitoring, the combination of multiple pulses delivered at Booligal in May-June may achieve a greater spread into the Great Cumbung when compared to a spring pulse. Depending on the objectives to be targeted and catchment conditions, the use of water in autumn-winter, delivered to Booligal, may be a more efficient at watering the Great Cumbung region than delivery during spring. Winter-autumn would take advantage of lower temperatures and possible winter rain. However, spring may remain a preferred time in terms of response from the core reed beds and upstream in-channel outcomes. Proposed research under MER will inform these decisions into the future. • Consistently reviewing the planned annual hydrograph can enable water saving to be made during the year (e.g., the dispersal pulse as end of fish nesting period may not be required if operational flows can achieve this).
Waterbirds	• Brandis (2016) concluded that even with the provision of flows, the abandonment of Booligal wetland nesting sites by straw necked ibis during June-October 2015 was in response to a combination of factors relating to hotter temperatures, declines in flows and water levels, reduction in foraging habitat and better habitat being available in other catchments. • Brandis and Lyons (2016) note the response of straw necked ibis during the August-November 2016 breeding event where the colony exceeded 200,000 nests at its peak. This work also showed the effectiveness of the use of drones to assist with monitoring waterbird outcomes. Dyer et al. (2017) notes that this response highlights the importance of regional weather patterns, and the value of extensive flooding to provide foraging areas and habitat for food resources to thrive in a successful breeding event. The strategy of using flows to support breeding events once they have established (rather than trying to trigger a breeding event) is therefore sound. The management of water levels at the second waterbird colony site in the Booligal Wetlands in 2016-17 demonstrates the value of this approach.

Stream metabolism	• Dyer et al. (2019) suggest that pulses at the warmer time of year may improve the ability of flows to provide a boost in productivity to the river system. Planning of flows for spring-early summer will take the following points into consideration:
	  • the other objectives that may also be targeted with the use of water
	  • where those objectives may be met as the water moves down the river channel
	  • how best to use environmental water with other water, such as the Lachlan Water Quality Allowance, also being delivered in the system, identifying and filling gaps in key component of the hydrograph where required.
	  ○ minimising the risk of generating hypoxic events by providing pulses into the river when water temperatures begin to exceed 16 degrees Celsius.

Other aquatic animals	• Frogs: At sites like the Booligal Wetlands and The Great Cumbung, there is a need for standing water to be present in the landscape to enable summer breeding frog species to be able to complete their life cycle Dyer et al. (2016). The provision of flows during warmer months of the year needs to include consideration of the potential to contribute to the breeding of carp in the same areas where frog outcomes may be sought. Carp exclusion/management activities may be required on a site-by-site basis prior to flows being delivered in summer for frog outcomes.

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12 Murrumbidgee River Valley Water Plan

12.1 Region overview

12.1.1 River system

The Murrumbidgee River Valley (Map MR1) covers 84 000 square kilometres of southern New South Wales. It is bordered by the Great Dividing Range to the east, the Lachlan River Valley to the north and the River Murray Valley to the south (Green et al. 2011). The river originates in the alpine area of Kosciuszko National Park and flows through the Monaro High Plains and the low-lying plains of the western Riverina, joining the River Murray south of Balranald.

Most of the flow in the Murrumbidgee River comes from the upper portion of the catchment (gaining stream) and is delivered by the main tributary rivers: Cotter, Yass, Molonglo, Queanbeyan, Bredbo, Numeralla, Goodradigbee and Tumut (Kingsford and Thomas 2001). Several tributaries located immediately downstream of the dams contribute significant inflows, including Adelong, Adjungbilly, Gilmore, Hillas, Tarcutta, Kyeamba, Jugiong, Muttama, Billabong and Houlaghans Creeks, and Goobarragandra River (SKM 2011). The middle and lower portions of the catchment do not contribute significant inflows (losing stream).

The Yanco, Billabong, Colombo and Forest Creek network (known as the Yanco Creek System) is an anabranch complex that broadly connects the Murrumbidgee River with the Edward River. Water can be diverted from the Murrumbidgee River into the Yanco Creek at the Yanco Weir. Unregulated flows from Billabong Creek enter the regulated system east of Jerilderie, in addition to regulated inlets via Coleambally Irrigation Co Ltd and Murray Irrigation Ltd drainage systems.

Regulated water is provided by two major headwater storages, Burrinjuck Dam on the Murrumbidgee River and Blowering Dam on the Tumut River. Collectively these storages have a capacity of 2654 gigalitres. Blowering Dam and Tantangara Reservoir catchments are also affected by the operation of the Snowy Mountains Hydro Electricity scheme.

12.1.2 Traditional Owners

The rivers and wetlands of the Murrumbidgee River Valley hold significant spiritual and cultural importance for Aboriginal people. The Wiradjuri are the largest Aboriginal nation in the Murrumbidgee River valley, with their nation extending from the River Murray in the south to beyond Dubbo in the north, and west to Balranald. At the western end of the catchment are the traditional land of the Barapa Barapa, Muthi Muthi, Nari Nari, Nyeri Nyeri, Wadi Wadi, Wamba Wamba, Weki Weki, and Wolgalu nations. The mountains at the eastern end of the Murrumbidgee River Valley are the country of the Ngunawal and Ngarigo nations. (MDBA 2021). The Commonwealth Environmental Water Office (CEWO) respectfully acknowledges these Nations, their Elders past and present, as the Traditional Custodians of the lands on which this chapter is focused.

12.1.3 Important sites and values

Supporting a complex range of natural ecosystems, the Murrumbidgee River Valley contains many significant in-channel and wetland habitats which provide important habitat for a range of aquatic and terrestrial species including frogs, fish and waterbirds.

Commonwealth water for the environment is delivered to several important regions in the Murrumbidgee River Valley, including but not limited to the mid-Murrumbidgee wetlands, Yanco Creek system, Lowbidgee floodplain and Murrumbidgee River. These regions provide critical habitat for a range of water dependent animals, including internationally listed migratory waterbirds and a range of

threatened species including the southern bell frog, Australasian bittern, trout cod, Murray cod, silver perch, native catfish, fishing bat; and freckled and blue-billed ducks.

Murrumbidgee River

The Murrumbidgee River spans approximately 1600 km (Frazier et al. 2005) and is heavily regulated with 26 dams, weirs and irrigation channels (SKM 2011). The lowland section of River between Gundagai and Balranald consist of meandering channels and wide floodplains, providing a range of aquatic habitats (Green et al. 2011) which play a critical role in the life cycles of a variety of species (MDBA 2012).

River regulation has affected the frequency and duration of floodplain inundation, with the magnitude of small to medium floods on the Murrumbidgee River having significantly reduced (Frazier et al. 1995). This has had a significant impact on the river and the plants and animals that depend on it. It has also altered the natural seasonal flow patterns, with higher flows now occurring in summer and early autumn to meet irrigation demand and lower flows occurring during winter and spring when inflows are captured in the dam (CSIRO 2008, Frazier et al. 2005). River regulation has significantly contributed to native fish declines in the Murrumbidgee, with the native riverine fish communities remaining in poor condition (Wassens et al. 2020a). Davies et al. 2008, as part of the Sustainable Rivers Audit, found the overall condition and ecosystem health of the Murrumbidgee Valley to be very poor.

Mid-Murrumbidgee Wetlands

The mid-Murrumbidgee wetlands are located on the Murrumbidgee River floodplain between Wagga Wagga and Carrathool and consist of hundreds of lagoons and billabongs (MDBA 2012a), with several listed as nationally significant in the Directory of Important Wetlands of Australia (EA 2001). The mid-Murrumbidgee wetlands are also part of the Natural Drainage System of the Lower Murray River Management Catchment aquatic endangered ecological community listed under the NSW *Fisheries Management Act 1994*.

The mid-Murrumbidgee wetlands system is characterised by river red gum forests with marginal black box woodlands, and open water habitat of permanent to semi-permanent wetlands with aquatic plants such as lignum, garland lily and spike rush (NSW DPIE 2020a, MDBA 2012a, CSIRO 2008). Many of these wetlands rely on higher flows in the Murrumbidgee River to fill (Murray 2008). However, due to river regulation, inundation frequency and duration has significantly reduced, resulting in the overall poor condition of the mid-Murrumbidgee wetlands. Whilst the use of pumping infrastructure to deliver water for the environment has helped to improve or maintain the condition of a small number of wetlands in the mid-Murrumbidgee, it is not as ecologically effective as filling wetlands with a reconnecting river flow. As such, a high priority for environmental watering is reconnecting these wetlands to help the recovery of aquatic vegetation and improve the health of the river by enabling nutrients and animals to flow to and from the river.

Murrumbidgee Irrigation Area wetlands

Several significant wetlands occur in the Murrumbidgee Irrigation Area and require the use of irrigation infrastructure to receive environmental water. This includes Fivebough and Tuckerbil Swamps which are listed as wetlands of international importance under the Ramsar Convention. Both wetlands support a high abundance and diversity of waterbirds, including migratory waterbirds listed under international agreements (JAMBA, ROKAMBA, CAMBA, Bonn Convention) and threatened species, including the endangered Australasian bittern and Australian painted snipe (EPBC Act). They also provide significant breeding habitat for waterbirds including egrets and brolgas (White 2011).

Yanco Creek System

The Yanco Creek system consists of four major creeks: the Yanco, Billabong, Colombo, and Forest Creeks; and receives the majority of inflows from the Murrumbidgee River supplemented by catchment inflows from the unregulated Billabong Creek. The system discharges into the Edward River which is an anabranch of the River Murray (Alluvium 2013). This system is known to provide important native fish habitat, including for the threatened trout cod and freshwater (eel-tailed) catfish (Alluvium 2013). Floodplain wetlands occur throughout the Yanco Creek system providing important habitat for a range of species. This includes Wanganella Swamp which is a significant waterbird breeding site located in the Forest Creek system.

Lower Murrumbidgee (Lowbidgee) Floodplain

The Lowbidgee floodplain is located between Maude and Balranald and is listed on the Directory of Important Wetlands in Australia (EA 2001) and forms part of the Natural Drainage System of the Lower Murray River Catchment aquatic endangered ecological community, listed under the *NSW Fisheries Management Act 1994*. The Lowbidgee floodplain contains the third largest river red gum forest in Australia (Murrumbidgee CMA 2009), some of the largest lignum wetlands in New South Wales (CSIRO 2008) and has significant black box and reed bed communities (Murrumbidgee CMA 2009). Some of the Murray-Darling Basin's largest breeding sites for colonial nesting waterbirds and migratory waterbird species listed under bilateral agreements occur on the Lowbidgee floodplain (Wassens et al. 2019a).

The Lowbidgee floodplain can be inundated through controlled diversions from Maude and Redbank weirs or via overbank flooding from the river. The Lowbidgee floodplain can be divided into three wetland systems based on distinctive hydrological and ecological characteristics and are Gayini Nimmie-Caira, Fiddlers-Uara and Redbank systems. Gayini Nimmie-Caira supports extensive areas of lignum shrubland that provides important waterbird breeding habitat and important habitat for the threatened southern bell frog. Fiddlers-Uara creeks are the most upstream major distributaries on the Lowbidgee and support black box woodlands with lignum, nitre goosefoot and river cooba understory (MDBA 2012b, SKM 2011, NSW DPIE 2020a). The Redbank system consists of North and South (Yanga National Park) Redbank and is dominated by river red gum forests and woodlands with marginal black box woodlands (CSIRO 2008), and a high proportion of open water and semi-permanent wetland communities, including aquatic herbs and spike rush sedgelands (MDBA 2012b, NSW DPIE 2020a). This area also provides important waterbird breeding habitat.

At the western edge of the Lowbidgee is the Western Lakes, which is a complex of ephemeral lakes, wetlands and connecting waterways. The Western Lakes were disconnected from the Murrumbidgee River in the early 1900's due to the construction of diversion structures on the floodplain (Kingsford and Thomas 2001, NSW OEH 2012) and remained isolated until flow diversion works enabled the delivery of water for the environment in 2011 (NSW OEH 2012). This area provides habitat for a diverse range of waterbirds.

Junction Wetlands

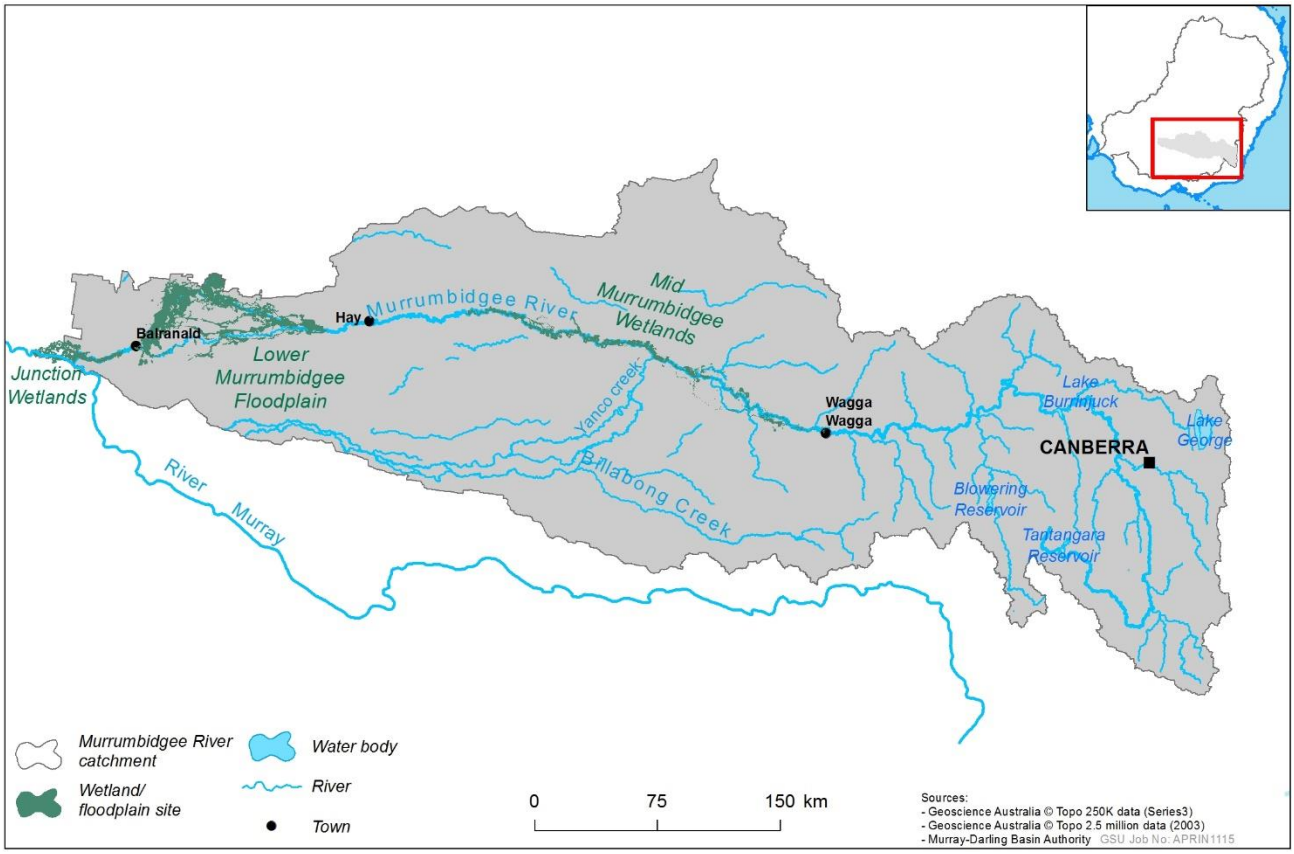
The Junction Wetlands lie between Balranald and the confluence of the Murrumbidgee and Murray Rivers. This area consists of several creeks, lagoons, and areas of river red gum forest, black box, and mallee (SKM 2011).

122.1.4 Stakeholder engagement

In the Murrumbidgee River Valley, the planning, management and delivery of Commonwealth water for the environment is undertaken in conjunction with a range of partners and stakeholder groups. Key stakeholders include the New South Wales Department of Planning, Industry and Environment (DPIE) – Biodiversity and Conservation, NSW Department of Primary Industries (DPI) - Fisheries, WaterNSW, Nari Nari Tribal Council, scientists from Charles Sturt University engaged in monitoring the outcomes of

Commonwealth environmental water use, Murray-Darling Wetlands Working Group, The Nature Conservancy and the Murrumbidgee Environmental Water Advisory Group (EWAG) which includes local councils, the major irrigation corporations and private landholders.

Map MR1 Murrumbidgee catchment including major towns and headwater storage



Source: Courtesy of the Murray-Darling Basin Authority

12.2 Environmental objectives

Objectives for environmental water delivery in the Murrumbidgee River Valley are based on long-term environmental objectives in the Basin Plan; state long-term watering plans; the Ramsar site ecological character description for Fivebough and Tuckerbil swamps and local ecological knowledge.

The objectives that are targeted in a particular year may vary, depending on available water, catchment conditions, operational feasibility, and demand for environmental water. These objectives will continue to be revised as part of the Commonwealth Environmental Water Office's (CEWO) commitment to adaptive management. The objectives are:

- Vegetation – Maintain or improve the condition and maintain or increase the extent of native riparian, in-channel, floodplain and wetland vegetation.
- Waterbirds – Increase waterbird abundance and maintain species diversity by supporting naturally triggered breeding events, and maintaining suitable refuge, feeding and breeding habitat.
- Native fish – Prevent loss of native fish species and improve population structure, distribution, and species abundance by supporting opportunities for movement, dispersal, reproduction, and recruitment.
- Other vertebrates – Provide habitat to support survival of other native aquatic species, including frogs and turtles; and support opportunities for reproduction and recruitment.

- Invertebrates – Provide habitat to support increased microinvertebrate and invertebrate survival, diversity, abundance and condition.
- Connectivity – Support longitudinal connectivity, including with the River Murray, and lateral connectivity (within constraints) between the river and floodplain and wetlands.
- Processes/water quality/resilience – Support in-stream and floodplain productivity; support nutrient, carbon and sediment transport; provide movement and dispersal opportunities for biota; create quality instream, floodplain and wetland habitat (including supporting water quality); and maintain or provide a diversity of drought refuge habitat across the landscape.

12.3 First Nations environmental watering objectives

Advice on environmental water objectives in the Murrumbidgee catchment has been provided through discussions with First Nations in the Murrumbidgee, particularly with the Nari Nari Tribal Council. Table MR1 includes just some of the objectives for the Murrumbidgee catchment raised. It is important to note these objectives do not represent the detail, depth and complexity of Nations' localised water-related objectives.

Some of these objectives sit outside the scope of water for the environment to influence, while for others, the link between water for the environment and the site or issues is not well understood. Environmental flows will aim to contribute to identified objectives, where possible. The Commonwealth Environmental Water Holder is committed to continuing to strengthen engagement with all Southern Basin First Nations to support those Nations to articulate objectives for water management.

The Commonwealth Environmental Water Office recognises the critical importance of strengthening involvement of First Nations people in environmental watering, and the importance of building transparent, respectful relationships with Traditional Custodians across the Basin. As such, we are developing a partnership agreement between the Nari Nari Tribal Council and the Commonwealth in relation to planning, delivery and monitoring of Commonwealth environmental water on Nari Nari Traditional Lands. The Partnership Agreement is nearing completion with the aim to maximise environmental outcomes over time by enabling the Nari Nari Tribal Council to facilitate environmental watering on Nari Nari Country, according to their lore and customary obligations. It is hoped, this will be the first of many partnerships with First Nations in the Murrumbidgee.

Table MR1 First Nations environmental water objectives for the Murrumbidgee system

Theme	Learnings
Waterways and Places in Need of watering	Murrumbidgee, Dry Lake, Yanga Lake, Billabong Creek, Wetlands, Billabongs, Floodplains, Creeks, Other places – parks, forests, islands, Major rivers, Tributaries, Ramsar-listed wetlands
River Flows and Connectivity	Improve water quality, improve timing and seasonality of flows, restore flows in degraded rivers, remove barriers and constraints, improve flows and quantity (rivers and general), restore wetland hydrology, improve river and or floodplain connectivity, and improve tributary flows
Vegetation	Old Man Weed, Cumbungi, Black Box, Lignum, River Red Gum, Grasses
Fish	Murray Cod, Yellowbelly, Catfish, Native fish
Waterbirds	Swan, Pelican, Ducks, Eastern Bittern, Sea eagle [a], Black Swan
Other species	Turtles, Frogs, Murray Cray, Shrimp, Mussels, Platypus, Yabbies, Water Rat (Rakali), Macroinvertebrates, Emu [a], Kangaroo [a], Birds

a Water for the environment targeting other environmental outcomes may influence this species or objective.

12.4 Recent conditions and seasonal outlook

12.4.1 Recent conditions and environmental water use

The Murrumbidgee Valley experienced dry conditions from early 2017 up until early 2020 when wetter conditions prevailed, contributing to the dry conditions easing (BOM 2021). Allocations against Murrumbidgee regulated high security, general security and conveyance entitlements reached 100% in January 2021.

The Murrumbidgee Valley experienced wet (about 25th percentile) conditions in 2020–21 (DPIE 2021a). That is, based on long term inflow statistics, about 25 out of 100 years would generally experience conditions that are wetter than those experienced across the year.

With the reasonably wet conditions and high-water resource availability in the valley, the primary focus for use of Commonwealth water for the environment was to maintain, and where possible, improve the health and resilience of aquatic ecosystems. This included the large-scale provision of water to the Lowbidgee floodplain, a flow down the Murrumbidgee River and small-scale water delivery to a network of wetland sites across the Murrumbidgee valley, including two new sites, with the first pumping of water to Rhyola Swamp and Middle Wetland in the Yanco/Billabong Creek system.

Delivery of Commonwealth and NSW water for the environment successfully:

- triggered and supported breeding of over 15,000 straw-necked and 3000 glossy ibis nesting pairs, including smaller numbers of many other species, at Eulimbah Swamp in Gayini Nimmie-Caira. This very large colony was established and supported solely by water for the environment
- supported over 20 waterbird breeding events across the catchment, 18 in the Lowbidgee' two in the mid-Murrumbidgee and one at Wanganella Swamp; with breeding of numerous species including threatened Australasian and little bitterns, egrets, spoonbills, herons, cormorants, darters, threatened blue-billed and freckled ducks, and brolgas
- supported six species of frogs (barking and spotted marsh frogs, Peron's tree frog, plains froglet, inland banjo frog and the threatened southern bell frog); with successive years of delivering water for the environment supporting the return of threatened southern bell frog populations in the Lowbidgee to pre-Millennium Drought numbers
- supported golden perch spawning and recruitment in the deep creek systems on the Yanga National Park floodplain and provided fish passage between barriers (weirs) in the Lowbidgee and between the Murrumbidgee and Murray rivers. The flow also provided lateral connection to floodplain creeks and lakes in Yanga National Park, enabling native fish to move between the river and floodplain creeks and lakes, as well as providing a critical exchange of carbon and nutrients
- led to the discovery, and supported, a small population of unspeckled hardy-head at Coonancoocabil Lagoon in the mid-Murrumbidgee: this species is very rare in the Murrumbidgee
- supported populations of a range of native fish including carp gudgeon, Australian smelt, flathead gudgeon, bony-bream, rainbow fish, Murray cod and golden perch
- supported an increased abundance of deep-water tolerant aquatic plant species such as common and red watermilfoil, common spike rush and floating pondweed in the Lowbidgee. Also promoted the emergence of new lignum, common spike rush, water primrose, starworts, and mud flat colonising species such as old man weed and lesser joyweed. Black-box trees that had been in poor health at Avalon Swamp in Gayini-Nimmie-Caira responded well to environmental watering which triggered their flowering along with establishing areas of nardoo, azolla, water primrose and swamp lily

supported all three Murrumbidgee turtle species (broad shelled, eastern long-necked and Macquarie River turtles).

Learn more about previous Commonwealth environmental water use in in the Murrumbidgee River Valley.

12.4.2 Seasonal outlook

The Bureau of Meteorology's seasonal outlook for June to August 2021 indicates that rainfall is likely to be above average across most of the Murrumbidgee River catchment with a greater than 75% chance of above median rainfall (BOM 2021). Additionally, the chance of exceeding maximum temperatures over the coming months is variable across the catchment, ranging from 60% in the eastern end of the valley reducing to 45% at the western end of the valley (BOM 2021).

This forecast should allow expanded system-scale and co-ordinated cross-catchment watering actions.

12.4.3 Water availability

The volume of Commonwealth environmental water carried over in Murrumbidgee River Valley for use in 2021–22 is 81.9 gigalitres, representing approximately 24.3% of general security and conveyance entitlement. In the Murrumbidgee regulated water source, general security and conveyance licences can carry over water up to a maximum of 30% of entitlement, the account limit (allocation plus carryover) is 100% of entitlement.

Allocations against Commonwealth water entitlements in the Murrumbidgee River Valley are determined by state governments and will vary depending on inflows. In the 1 July 2021 Water Allocation Statement (DPIE 2021b), opening allocations to high security entitlements are 95%, 30% for general security entitlements, and conveyance entitlements as per the valley's water sharing plan.

Based on the available volume of water held by the Commonwealth and other water holders (including carryover and forecast allocations), as well as recent and forecast catchment conditions, it is expected that the overall resource availability will be moderate to high in 2021–22.

12.4.4 Environmental demands

The environmental water demands for assets in the Murrumbidgee River Valley in 20221–22 are represented in Table MR2. A low-level mid-Murrumbidgee reconnection is a high priority under all water resource scenarios, and under current forecasts there is sufficient environmental water for this action to proceed.

Table MR2 Environmental demands and watering priorities, 2021–22, and outlook for coming year, Murrumbidgee catchment

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	Required frequency (maximum dry interval)		Environmental demands for water (all sources)	Potential Commonwealth environmental water contribution?	Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22
Mid-Murrumbidgee Wetlands[a] (includes pumping to Toogimbie Indigenous Protected Area) (PU 4, 5, 6, 9 and may also contribute flows in PU 7, 8, 10, 11, 12, 13)	Critical refuge habitat, aquatic vegetation, waterbirds, native fish, frogs, turtles, nutrient dispersal	Infrastructure assisted delivery to individual high priority wetland assets targeting provision of refuge habitat and maintenance of wetland vegetation (minimum of 4 GL required under a very low inflow scenario to support critical refuge requirements) (PU 6)	8 in every 10 years – annual (2 years)	Demand met or partially met over the last 5 years	HIGH to CRITICAL Provide refuge habitat for aquatic animals and maintain established aquatic habitat. However overbank connection is preferred	High Potential for water use under Very Low to Moderate inflow scenarios Up to 15 GL (volume contributed will be dependent on resource availability/antecedent conditions, with a minimum of 4 GL required under a Very Low inflow scenario)	HIGH to CRITICAL
		Tombullen storage releases to augment flows over 13 GL/day at Darlington Point (PU 6, 7, 8)	7–8 in every 10 years (2 years)	Demand partially met over the last 3 years	HIGH The condition of the mid-Murrumbidgee wetlands is generally poor due to a lack of inundation.	High Potential for water use under Moderate to High inflow scenarios subject to natural flow event triggers Up to 10 GL per event	HIGH
		Minimum of 15.5 GL/day at Darlington Point for up to 6 days plus a gradual recession targeting low-lying wetland vegetation and aquatic habitat up to 180 GL (multiple PU's)	7–8 in every 10 years (2 years)	Demand met 2 out of the last 5 years, last met 2017–18.	HIGH to CRITICAL The condition of the mid-Murrumbidgee wetlands is generally poor due to a lack of inundation.	Up to 170 GL under Moderate to High inflow scenarios	MODERATE
		Augment Airspace and/or Translucent Flow releases to maximise flow peak for inundation of mid-Murrumbidgee wetlands. Up to 40 GL ordered from opposing dam or other storage.	Opportunistic in response to natural cues and river operations	Opportunistic in response to natural cues and river operations	HIGH The condition of the mid-Murrumbidgee wetlands is generally poor due to a lack of inundation.	Up to 40 GL under Moderate to High inflow scenarios	HIGH
Murrumbidgee Irrigation (MI) Area Ramsar sites (Fivebough and Tuckerbil wetlands) and includes other important wetlands in MI Area (PU 14)	Ramsar ecological character, waterbirds, aquatic vegetation	Fivebough 500 ML to inundate 60% of wetland.	Fivebough: Shallow water 9 in every 10 years.	Demand met over the last 7 years	HIGH Required to maintain ecological character under Ramsar	High Potential for water use Minimum of 2 GL under a Very Low inflow scenario	HIGH
		Tuckerbil 500 ML to fill	Fill Tuckerbil 4 of every 10 years	Demand met over the last 6 years	HIGH Required to maintain ecological character under Ramsar	High Potential for water use. Up to 5 GL under Low inflow scenario	HIGH
Yanco/Billabong/Forest Creeks System (PU 12, 13)	Low-lying wetland vegetation and aquatic habitat, and native fish spawning and movement	Up to 20 GL in-channel, targeting up to 1400 ML/day at Yanco Creek off-take. Objectives also achieved by a mid-Murrumbidgee wetlands reconnection flow	7 in every 10 years (2 years)	Demand met or partially met in 3 of the last 6 years, however watering required to maintain condition of wetland-floodplain vegetation	MODERATE Watering, required to maintain the good condition of wetland-floodplain vegetation	Moderate Potential for water use Up to 10 GL under Moderate to High inflow scenarios. Supplementary use prioritised if available.	MODERATE Subject to natural cues
Yanco Creek System – Wanganella and Rhyola Swamps (PU 12, 13)	Aquatic vegetation, waterbirds	Pumping up to 2.5 GL	7–8 in every 10 years (2 years)	Demand met 3 out of the last 6 years	CRITICAL Prevent loss of aquatic vegetation species (cumbungi rhizomes)	High Potential for water use Up to 2.5 GL under Very Low to Moderate inflow scenarios	HIGH
Yanco Creek System – Wanganella, Rhyola and Old Coree Swamps (PU 12, 13)	Wetland and black box vegetation communities	Up to 6 GL	3 in every 10 years (3 years)	Demand met or partially met in 3 of the last 6 years	MODERATE Watering following natural cues to maintain condition of wetland-floodplain vegetation	Moderate Potential for water use up to 4 GL if natural flow event triggers an opportunity under Moderate to High inflow scenario. Supplementary use prioritised if available.	LOW, subject to natural cues

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	Required frequency (maximum dry interval)		Environmental demands for water (all sources)	Potential Commonwealth environmental water contribution?	Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22
Lowbidgee - Core refuge and permanent aquatic habitat sites (PU7)	Critical refuge habitats	Up to 73 GL targeting critical refuge habitat requirements (minimum of 8 GL is required under a Very Low inflow scenario to meet these needs)	Annual	Demand met over the last 6 years	HIGH to CRITICAL Annual watering required for critical habitat requirements	High Potential for critical/permanent habitats. Volume contributed will be dependent on resource availability/antecedent conditions, with a minimum of 5 GL required under a Very Low inflow scenario increasing to 50 GL under Moderate inflow scenarios Supplementary use prioritised if available.	HIGH to CRITICAL
Lowbidgee – Rookery sites (PU7)	Naturally triggered colonial waterbird breeding	Up to 30 GL	As required in response to naturally triggered colonial bird breeding event	As required	HIGH Support successful completion of waterbird breeding events	High Potential, if colonial waterbird breeding is triggered under Moderate to Very High inflow scenario	HIGH
Lowbidgee - North Redbank (PU7)	Wetland vegetation and habitat for native fish, frogs, turtles, and waterbirds	Up to 60 GL[b]	River red gum forest and spike rush wetlands 1–3 years (3 years)	Met or partially met over the last 6 years	MODERATE Watering following natural cues, to maintain the good condition of wetland-floodplain vegetation	Moderate Potential for wetland inundation Up to 40 GL under Moderate to High inflow scenarios Supplementary use prioritised if available.	LOW, subject to natural cues
Lowbidgee - Yanga National Park (PU7)	Wetland vegetation and habitat for native fish, frogs, turtles, and waterbirds	Up to 50 GL[b]	River red gum forest and spike rush wetlands 1–3 years (3 years)	Met or partially met over the last 6 years	HIGH Watering required to maintain deep creek fish refuges and condition of wetland-floodplain vegetation	High Potential for wetland inundation Up to 30 GL under Moderate to High inflow scenarios Supplementary use prioritised if available.	MODERATE, subject to natural cues
Lowbidgee - Gayini Nimmie-Caira (PU7)	Wetland vegetation and habitat for native fish, frogs, turtles, and waterbirds	Up to 50 GL[b]	Refuge habitat annual Lignum dominated wetlands 1 to 5 years, with duration of up to 7 months	Met or partially met over the last 6 years	HIGH Watering following natural cues to maintain the good condition of wetland-floodplain vegetation	High Potential for wetland inundation Up to 30 GL under Moderate to High inflow scenarios Supplementary use prioritised if available.	MODERATE, subject to natural cues
Lowbidgee - Fiddlers-Uara (PU7)	Wetland vegetation and habitat for native fish, frogs, turtles, and waterbirds	Up to 20 GL	Black box and lignum wetlands every 3 to 7 years	Met or partially 3 out of the last 7 years	MODERATE Watering following natural cues to maintain the good condition of wetland-floodplain vegetation	Moderate Potential for wetland inundation Up to 15 GL under High inflow scenarios Supplementary use prioritised if available.	LOW, subject to natural cues
Lowbidgee - Western Lakes (PU7)	Maintain open water habitats and floodplain vegetation	Up to 30 GL	Wetland habitats and open water, black box, and lignum wetlands every 3 to 7 years	Met or partially met over the last 6 years	LOW Watering following natural cues, to maintain open water bodies and good condition of wetland-floodplain vegetation	Low Potential Up to 15 GL under Moderate to High inflow scenario	MODERATE
Lowbidgee full system watering (PU7)	Waterbird recovery, improve floodplain habitat condition	Up to 180 GL for Basin-wide waterbird habitat and future population recovery.	Opportunistic based on natural occurring rain and flow events	Met or partially met over the last 6 year	MEDIUM Improve the complexity and health of priority waterbird habitat to maintain species richness and aid	Low Potential Up to 120 GL under High inflow scenario. Lowbidgee supplementary allocations will be prioritised if made available under High to Very High inflow scenarios.	HIGH

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	Required frequency (maximum dry interval)		Environmental demands for water (all sources)	Potential Commonwealth environmental water contribution?	Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22
					future population recovery		
Murrumbidgee River channel, distributaries, and anabranches (PU 6, 7, 8, 9, 10, 11, 12, 13)	Native fish spawning, recruitment, movement, and dispersal.	Contribute up to 10 GL from Tombullen storage to higher river flows (freshes) in spring-summer	7 in every 10 years	Met 2 out of the last 7 years	MODERATE Watering following natural cues, required to continue recovery of native fish populations.	Moderate Potential Up to 10 GL if natural flow event triggers an opportunity under Moderate to High inflow scenario.	LOW
	Native fish movement and recruitment, productivity, and in-stream vegetation	Moderate in-channel pulse (flows >3500 ML/day at Balranald) up to 50 GL	7 in every 10 years	Met 3 out of the last 6 years	MODERATE Native fish populations in the lower Murrumbidgee River are in poor condition. Water required for improved fish passage and connectivity, aquatic habitat, and riverine productivity	Moderate Potential Up to 30 GL under Moderate to High inflow scenarios	MODERATE
	Native fish, wetland vegetation	Distributary and anabranch freshes to restore flow components most impacted by river regulation up to 15 GL	7 in every 10 years to annual	Demand met 2 out of the last 6 years	MODERATE Watering following natural cues to maintain the good condition of wetland-floodplain vegetation	Moderate Potential subject to natural cues up to 10 GL	MODERATE, subject to natural cues
	Water quality	Contribute to managing water quality issues within in-stream and wetland environments across the Murrumbidgee Catchment	Contingency in response to poor water quality	As required	CRITICAL Provide refuge habitat for aquatic animals due to poor water quality, including potential hypoxic conditions.	Contingency in response to poor water quality/aquatic habitat availability. This may include up to 15 GL contingency under very low to low inflows, in the absence of IVT (Lower Murrumbidgee weir pool stratification, high risk fish kills). Or may include a very large contingency volume (when allocations allow) under very high inflows and natural flooding to mitigate potential hypoxic blackwater affects	CRITICAL (Contingency)
Junction Wetlands (PU8)	Wetland vegetation and habitat for native fish, frogs, turtles, and waterbirds	Flows greater than 5 GL/day at d/s Balranald Weir and >10 GL/day on the Murray at Murrumbidgee confluence	5 in every 10 years	Demand met in 2 of the last 6 years	HIGH The condition of the Junction Wetland is generally poor due to a lack of inundation	Low Potential under low inflows. Likely to be achieved by other environmental watering actions and through Lowbidgee Supplementary allocations under Moderate to High inflow scenarios	HIGH
		Flows greater than 7 GL/day at d/s Balranald Weir	5 in every 10 years	Demand met in 1 of the last 6 years	HIGH The condition of the Junction Wetland is generally poor due to a lack of inundation	Low Potential under low inflows. Likely to be achieved by other environmental watering actions and through Lowbidgee Supplementary allocations under Moderate to High inflow scenarios	HIGH

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	Required frequency (maximum dry interval)		Environmental demands for water (all sources)	Potential Commonwealth environmental water contribution?	Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22
		Pumping up to 4 GL to individual high priority wetland assets	7–8 in every 10 years (2 years)	Demand met in 5 of the last 6 years	MODERATE To support continued recovery of wetland vegetation and provide refuge habitat	Moderate Potential for water use up to 4 GL under Very Low to Moderate inflow scenarios (volume contributed will be dependent on resource availability/antecedent conditions, with a minimum of 1.5 GL required under a Very Low inflow scenario)	HIGH

Note: Planning Units (PU) 4 – 14. Identified in the Murrumbidgee Long Term Water Plan Part B (NSW DPIE 2020b).
a Difference in filling height (i.e. flows required to fill a wetland) vary among the lagoons that make up the mid-Murrumbidgee wetlands, and so their condition and watering requirements vary accordingly. **b** Cumulative volume - includes volume allocated for this asset under Lowbidgee Core refuge and permanent aquatic habitat.

PU4: Murrumbidgee River – Tumut River Junction to Berembed Weir	PU8: Murrumbidgee River – Balranald to Murray	PU12: Lower Yanco Creek to Lower Billabong Creek
PU5: Murrumbidgee River – Berembed Weir to Gogeldrie Weir	PU9: Beavers and Old Man's Creek	PU13: Lower Billabong and Intersecting Streams
PU6: Murrumbidgee River – Gogeldrie Weir to Maude Weir	PU10: Upper Yanco Creek	PU14: Murrumbidgee Infrastructure Dependent Floodplain Wetlands
PU7: Lower Murrumbidgee Floodplain	PU11: Colombo & Billabong Creeks	

Key

Potential watering in 2020–21

- High priority for Commonwealth environmental watering (likely to receive water even under low water availability)
- Secondary priority for Commonwealth environmental watering (watering to occur only if natural trigger is met, or under moderate – high water resource availability); or water demand likely to be met via other means
- Low priority for Commonwealth environmental watering (under high – very high-water resource availability); or unable to provide water because of constraints or insufficient water

Environmental demands (demand is considered at a generalised scale; there may be specific requirements that are more or less urgent within the flow regime)

- High to critical demand for water (needed in that particular year or urgent in that particular year to manage risk of irretrievable loss or damage)
- Moderate demand for water (water needed in that particular year, the next year, or both)
- Low demand for water (water generally not needed in that particular year)

12.5 Water delivery in 2021–22

Based on the demand for water for the environment, water availability (supply), and catchment conditions, the overall purpose for managing Commonwealth water for the environment in the Murrumbidgee River Valley in 2021–22 is to continue to improve, and where possible recover, important wetland habitats and threatened species populations specifically by undertaking large system-scale actions to link the floodplain to the main river channel. Specifically, for the mid-Murrumbidgee wetlands the purpose is to maintain and ensure their ecological capacity for recovery and remains a priority subject to available allocations.

Planning for water delivery in the Murrumbidgee River Valley considers all water resource availability scenarios from extreme dry to wet, thereby enabling water managers to respond efficiently and effectively to changing conditions. Delivery of water for the environment to many sites and landscapes in the Murrumbidgee River Valley is scalable (i.e., increase the area, volume delivered, and number sites inundated on the floodplain), depending on the volume of water available and catchment conditions. For instance, should climatic conditions and water availability improve there may be opportunities to increase the number of sites inundated on a floodplain, including sites that require substantial volumes of water to fill.

In the Murrumbidgee Valley, the availability of water for the environment forecast for the beginning of 2021–22 will likely enable water managers to undertake environmental watering actions planned under all dry and moderate resource scenarios, including very high priority actions identified under wet to very wet resource scenarios.

A very high priority for Commonwealth water for the environment remains a managed low-level mid-Murrumbidgee wetlands reconnection action. Wetlands in this area are generally in poor condition due to lack of repeated inundation. Ideally, a low-level wetlands reconnection with the Murrumbidgee River is required annually to enable the recovery of wetlands and their aquatic ecosystems. Low-level wetlands were last inundated by the Murrumbidgee River through a managed reconnection in winter 2017. The action is subject to dam release capacities and assessments of potential third-party impacts. The watering action will also contribute to downstream demands, including Yanco Creek, the Lowbidgee floodplain including the Junction Wetlands and potentially the lower Murray (where 'return flows' are available under NSW "pre-requisite policy measures"). Should the wetlands receive water from natural flows in winter-spring, a reconnection flow for these wetlands will still remain a high priority for autumn.

Under moderate and wet conditions, large-scale wetland and floodplain inundation including river-floodplain connection will be targeted to restore components of natural flow regimes in the Lowbidgee and Yanco-Billabong-Forest Creek systems. These flows aim to disperse essential nutrients, plants and animals, and support reproduction and improve condition of native plants, waterbirds, native fish, frogs, turtles and other water dependent animals. These broader scale watering actions will help to improve the condition and resilience of important sites in the Murrumbidgee River Valley. They also build resilience of the system to help sites to maintain condition and function in dry years and to help cope with climate change.

Floodplain habitats have been found to be critical for native fish spawning, growth, and recruitment (particularly golden perch) and provide high-quality refuges during extreme drought conditions. Therefore, river-floodplain connectivity in the lower Murrumbidgee may

also be supported by in-channel flows targeting native fish movement and recruitment, including for floodplain to river movement, and in-channel productivity.

Note that under wet or very wet conditions, unregulated flows are likely to meet many of the Murrumbidgee River Valley's environmental demands. However, water for the environment may be used to extend the duration of unregulated flows or undertake follow-up watering to achieve environmental watering objectives, subject to constraints and third-party impacts.

If a decline in water quality of in-stream or wetland environments across the Murrumbidgee catchment occurs due to low inflows and dry conditions, or very wet conditions, water for the environment will target protecting refuge habitats for aquatic animals, including for native fish, subject to available allocations.

Additional environmental demands may also be identified during the water year as new information becomes available. Note, under certain levels of water availability, watering actions may not be pursued for a variety of reasons. For example, this may be due to the environmental demand being met by unregulated flows or the ability to deliver environmental water may be limited by constraints or infrastructure works and/or risks.

12.6 Monitoring and lessons learned

12.6.1 Monitoring

Operational monitoring is undertaken for all Commonwealth environmental watering actions and involves collecting on-ground data with regard to environmental water delivery such as volumes delivered, impact on the river systems hydrograph, area of inundation and river levels. It can also include observations of environmental outcomes.

The Monitoring, Evaluation and Research (MER) Program (previously the Long-Term Intervention Monitoring Project 2014–2019) has sites in the mid-Murrumbidgee Wetlands, Lowbidgee Floodplain and Murrumbidgee River as focus areas. It aims to understand the environmental response from Commonwealth environmental watering with respect to the targeted objectives by carrying out monitoring of site condition over many years.

Learn more about monitoring activities funded by the CEWO in the Murrumbidgee River Valley.

12.6.2 Lessons learned

Outcomes from monitoring and lessons learned in previous years are a critical component for the effective and efficient use of Commonwealth water for the environment. These lessons are incorporated into the way water for the environment is managed.

Key findings and recommendations from environmental monitoring projects (Baldwin 2019; Wassens et al. 2021; Wassens et al. 2020 a and b; Kopf et al. 2019; Wassens et al. 2019 b and c) in the Murrumbidgee River Valley is summarised in Table MR3.

Table MR3 Key lessons learned in the Murrumbidgee River Valley

Theme	Lesson learned
Native fish	• Spawning and recruitment of native fish species, such as golden perch, can occur from within the floodplain system. Spawning of golden perch on the floodplain can be triggered using environmental flows, as demonstrated by monitoring in 2018 and 2021.

Theme	Lesson learned
	• Floodplain habitats may be critical for golden perch spawning, growth and recruitment, and importantly provide rare refuges of high-quality habitat and productivity during extreme drought conditions. Management decisions to deliver environmental water to inundate and maintain Lowbidgee floodplain habitats during spring and summer are important to maintain viable native fish populations, and to provide food and habitat for resident populations of fish, frogs and a diverse assemblage of waterbirds. • Poor recruitment to the juvenile stage was found for large-bodied native fish species within the main river channel although young of year golden perch have been detected in floodplain wetlands. • Further locations and water delivery options could be investigated to improve off-channel nursery habitat for golden and silver perch. • Spawning of golden or silver perch in the Murrumbidgee River does not appear to be translating to recruitment for either of these species. As stocking of silver perch does not occur in the Murrumbidgee and golden perch stocking is thought to contribute to around 14% of the golden perch population the Narrandera zone, it can be assumed that the population is comprised of wild adults that spawned and recruited locally. Poor young of year recruitment response have also been exhibited by Murray cod, with abundance of juveniles being considerably lower in 2018–19 compared with 2014–15 and 2015–16, but similar to those recorded in 2016–17. The drivers of successful recruitment, the key locations which support juveniles and the causes for the recent failures in recruitment remain unknown. • Since monitoring commenced in 2014, there has been little evidence to suggest that managing discrete flow peaks within the monitored reaches of the mid-Murrumbidgee influenced native fish spawning. This might be in part due to the already higher water flows occurring in the mid-Murrumbidgee compared to other parts of the river, with irrigation deliveries creating conditions suitable for spawning throughout the breeding season. • Wetland native fish species diversity was highest in wetlands that have an area of permanent water, including Avalon swamp, Telephone Creek and Waugorah Lagoon.
Frogs	• Breeding of many frog species, including the southern bell frog (EPBC Act vulnerable), is triggered by rising water levels in wetlands during October and November. Therefore, watering actions in early spring are important to enhance frog breeding activity and recruitment. • Southern bell frog numbers have now reached pre-Millennium drought levels in the Lowbidgee. The combination of watering actions targeted at maintaining refuge habitat, complemented by larger deliveries during spring and summer should be continued. • The southern bell frog is highly sensitive to environmental water management and has very narrow flow requirements – requiring shallow, well vegetated areas with longer duration. Southern bell frogs also appear to be sensitive to high fish numbers and pumping of wetlands has been used with considerable success to support southern bell frog populations in the Lower Murray (NSW) and Lower Murray (SA) and the mid-Murrumbidgee (Mason 2020, Waudby et al. 2021).
Turtles	• Maintaining the availability of permanent water holes, particularly at Mercedes Swamp, Telephone Creek and Wagourah Lagoon, refuge sites is important to support high turtle numbers. • Evidence of turtle recruitment remains limited most likely due to high levels of nest predation. – Ongoing fox control at key wetlands will also be important for maximising nesting success. – Investigate opportunities for head-starting which can involve collecting eggs to hatch in captivity before release of hatchlings. • Breeding of turtles is influenced by food availability in previous year.
Waterbirds	• Higher waterbird species richness and abundance has been observed at sites that were inundated by water for the environment compared to wetlands that were dry for extended periods.

Theme	Lesson learned
	• Where possible, Commonwealth environmental water should be prioritised to provide annual seasonally inundated habitat (spring-summer) for waterbirds in the Lowbidgee floodplain and mid-Murrumbidgee wetlands – Deliver flows in early spring rather than late summer, and top-up to increase duration into autumn • Most waterbirds commence breeding in spring, however, the stimulus for breeding is usually a combination of season, rainfall and flooding. • When breeding occurs, water levels in active sites need to be maintained into summer months to ensure the successful fledging of young birds. • In the years following large-scale flooding events, provision of environmental water is likely to be extremely important in creating feeding habitat to support survival of young birds. • When there is limited natural overbank flooding, inundating floodplain habitat to create foraging habitat would benefit waterbird populations in the Murray-Darling Basin by promoting the survival of juvenile and adult waterbirds. • Maintaining refuge and foraging habitat for waterbirds during dry periods, should also consider watering wetland sites earlier in spring to increase productivity the availability of shallow water and mudflats as well as supporting longer duration inundation duration of floodplain inundation. • Keeping the water levels stable at Wanganella Swamp during the months of November, December and January is paramount. The water should be rising in September and rising slightly in October before stabilising in November, December and January, and then slowly drawing down in February/March. – Straw-necked ibis require 60 to 90 cm of water under the reeds or lignum for nesting, which also satisfies requirements for breeding of many other waterbird species. • The draw-down of large floodplain lake systems including Yanga Lake can provide high value foraging habitat for waterbird species. Timing the drawdown of lakes to spring or late summer also coincides with the movement patterns of migratory shorebirds – benefiting populations that extend well beyond the Murrumbidgee Catchment.
Vegetation	• Despite the wide range of hydrological regimes and geomorphologies of wetlands in the Murrumbidgee, there is a clear trend that wetlands which have received environmental water more frequently support higher species richness of water dependent vegetation species and lower numbers of exotic species. • Inundating Wagourah Lagoon and Telephone Creek in the Lowbidgee during years of high water availability should be a priority. And future watering actions at Avalon Swamp should aim to achieve complete inundation of the main wetland for approximately 8 weeks, to support the growth and reproduction of key species. • River red gum encroachment remains a concern in the mid-Murrumbidgee wetlands, particularly at McKennas Lagoon. Given the current level of river red gum at this and other wetlands, mechanical removal coupled with repeat inundation over several years may be required for restoration. • Pumping environmental water into wetlands within the mid-Murrumbidgee can limit the biomass of carp entering the wetland, which in turn can improve germination and establishment of water dependent plant species. – During natural reconnections, it is likely that these wetlands will again be recolonised by large carp. Managed drawdowns in autumn or winter may be required to again reduce carp biomass and support vegetation establishment.
Microinvertebrates	• Higher river levels and cooler temperatures in the Narrandera zone may impact the development of a productive and diverse microinvertebrate community. Environmental flows that inundate dried sediments without creating stable high flows or colder water temperature may be important for maintaining high levels or riverine microinvertebrate density. • Watering actions that allow key wetlands to drawn down and temporarily dry out will contribute to maintaining microinvertebrate densities.

Theme	Lesson learned
Processes **Connectivity**	• Although rates of metabolism were low during 2019–20, overall, rates of metabolism have remained relatively stable over the past six years despite considerable variability in flow volume. There seems to be little capacity for Commonwealth environmental water to have a significant influence on the rates of stream metabolism and nutrient availability via manipulation of water levels in the Murrumbidgee River within existing capacity constraints under normal flow conditions. However, previous work has shown that managed return flows do have the capacity to influence riverine nutrient availability at local scales, as was the case of the Redbank return flows undertaken in 2014–15. • Broad-scale wetland reconnections and periods of low flow are necessary to promote resources for river food webs. Future planning of watering actions that allow for wetland reconnections either via managed return flows or by generating peaks in river height may assist with the mobilisation of carbon and nutrients from the floodplain to the river.
Water Quality	• Monitoring of weir pool stratification (the establishment of a thermocline, with warmer, oxygenated water above and cooler, low dissolved oxygen below) and hypoxic water management in the Lower Murrumbidgee River in 2019 showed that high temperatures and low flow conditions have the potential to adversely affect water quality. Mixing of the hypoxic bottom water with oxygenated surface water can result in low dissolved oxygen concentrations throughout the water column thereby potentially causing fish kills. Water quality can be improved, and fish kills mitigated against by: – steadily increasing in-channel flows and gradually releasing hypoxic water from weirs, and – exporting hypoxic water from weirs onto the floodplain using existing regulators. • In the absence of Inter Valley Transfers during Summer, targeted end-of-system flow rates alone (under the Murrumbidgee Water Sharing Plan) are inadequate to maintain acceptable water quality thresholds for aquatic biota under extreme climatic conditions. • Physicochemical measurements from monitored wetland sites during the previous six-year period (2014–20) have been largely consistent and remained within acceptable upper and lower ranges reflecting that wetlands are in good condition. – Delivering water in spring to managed wetlands more closely matches natural inundation and reduces the risk of hypoxic black water events.
Hydrology	• Water for the environment is the primary driver of ecological responses for water dependent species in the mid and lower Murrumbidgee floodplains. Maintaining core permanent refuge habitats and providing foraging opportunities for resident species should be a priority in all water years. In years of moderate and high-water availability, inundation of larger, continuous areas of floodplain habitats that support breeding opportunities should continue to be a priority.
Operational	• Very dry conditions occurred through the 2019–20 water year and watering actions were undertaken in-line with very low water availability. Environmental water deliveries were the lowest since monitoring began in 2014. Under these conditions, watering actions maintained critical refuge habitats for water dependent animals and vegetation condition and resilience in key wetland and floodplain habitats. • Removal of carp from a wetland prior to pumping, either through physical removal and/or short-term drying of the wetland, have shown to have positive benefits for frogs and vegetation. It is recommended that this management intervention be implemented when carp numbers increase and declines in vegetation and tadpole diversity become apparent.

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13 Victorian Rivers Water Plan

13.1 Region overview

13.1.1 River system

The Victorian rivers in the Murray-Darling Basin include the Goulburn-Broken, Campaspe, Loddon, Ovens and Wimmera catchments (Map VR1 and Map VR2). The northern Victorian rivers, particularly the Ovens and Goulburn-Broken, contribute significantly to the water resources of the River Murray. Although part of the Victoria rivers region, the Wimmera River in central-west Victoria flows into a series of terminal lakes, including Hindmarsh and Albacutya, and does not connect to the River Murray.

Around 20% of the basin's total water resources originate in the northern Victorian rivers (MDBA 2020). Lake Eildon on the Goulburn River is one of the Basin's major water storages, with a capacity of around 3,334 GL (GMW 2021). The region has a highly developed agricultural sector and a population of almost half a million people (DELWP 2019).

13.1.2 Traditional Owners

Aboriginal people have had a long association with the river valleys of northern and central Victoria (MDBA 2020). The Commonwealth Environmental Water Office (CEWO) respectfully acknowledges these Nations, their Elders past and present, as the Traditional Custodians of the lands on which this chapter is focused:

- The Ovens River catchment falls in the traditional lands of the Bangerang nation and neighbouring Taungurung and Yorta Yorta nations, to the south and west, respectively. The Waywurru nation is also located within the Ovens River valley
- The Aboriginal people of the northern plains of the Goulburn and Broken catchments are the Yorta Yorta and Bangerang Nations. The Taungurung is the main Nation of people in the Broken River Valley and upper Goulburn Valley
- West of the Campaspe River is the traditional land of the Dja Dja Wurrung Nation and east is the land of the Taungurung Nation. On the plains north of Rochester, the area is the traditional land of the Yorta Yorta and Bangerang Nations
- Most of the Loddon catchment and the Avoca catchment is the traditional land of the Dja Dja Wurrung Aboriginal nation. On the floodplains, around Kerang and Kow Swamp, is the traditional land of the Barapa Barapa nation
- The Wimmera catchment is large and diverse, and covers the traditional country of several Aboriginal Nations, including the Dja Dja Wurrung, Wotjobaluk and Wergaia in the mid and lower catchment. The north of the catchment, towards the River Murray, is the traditional lands of the Latji Latji, Tatti Tatti and Wamba Wamba Nations.

13.1.3 Important sites and values

The northern Victorian rivers are identified in the Basin-wide environmental watering strategy (MDBA 2019) as being important Basin environmental assets for native fish, including supporting high fish diversity and as a fish refuge during dry periods. They create key native fish movement corridors and are recognised as priority sites for improving the core range of numerous threatened species, notably the nationally threatened silver perch.

These rivers also support additional species and communities listed under the *Environment Protection and Biodiversity Conservation Act 1999*. Faunal species include Murray cod, Macquarie perch, trout cod, Australasian bittern, swift parrot and the growling grass frog; vegetation includes rigid water milfoil and box-dominated grassy woodland communities.

The river system also supports bird species listed under international migratory species agreements (such as those agreements with Japan, China and the Republic of Korea, and the Ramsar convention). Protected species observed in the Victorian river system include the sea eagle, Australasian bittern, brolga, royal spoonbill, yellow-billed spoonbill, Australasian shoveler, eastern great egret, white-bellied sea eagle, glossy ibis and Latham's snipe.

Located at the terminus of the Wimmera system is the Lake Albacutya Ramsar wetland. This internationally listed wetland only receives water in exceptionally wet years. Further, the Kerang Wetlands Ramsar site is located at the junction of three major floodplains associated with the Avoca, Loddon and Murray rivers, and is hydrologically linked to the Loddon River. Several sites are listed in the Directory of Important Wetlands in Australia including the Broken River, Upper Broken Creek, Lower Ovens River, Wimmera River, Lake Hindmarsh and Moodie Swamp.

The delivery of environmental water to the northern Victorian rivers also supports ecological values and outcomes in the River Murray valley. This includes Ramsar-listed wetlands such as the Barmah Forest, Gunbower Forest, Hattah Lakes, and the Coorong, Lower Lakes and Murray Mouth.

13.1.4 Stakeholder engagement

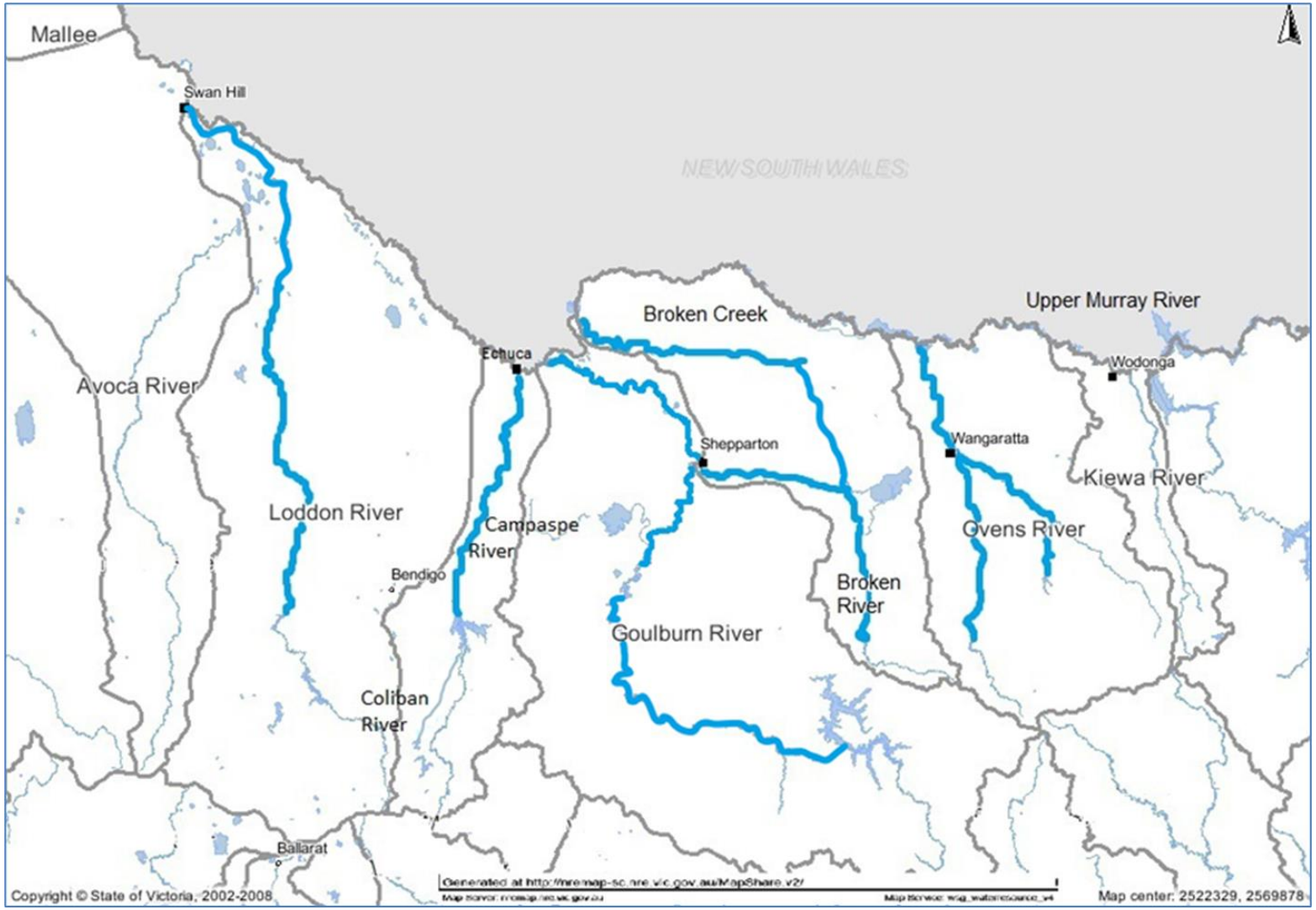
The planning, management and delivery of Commonwealth water for the environment throughout the northern Victorian valleys is undertaken in collaboration with a range of partners and stakeholder groups, including both government and non-government entities.

The implementation of watering actions within the Victorian rivers is coordinated by the Victorian Environmental Water Holder (VEWH) and managed by regional waterway managers including the Goulburn-Broken Catchment Management Authority (GBCMA), North Central Catchment Management Authority (NCCMA), North East Catchment Management Authority (NECMA) and Wimmera Catchment Management Authority (WCMA). Goulburn Murray Water (GMW) is the principal storage and water supply manager in northern Victorian catchments and is responsible for the day-to-day delivery of water (including environmental water) throughout its river systems and irrigation supply network. Grampians Wimmera Mallee Water (GWMW) is the storage and water supply manager for the Wimmera catchment.

Early input to the potential watering actions for 2021–22 was received via the Environmental Watering Advisory Group meetings organised and chaired by the NCCMA and the GBCMA. Membership includes government agencies, land holders, community members and representatives from the Yorta Yorta, Taungurung, Dja Dja Wurrung and Barapa Bapara-Wemba Wamba Nations.

Delivery partners and the CMAs attended workshops to review the 2020–21 watering events, including to identify any risks that arose, and discuss mitigating actions going into 2021–22. Feedback on excerpts of this Water Management Plan were provided by the VEWH and the CMAs and incorporated into the final version.

Map VR1 Northern Victorian rivers



Source: CEWO (2020)

Map VR2 Victorian Wimmera system

13.2 Environmental objectives

The objectives in Table VR1 are relevant for environmental watering in Victorian Rivers. They are based on long-term environmental objectives in the Basin Plan, Victorian state government long-term watering plans, site management plans, and best available knowledge. The following objectives are relevant for environmental watering in the Victorian Rivers.

The objectives that are targeted in a particular year may vary, depending on available water, catchment conditions, operational feasibility, and demand for environmental water. These objectives will continue to be revised as part of the Commonwealth Environmental Water Office's (CEWO) commitment to adaptive management.

Table VR1 Summary of objectives being targeted by environmental watering in the Victorian rivers

Basin-wide matters	In-channel assets	Off-channel assets
Vegetation	Re-establish/maintain and improve riparian and in-channel vegetation cover, extent, condition and diversity. Increase periods of growth for inundation tolerant vegetation communities that closely fringe or occur within river channels.	Maintain the current extent, condition and diversity of water-dependent vegetation. Improve condition of black box, river red gum and lignum shrublands. Improve recruitment of trees within black box and river red gum communities.
Waterbirds	Provide habitat and food sources to support waterbird breeding, survival and recruitment, and maintain condition and current species diversity.	Support waterbird breeding, including brolga in Moodie Swamp.
Fish	Provide flows to support habitat and food sources to promote increased movement, breeding, recruitment and survival of native fish. Improve abundance and maintain species richness. Provide native fish passage through fishways.	Provide flow cues to support habitat and food sources and promote increased movement, recruitment and survival of native fish (particularly for floodplain specialists).
Invertebrates	Provide habitat to support increased microinvertebrate and macroinvertebrate survival, diversity, abundance and condition.	Same as in-channel.
Other vertebrates	Provide habitat and food sources to support survival, maintain condition and provide recruitment opportunities for frogs, turtles, platypus and native water rats (Rakali).	Same as in-channel.
Connectivity	Support longitudinal connectivity along Victorian rivers and to the River Murray for environmental functions such as nutrient and sediment transport, organism dispersal and water quality. Support lateral connectivity to low-lying wetlands and anabranches adjacent to river channel by increasing the frequency of freshes.	Support lateral connectivity (within operational limits) to wetlands and floodplains by contributing to an increase in the frequency of lowland floodplain flows.
Processes	Support primary productivity, sediment, nutrient and carbon transport and cycling; biotic dispersal/movement; and channel maintenance. Minimise erosion and mass-failure and reintroduce sediments/seed.	Same as in-channel.
Water quality	Maintain water quality and provide refuge habitat from adverse water quality events (e.g. low dissolved oxygen, hypoxic blackwater and hypersalinity), including minimising	Support the transport of nutrients and carbon off the floodplain and into the river channel and downstream.

Basin-wide matters	In-channel assets	Off-channel assets
	accumulation of Azolla (aquatic plant) in lower Broken Creek to help maintain DO levels.	
Resilience	Provide drought refuge habitat.	Same as in-channel.

In-channel assets: Goulburn (lower and middle reaches), Broken, Campaspe, Loddon, Ovens and Wimmera rivers; Upper and lower Broken Creek. **Off-channel assets**: Goulburn River wetlands; Lower Broken wetlands; Upper Broken Creek wetlands (Moodie Swamp); Ovens wetlands (Mullinmur Billabong).

13.3 First Nations environmental watering objectives

The CEWO is committed to working with First Nations groups to better understand their objectives. For example, the CEWO has funded Taungurung Land and Waters Council and Goulburn-Broken Catchment Management Authority to identify off-channel wetlands in the mid-Goulburn where management of water could jointly achieve ecological and cultural objectives. The VEWH Seasonal Watering Plan for 2021–22 (VEWH 2021) identifies Traditional Owner cultural values and uses for each of the valleys within Northern Victoria. These site and valley-based objectives and planning will work hand-in-hand with broader system scale objectives and outcomes identified in the *Statement on environmental water use in 2021–22* made by participants at the Southern Basin First Nations' Environmental Watering Forum 2021 (see Chapter 2).

The CEWO will use environmental flows to contribute to these objectives where possible and where this is consistent with the Commonwealth Environmental Water Holder's statutory responsibility of protecting and restoring environmental assets in the Basin. The CEWO is committed to improving our direct engagement with Traditional Owners and recognises there are many areas for improvement in this space.

13.4 Recent conditions and seasonal outlook

13.4.1 Recent conditions and environmental water use

The health of the Victorian rivers in the Murray-Darling Basin reflects 15 years of harsh climate conditions. Over this period there was prolonged drought between 1997 and 2010, significant flooding in 2010 and 2011, wet conditions in 2012–13 and a subsequent series of three moderate to dry years until 2016–17 which was wet. Dry years followed in 2017–18 to 2019–20 with dry to moderate conditions in 2020–21. Environmental watering in northern Victoria has focused on supporting year-round low flows along with higher in-channel flows (such as freshes) in winter and spring. This has contributed to positive ecological outcomes such as maintaining vegetation condition along riverbanks and riparian zones, improved water quality and providing habitat for water bugs and native fish. However, in the last four years large volumes of operational water have been delivered over the summer months in the Campaspe and Goulburn Rivers to meet the need of downstream users (known as inter-valley transfers). This has caused bank erosion and damage to vegetation on the lower parts of the riverbanks in these catchments.

Impacts of historical dry conditions across the northern Victorian catchments mean that many of the sites continue to require water for the environment to maintain the ecological health of the waterways and have high demand, as outlined in Table VR3.

Learn more about the use of Commonwealth environmental water in Victorian Rivers.

13.4.2 Seasonal outlook

According to the Bureau of Meteorology outlook (BoM 2021), across northern Victoria there is largely a 75-80% chance of above median rainfall from July to September 2021.

This forecast indicates the continuation of wetter conditions following the end of last water year. Additionally, across northern Victoria there is a 50% chance or less of exceeding median max temperature across July to September.

13.4.3 Water availability

Allocations against Commonwealth water entitlements in the Victorian rivers are determined by the Victorian Government and will vary depending on inflows. The following forecasts in Table VR2 are based on the best available information including state forecasts and historical inflow scenarios.

Table VR2 Carryover and forecast allocation of Commonwealth environmental water for Victorian rivers in 2021–22

Valley	Carryover from 2020–2021 (GL)	Forecasts of Commonwealth water allocations (including carryover) in 2021–22 (GL)	
		Very dry	Very wet
Goulburn	190.9	369.3	551.9
Upper Broken Creek and Broken River	0	0.1	0.5
Campaspe	2.0	4.0	8.6
Loddon	1.4	2.8	3.9
Ovens	0	0.1	0.1
Wimmera	0	0	0
Southern-connected Basin	538	1,381	2,070

Note: The Southern-connected Basin is the network of rivers that feed into the Murray River between the Hume Dam and the sea. This includes the lower Darling/Baaka, Murrumbidgee, Murray, Ovens, Goulburn-Broken, Campaspe and Loddon valleys.

13.4.4 Environmental demands

Not all environmental demands can and will be met using held environmental water. Some demands are met by regulated water deliveries for consumptive purposes and inter-valley transfers, while others are met by large unregulated, natural flow events or are beyond what can be delivered within current operational limits. There may be opportunities for Basin State governments to relax these limits, which will improve the efficiency and/or effectiveness of environmental watering.

For the environmental water demands for assets in Victorian Rivers in 2021–22 (Table VR3).

The CEWO works closely with the VEWH and the CMAs to deliver its water and the information in this table is consistent with their planning documents referenced at GBCMA 2021a, GBCMA 2021b, GBCMA 2021c, GBCMA 2021d, NCCMA 2021a NCCMA 2021b, NECMA 2021, VEWH 2021, Wimmera 2021.

Table VR3 Environmental demands and watering priorities, 2021–22, and outlook for coming year, Victorian Rivers catchment

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	Required frequency (maximum dry interval)		Environmental demands for water (all sources)	Potential Commonwealth environmental water contribution?	Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22
Goulburn River *Reach 4 Goulburn Weir to Loch Garry; and reach 5 Loch Garry to the River Murray* • Native fish - Murray cod, trout cod, Macquarie perch, golden perch and freshwater catfish • Bank vegetation, especially littoral vegetation and river red gum trees that shade the river and provide: habitat for animals including the squirrel glider; carbon from fallen leaves; habitat for birds such as egrets, herons and cormorants. • Frogs also benefit from inundated vegetation at the edge of the river channel. • Waterbugs • Platypus and turtles During the past three years very high volumes of intervalley transfer water has impacted on the planned deliver of e-water and this may continue during 2021–22 as part of the trial of the new operation rules.	Providing variable base flow will contribute to sustaining the system including for: • fish passage • increasing the width of literal zone vegetation for fish and water bug habitat • instream productivity to feed water bugs which feed fish, turtles and platypus.	Lowflow: year-round - variable 600–1000 ML/day. When higher volumes are available the upper end of the range will be delivered	Ever year under all climate scenarios to increase the required minimum passing flow of 200-400 ML/day.	Minimum low flows have been delivered every year since the Millennium drought.	High	High – with volumes depending on contributions from natural or operational flows throughout the year	High
	Recession flows to slow rapid fall in river levels and aims to: • reduce damage to the banks from mass failure (slumping) • bring sediment and propagules into the river.	Recession flow: when required - to slow the recession of natural flows and releases from Goulburn Weir. Commence flow at • 3,000 ML/day and below in summer /autumn when event magnitudes are lower and rates of fall are slower • 6,000 ML/day and below in winter/spring when event magnitudes are higher and rates of fall are more rapid	Every year when required, likely frequency depending on the climate scenario: • extreme dry and dry – no event • below Average – one event for winter/spring • average – one event for summer/autumn and one event for winter/spring • wet - two events for summer/autumn and two events for winter/spring	A standing order for recession flows was introduced in 2020–21.	High	High – with volumes depending on the number of unplanned high flow events	High
	The winter fresh aims to: • provide cues to platypus to build their nests higher on the bank to prevent later flooding • start channel forming processes if flows are over 7,500 ML/day and increase with the magnitude of the action • benefit lamprey migration from South Australia when delivered during July/August	Fresh: winter (July-Aug 2021 and May-June 20122) >7,300 ML/day for two days (or as high as possible)	Every year except under an extremely dry climate scenario (99% POE)	The winter fresh was first delivered in 2014–15, then not delivered in 2015–16 due to low water availability. It was delivered in each year between 2016–17 and 2018–19 but not in 2019–20 due to low water availability. In 2020–21 natural freshes up to 8,500 ML met this target.	High	High	High
	Variable flows which utilise mid-Goulburn tributary flows between the end of the winter fresh and the early spring fresh will: • improve abundance of macroinvertebrates • maintain lower and mid-bank vegetation • increase instream habitat complexity e.g. movement of sediment through the system and maintenance of deep pools	Variable flows: winter/spring - Achieve variability with flows up to 5,000 ML/d when flows in reach 3 are above 4,000 ML/d	Every year according to the climate conditions: • variable flows only in dry to wet scenarios. Can be delivered in a drought scenario if supply is available	This is the first year this flow action has been included in the Water Management Plan.	High	High	High

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	Required frequency (maximum dry interval)		Environmental demands for water (all sources)	Potential Commonwealth environmental water contribution?	Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22
	An early spring fresh provides the best ecological benefit of all freshes as it primes the system and drives the food cycle by: • providing conditions for lower bank vegetation establishment and maintenance by: transporting plant propagules, increasing moisture in bank soils, driving germination, establishing new plants and encouraging the growth of existing plants • scouring and transport of fine sediment and biofilms which improves macroinvertebrate habitat. • provides cues for spawning and migration for flood specialist native fish.	Fresh: early spring (over Sept and Oct) Up to 10,500 ML/day with 7 days >7,300 ML/day	At least one every year in all climate scenarios	An early spring flow was delivered in 2012–13, not delivered in 2013–14 and partially met during 2014–15 and 2015–16. It has been delivered in every year since 2016–17 and including 20–21.	High	High	High
	Low flows after the spring fresh will allow: • littoral and lower bank vegetation to germinate and establish prior to a late spring fresh or summer high IVT deliveries • this vegetation to be maintained for more than one season.	Lowflow: after the early spring fresh <1,000 ML/day for as long as possible (6-8 weeks) This is a prerequisite for the delivery of a late spring fresh	1 in 2 to 4 years	Partially achieved in 2019–20, the first year it was included as a flow requirement. Prior to that it had not been met since 2016. Not met in 2020–21 due to frequent high natural flows during winter and spring.	This is a demand to not provide water above a given flow rate	This is a demand to not provide water above a given flow rate	This is a demand to not provide water above a given flow rate
	A late spring fresh when water temperature is over 19°C will: • provide cues for golden perch spawning if delivered in Nov/Dec • provide cues for silver perch spawning if delivered in Dec • scour old biofilms from hard substrates, resetting them and improving food resources for macroinvertebrates • transport fine sediments, helping to maintain instream habitat	Fresh: late spring (Nov or Dec) > 6,000 ML for 2 days >7,500 ML/d for greatest spawning response >5,600 ML/d for any benefit	Under an average or wet climate scenario and if • there has been 6 to 8 weeks of lowflows of around 1,000 ML/day prior to delivery or; • lower bank vegetation has not been inundated for less than a week Can also be delivered under drought to below average scenarios if supply is available, subject to the above conditions	A late spring fresh was delivered from 2012–13 to 2014–15 but with dry conditions in 2015–16 it was not delivered. In 2016–17 fish spawning objectives were met by natural flows so the fresh was not delivered to protect low bank vegetation after prolonged periods of high natural flows. It was delivered in 2017–18 but not in 2018–19 and 2019–20 due to the need for a drying phase for bank vegetation ahead of expected higher summer operational flows. This fresh was delivered in 2020–21.	Moderate – as delivered in 2020–21	High- if a decision is made to deliver the action	Moderate

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	**Required frequency (maximum dry interval)**		**Environmental demands for water (all sources)**	**Potential Commonwealth environmental water contribution?**	**Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22**
	The autumn fresh should not be in the same area of bank targeted by IVT delivery over spring/summer and be of a higher magnitude. A fresh during autumn may: • encourage germination of new seed on the lower banks and benches and maintain existing vegetation • provide moisture and nutrients to mid-bank vegetation following low flows over summer • stimulate plant growth to stabilise the banks following IVT delivery over summer. • improve water quality • provides cues for fish movement through the system allowing dispersal • promote the migration of juvenile golden and silver perch into the if Murray River flows are relatively low • scour old biofilms from hard substrates, resetting them and improving food resources for macroinvertebrates • transport fine sediments and maintain instream habitat	Fresh: autumn (Between March and May) >5, 700 ML/day for 2 days	Every year in all climate scenarios, • If the IVT pulses have not delivered the fresh required and if • flows over summer and autumn have not exceeded 2000 ML/day for more than 20 days.	An autumn fresh was delivered from 2012–13 to 2015–16. It was not delivered in 2016–17 or 2017–18 after a fish attractant flow in those years. This fresh was not delivered in 2018–19 due to the already high volumes delivered as intervalley transfers and in 2019–20 due to dry conditions and low water availability. It was delivered in 2020–21.	High	High - depending on IVT demand	High
Goulburn River *Reach 1 Lake Eildon to Goulburn Weir* • Native fish – river blackfish • Platypus • Rakali (native water rat) • Turtles • Waterbugs • Vegetation • Macquarie perch Only receives water when it is released from Lake Eildon	A winter fresh aims to increase platypus populations. The platypus nesting period is September to November and the timing of this flow is to provide cues for platypus to build nests high on the bank to avoid drowning of nests during the higher spring flows	Fresh: winter 5,000 ML/day for 2 days	Every year whenever releases from Lake Eildon are low, likely in extremely dry, average and wet climate scenarios	This is the first year that this flow action has been planned.	High	High	High
	Low flows maintain water quality and instream habitat to: • increase native fish abundance including the threatened river blackfish. • maintain platypus, rakali and turtle populations • maintain the cover and condition of native instream and littoral vegetation. • maintain the diversity and abundance of macroinvertebrates.	Low flow – variable: year-round 400–1,000 ML/day	Every year whenever the volume is <400 ML/day, likely in below average, average, and wet climate scenarios	This low flow was delivered during the non-irrigation period each year between 2017–18 and 2019–20. This target has been extended to the full year and was met in 2020–21.	High	High, depending on IVT demand	High

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	Required frequency (maximum dry interval)		Environmental demands for water (all sources)	Potential Commonwealth environmental water contribution?	Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22
Lower Broken Creek *Reach 4 Nathalia Weir to River Murray with en-route benefit to reach 1 (Boosey Creek to Nine Mile Creek), reach 2 (Nine Mile Creek) and reach 3 (Broken Creek confluence with Nine Mile Creek to Nathalia Weir).* • Native fish – Murray cod, golden perch, silver perch, unspecked hardyhead and Murray-Darling rainbow fish • Platypus, turtles, rakali • Vegetation – box-dominated grassy woodland communities, river swamp wallaby-grass • Birds – Australian Bittern • Environmental demand requires water in addition to irrigation supply • Source of return flows for use downstream in the River Murray.	Winter low flows to: • provide year-round habitat and instream refuge areas for native animals. • improve platypus carrying capacity and reduce predation risk. • minimise exposure of turtles during winter dormancy. • maintain longitudinal connectivity to allow instream fauna to access food and shelter. • maintain inundation of instream aquatic plants, so they persist and provide food and cover for native fauna. • reduce stagnation of water in weir pools.	Low flows: May to August 20 to 40 ML/day continuous	Every year under all climate scenarios	The minimum requirement and has been met or partially achieved since 2011–12.	High	High, depending on IVT demand	High
	Spring, summer; and autumn low flows to: • increase availability of instream habitat for native fauna. • increase flow cues for fish movement and spawning. • provide soil moisture to improve the establishment and growth of native littoral vegetation. • inundate benches to promote the growth of instream aquatic species. • increase mobilisation of *Azolla* accumulations. • reduce stagnation of water in weir pools.	Spring/summer/autumn low flows: Sept to May 200–250 ML/day continuous	Every year under all climate scenarios	Spring/summer/autumn low flows have been met or partially achieved since 2011–12 through a combination of environmental water and consumptive deliveries. In recent years, Inter-Valley Transfers and Murray Bypass flows have significantly contributed to the provision of these flows.	High	High, depending on IVT demand	High
	Winter/spring freshes will: • Flush and mobilise Azolla when it has accumulated Note: flows over 300 ML/d can flush *Azolla* whilst it is still in single layers or individual plants. Flushes up to 450 ML/d disperse large blooms • Trigger native fish movement and spawning • Encourage germination and growth of bank and in-stream vegetation	Winter/spring freshes: July to September 1 to 3 actions of 300–450 ML/day for 1 to 2 weeks	Every year under all climate scenarios	Freshes have been met in most years since 2011–12 and partially achieved in others. Environmental water deliveries have contributed significantly to the provision of spring freshes. A late winter/spring fresh through environmental water delivery was not required in 2019–20 as Azolla levels remained low.	Moderate - unless there is high Azolla presence	High - if there is high Azolla presence and depending on the volumes of IVT and operations water delivered from the Goulburn and Murray systems	Moderate - unless there is high Azolla presence

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	Required frequency (maximum dry interval)		Environmental demands for water (all sources)	Potential Commonwealth environmental water contribution?	Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22
Goulburn-Broken catchment wetlands (Moodie Swamp) *Accessed via Gearys channel from reach 2; Waggarandall Weir to Reillys Weir* • Birds – Brolga and Australasian Bittern Native vegetation - cane grass and rigid water milfoil	Encourage flocking and breeding of Brolga and improve Cane Grass Wetland EVC and maintain rigid water milfoil population.	Fill Moodie Swamp to a variable depth of 0.5-1m for 6 -9 months - in autumn 2022 and top-up when required.	Moodie Swamp maximum dry interval is 1 year for waterbirds and 3 years for vegetation	Environmental water has been delivered to Moodie Swamp each year between 2013–14 and 2017–18. No water was required in 2018–19 and in 2019–20 natural flows partially filled the wetland.	High	High	Low
Upper Broken Creek *Reach 1 Casey's Weir to Waggarandall Weir* • Native fish – Murray cod, golden perch, Murray-Darling rainbow fish • Vegetation – instream vegetation, box riparian vegetation, remnant plains grassy woodland, buloke trees and rigid water milfoil (Moonie Swamp) • Platypus • Common long-necked turtle • Birds – brolga, Australasian bittern (Moonie Swamp)	These low flows are to maintain: • habitat for native fish, water bugs and platypus • water quality and oxygen levels for native fish, platypus and waterbugs	Low flows: winter 1–10 ML/day Low flows: spring 1–10 ML/day Low flows: summer 1–5 ML/day Low flows: autumn 1–5 ML/day	All year round under all scenarios	Lowflows of 5 ML/day were not met in 2011–12, 2013–14 and 2019–20 and were partially met in other years including 2020–21. Lowflows of 10 ML/day have been partially met 2014–15 and 2017–18 and not met in other years since 2010–11, including in 2020–21.	High	High, depending on IVT demand	High
	This fresh is to flush pools to improve water quality and to increase dissolved oxygen levels	Fresh: Dec to May 1 action of 50–100 ML/day for 10 days	One delivery per year under all climate scenarios	This is the first time this flow action has been planned	High	High, depending on IVT demand	High
Broken River • Native fish - Murray cod, golden perch, silver perch, Murray-Darling rainbow fish, Macquarie perch, river black fish and mountain galaxias • Vegetation – riparian and instream vegetation including eel grass, common reed and water ribbon	Low flows in all reaches to maintain: • riffles, slackwater and pool habitats for native fish, plants, platypus and waterbugs • water quality and oxygen levels to support native animals • instream and fringing vegetation	Low flows: all year 15–30 ML/day	Under extremely dry and dry climate scenarios	Natural flows, consumptive water and banked flows have met/partially met this flow target since 2010–11	High if not met by operational releases (consumptive water and IVT) or natural flows	High if not met by operational releases (consumptive water and IVT) or natural flows	High if not met by operational releases (consumptive water and IVT) or natural flows
	Summer/autumn fresh in Reach 1 to: • turn over bed sediments • scour around large wood • provide flow cues to stimulate native fish breeding and movements • promote biofilm productivity	Fresh – summer/autumn 1 action of 400–500 ML/day for 2 to 5 days	Under dry and average climate scenarios	This target was met in 4 years between 2010–11 and 2019–20. It was achieved in 2020–21.	High if not met by operational releases (consumptive water and IVT) or natural flows	High if not met by operational releases (consumptive water and IVT) or natural flows	High if not met by operational releases (consumptive water and IVT) or natural flows

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	Required frequency (maximum dry interval)		Environmental demands for water (all sources)	Potential Commonwealth environmental water contribution?	Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22
	• provide habitat for native fish passage						
Ovens River *Reach 1 immediately below Lake Buffalo on the Buffalo River; reach 2 immediately below Lake William Hovell on the King River; reach 3 Mohyu to the Ovens River; reach 4 Ovens River from the confluence of the Buffalo River to the confluence of the King River; reach 5 Ovens River downstream of the confluence of the King River to the Murray River; and Mullinmur wetland downstream of Wangaratta.* • Native fish – Murray cod, trout cod, golden perch, Macquarie perch and eel tailed catfish • Frogs – giant bullfrog and growling grass frog • Waterbirds – egrets, herons, cormorants and bitterns • Vegetation – river red gum forests and woodlands	Summer/autumn low flows to: • increase pool connectivity to encourage fish movement • provide small variation in river level to move sediment and maintain waterbug habitat • ensure sufficient dissolved oxygen levels	Low flow fresh below Lake Buffalo – March/April at the end of the irrigation season	Under an average climate scenario if a bulk release is being delivered	In 2011–12 to 2013–14 and 2016–17, 2019–20 and 2020–21 CEW was delivered as part of a bulk release by GMW.	High – delivered each year	High	High – delivered each year
		Low flow contribution below Lake Buffalo – February to March	Under a dry to average climate scenario if a low flow fresh is not delivered as part of a bulk release	In 2014–15, 2015–16, 2017–18 and 2018–19 CEW this flow action was met.	High – delivered each year	High	High – delivered each year
		Low flow contribution below Lake Willian Hovell – February to March	Under a dry to average climate scenario	This flow action has been met since 2021–13, including in 2020–21	High – delivered each year	High	High – delivered each year
Mullinmur wetland • *Is located on the Lower Ovens River floodplain within Wangaratta.* • Native fish - catfish and southern pygmy perch • Vegetation – river red gum, herbland species, gold-dust wattle and common swamp wallaby-grass	To maintain water level to support aquatic vegetation and habitat for native eel-tailed catfish and other native fish.	Top up when required	Likely under a dry to average scenario.	This action was included in the planning for the first time. In 2019–20 when 20 ML was delivered to support the translocation of native eel-tailed catfish. Natural inflows filled the wetland during 2020–21 and no environmental water was required.	High – if not filled by natural flows	High, if needed	High – if not filled by natural flows
Campaspe	A winter low flow will:	Winter/spring low flow (50- 200 ML/day during June to November)	For 180 days in all climatic scenarios (may be met naturally in wet scenario, delivered	This flow component has been delivered every year since 2012–13.	High	May be met by other means	High

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	Required frequency (maximum dry interval)		Environmental demands for water (all sources)	Potential Commonwealth environmental water contribution?	Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22
Reach 2 Eppalock to Campaspe Weir; reach 3 Campaspe Weir to Campaspe Siphon at Rochester; and reach 4 Campaspe Siphon to River Murray • Native fish - Murray cod, silver perch, golden perch, Murray-Darling rainbow fish and flat headed gudgeon • Platypus, rakali, turtles and frogs • Bank and instream vegetation, especially mature river red gum trees that support terrestrial fauna, including the swift parrot and squirrel glider. During the past four years very high volumes of intervalley transfer water has impacted on the planned delivery of environmental water and this may continue during 2021–22 unless wetter conditions persist.	• Maintain water quality, preventing pools from stratifying • Increase connectivity to allow native fish to access new habitats • Facilitate male platypus long-distance movement, especially in the August–October breeding season • Provide female platypus foraging opportunities before breeding • Discourage terrestrial plants colonising the lower riverbank/channel benches • Maintain soil moisture in the riverbank, water established river red gums and woody shrubs • Help establish littoral vegetation.		at increased magnitude in moderate-wet scenarios, may not be delivered in drought scenario)	Environmental water releases, natural flows and IVT maintained winter low flows for vegetation, longitudinal connectivity for native fish, macroinvertebrates and water quality in 2020–21. During dry conditions this flow has been delivered at the lower end of the flow ranges.			
The winter freshes aim to: • Flush accumulated leaf litter from banks/low benches to reduce risk of blackwater events during high river flow in summer • Maintain soil moisture for established river red gum/ woody shrubs • Maintain connectivity to allow native fish movement/access to new habitats, especially during Murray cod nesting period • Encourage platypus to nest higher up the bank, reducing risk of high flows flooding burrows with juveniles.	Winter/spring freshes (two freshes of approximately 1,000- 1,600 ML/day for two to three days during June to November)	Two deliveries per year under dry and wet scenarios, one delivery in a moderate scenario	This flow component has been delivered every year since 2012–13. Environmental water releases and IVT provided winter high flows for native fish and macroinvertebrate populations and native vegetation in 2020–21. High flow mitigated the risk of Blackwater events during summer from natural or managed high flow events. During dry conditions this flow has been delivered at the lower end of the flow ranges.	Moderate	High	Moderate
A summer low flow will: • Maintain slackwater habitats for zooplankton and nursery habitats for native fish • Maintain water depth, preventing stratification in deep pools, to maintain habitat for native fish and platypus, allowing safe movement between pools while foraging.	Summer/autumn low flow (maintained at 40-50ML/day during December to May, will only drop below this in drought scenarios)	For 180 days under all climate scenarios (high magnitude range for mod-wet scenarios, low magnitude range for dry scenarios)	This flow component has been delivered every year since 2012–13. Since 2017–18, annual intervalley transfers have exceeded the recommended summer low flows and freshes. In 2020–21, Inter-valley trade deliveries and irrigation resulted in higher then recommended summer low flow.	High	May be met by other means	High
The summer freshes aim to:	Summer/autumn freshes (three freshes of 50-	Three deliveries per year under all climate scenarios	Environmental water releases in addition to base IVT deliveries	Moderate	May be met by other means	Moderate

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	Required frequency (maximum dry interval)		Environmental demands for water (all sources)	Potential Commonwealth environmental water contribution?	Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22
	• Increase connectivity to allow native fish to access new habitats • Promote new biofilm growth and increase waterbug productivity for native fish and platypus • Facilitate downstream dispersal of juvenile platypus to colonise other habitats (April-May).	200 ML/day for one to three days during February to April)		provided one summer fresh in January 2020. Since 2017–18, annual intervalley transfers have exceeded the recommended summer low flows and freshes.			
	If triggered, the year-round fresh aims to de-stratify pools and improve water quality (increase oxygen levels) along the river in reach 4, ensuring adequate oxygen to support aquatic animals.	Year-round fresh (trigger- based, 5-200 ML/day, as required) Triggers • oxygen levels are below 5 mg/L • air temperatures are above 28° • there are high water temperatures and/or low river flow	As required based on trigger	Freshes have been delivered every year since 2012–13, the year-round fresh is a new action intended to support aquatic animals in critical scenarios.	High	High	Moderate
Loddon *Reach 4 Loddon Weir to Kerang Weir with en route benefit to reaches 1 to 3 storage reservoirs to Loddon Weir and to reach 5 downstream Kerang Weir.* • Native fish - river blackfish, Murray-Darling rainbow fish and golden perch • Vegetation – cane grass, tangled lignum, black box and river red gum • Platypus	A winter low flow will: • Increase water depth for fish, platypus and rakali dispersal (juvenile male platypus can colonise new winter breeding territory), providing foraging habitat • Prevent silt/fine sediment settling on hard surfaces • Inundate habitats to increase biofilms and support waterbug productivity • Water native fringing bank vegetation, to support seed germination/growth and prevent encroachment of exotic terrestrial plants.	Winter/spring low flow (50- 100 ML/day during June to November)	Delivered in all scenarios (at a passing flow rate in dry-average scenarios, delivered at lower magnitude in a drought scenario. In a supply deficit, delivered at higher magnitude in dry and average scenarios)	The winter low flow has been delivered in every year since 2012–13 except for 2016–17 when it was partially achieved due to natural flooding causing water to be delivered at a higher rate and longer duration.	Moderate	May be met by other means	High

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	Required frequency (maximum dry interval)		Environmental demands for water (all sources)	Potential Commonwealth environmental water contribution?	Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22
• Rakali	A winter high flow will: • Scour biofilms and accumulated sediment from pools • Flush accumulated organic matter from bank/benches, to increase productivity and reduce the risk of a summer hypoxic blackwater event • Wet banks to promote the recruitment/growth of streamside and emergent vegetation • Stimulate native fish movement and breeding.	Winter/spring high flow (one high flow of 450 ML/day for six to 10 days during August to November)	Delivered in all climate scenarios (at lower duration for drought-dry scenarios)	A winter fresh was partially delivered in 2013–14, 2014–15 and 2015–16, and fully delivered in 2012–13 and since 2016–17.	High	High	Moderate
	A summer low flow will: • Maintain adequate depth in pools for aquatic plants and provide habitat for waterbugs, fish and rakali • Maintain water quality, by continuous flow through the reach, • Wet banks/shallow riffles, supporting growth of in-stream and fringing non-woody vegetation	Summer/autumn low flow (25-50 ML/day during December to May)	Delivered in all climate scenarios (at lower magnitude for drought-dry scenarios. In a supply deficit, delivered at higher magnitude in a dry scenarios)	The summer low flows have been delivered in every year since 2012–13 in reach 4.	High	May be met by other means	High
	The summer freshes aim to: • Increase water level, promoting seed germination/growth of fringing emergent macrophytes • Increase connectivity between deep pools, prompting the local movement of fish and dispersal of juvenile platypus in autumn • Flush fine sediment and old biofilms from submerged hard surfaces, promoting growth of new biofilms and increasing waterbug productivity • Freshen water quality and reoxygenate pools.	Summer/autumn freshes (three to four freshes of 50-100 ML/day for three days during December to May)	Delivered in all climate scenarios (with potential additional fresh in drought scenario).	The summer freshes have been delivered in every year since 2012–13, except in 2018–19 when it was partially achieved.	Low	High	High

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	Required frequency (maximum dry interval)		Environmental demands for water (all sources)	Potential Commonwealth environmental water contribution?	Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22
	The autumn high flow will: • Trigger and facilitate upstream movement of golden perch, silver perch and Murray cod older than 1 year • Facilitate dispersal of juvenile platypus • Flush fine sediment/old biofilms from submerged hard surfaces, promoting growth of new biofilms and increasing waterbug productivity.	Autumn high flow (one high flow of 400 ML/day for six days during March to May)	Delivered in wet scenario only, or in average scenarios with a supply deficit.	The autumn high flow has only been achieved in 2016–17. It was not delivered in 2020–21.	High	May be met by other means	Moderate
Serpentine *Reach 1 is the priority reach in the Serpentine Creek system.*	A winter low flow will: • Maintain habitat for native fish and facilitate movement for aquatic animals • Wet exposed roots, woody debris, emergent vegetation and leaf packs, to provide habitat for aquatic animals • Maintain water quality by preventing stagnation • Provide flow variability to maintain diversity of fringing vegetation • Provide sufficient water depth and flow variability to maintain microbial biofilms.	Winter/spring low flow (20- 50 ML/day during June to November)	Annually in all climate scenarios	This flow was partially delivered in 2017–18 and 2020–21, and not achieved in 2018–19 or 2019–20.	High	Met by other means	Moderate
	The winter fresh aims to: • Maintain the channel form and scour pools[a] • Provide connectivity for fish and waterbugs to access different habitat, supporting a diversity of functional feeding groups • Transport accumulated organic matter in the channel, to increase decay in winter/spring and reduce risk of a summer hypoxic blackwater event* • Encourage platypus to nest higher up the bank (when delivered at 120-150 ML/day), reducing risk of high flows flooding burrows with juveniles.	Winter/spring fresh (one fresh of 40-150 ML/days for two days during August to November)	Delivered in all climate scenarios (at lower magnitude for drought-dry scenarios)	This fresh has been delivered every year since 2017–18.	Moderate	High	Moderate

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	Required frequency (maximum dry interval)		Environmental demands for water (all sources)	Potential Commonwealth environmental water contribution?	Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22
	A summer low flow will: • Provide connectivity between pools to allow dispersal of native fish • Wet exposed roots, leaf packs and woody debris, to provide habitat for aquatic animals • Maintain water quality by oxygenating pools • Maintain foraging habitat for platypus • Maintain wetted area to support in-stream aquatic vegetation.	Summer/autumn low flow (10-20 ML/day during December to May)	Annually in all climate scenarios	This flow was not delivered in 2017–18 and 2018–19; it was fully delivered in 2019–20 and 2020–21.	High		High
	The summer freshes aim to: • Maintain channel form by inundating benches • Flush fine sediment/old biofilms from hard surfaces, increasing productivity and replenishing food supply for aquatic animals • Transport accumulated organic matter in the channel, providing carbon and nutrients downstream • Provide flow variability to maintain diversity of fringing vegetation • Freshen water quality by diluting salt and re-oxygenate pools.	Summer/autumn freshes (three freshes of 40 ML/ day for two days during December to May)	Up to three freshes in all climate scenarios	These freshes were partially delivered in 2017–18 and 2018–19 and fully delivered in 2019–20. They were not delivered in 2020–21.	High		Moderate
Wimmera system	To support native riparian vegetation, native fish and waterbugs, and improve connectivity and water quality.	Up to the total Commonwealth entitlement of 28 000 ML (low reliability water share) per year to contribute toward instream flows within the Wimmera River (lowflow and freshes)	Annually	In 2016–17 the Commonwealth received its first and only allocation of 14,280 ML against this entitlement. Through careful management and carryover this water was progressively used (alongside VEWH water) throughout 2017 to early 2020 to support lowflows in the Wimmera system.	Critical	Low. The Commonwealth has no allocations or carryover currently available in the Wimmera. It will take significant inflows under a wet or very wet scenario before water becomes available to use.	Critical

Note: The planned flow actions outlined in this table are consistent with the potential environmental watering actions presented in the Catchment Management Authorities 2021–22 Seasonal Watering Proposals and the Victorian Environmental Water Holder *Seasonal Watering Plan 2021-22*. Demand is considered at a generalised scale, there may be specific requirements that are more or less urgent within the flow regime. a) Augmented response expected when delivered at 120-150 ML/day.

Key

Potential watering in 2021–22

- High priority for Commonwealth environmental watering (likely to receive water even under low water availability)
- Secondary priority for Commonwealth environmental watering (watering to occur only if natural trigger is met, or under moderate – high water resource availability); or water demand likely to be met via other means
- Low priority for Commonwealth environmental watering (under high – very high water resource availability); or unable to provide water because of constraints or insufficient water

Environmental demands (demand is considered at a generalised scale; there may be specific requirements that are more or less urgent within the flow regime)

- High to critical demand for water (needed in that particular year or urgent in that particular year to manage risk of irretrievable loss or damage)

Moderate demand for water (water needed in that particular year, the next year, or both)

Low demand for water (water generally not needed in that particular year)

13.5 Water delivery in 2021–22

Consistent with the demands and purpose identified in Table VR3, and as water for the environment becomes available, the CEWO is considering supplying water for the environment to contribute to:

- low flows and freshes in each river, as well as off channel wetland actions that support a range of environmental outcomes for plants and animals
- flows that are coordinated across the Southern-connected Basin when conditions are conducive to achieve identified ecological outcomes, for example, golden and silver perch migration
- enhancing ecological benefit from natural flows and when possible, intervalley transfer flows, for example, adding water to the peak or during the recession of the flow – these recession flows can help reduce bank slumping (by avoiding rapid drops in water levels) and can help reduce the impacts of adverse water quality events (e.g. low oxygen blackwater events).

The use of Commonwealth water will be consistent with and contribute to the objectives and actions identified in the Victorian Seasonal Watering Plan.

As in previous years, the use of Commonwealth, Victorian and The Living Murray water will be adaptively managed together throughout 2021–22, in response to changing water resource availability and environmental conditions and demands.

13.6 Monitoring and lessons learned

13.6.1 Monitoring

Monitoring in the Goulburn is now in its eighth year encompassing the CEWO-funded Monitoring, Evaluation and Research (MER) program from 2019–20 to 2021–22 and the Long Term Intervention Monitoring Project (LTIM) from 2014–15 to 2018–19. This work complements the Victorian Environmental Flow Monitoring Assessment Program (VEFMAP), which examines the effect of water for the environment along 13 Victorian Rivers.

13.6.2 Lessons learned

Outcomes from monitoring and lessons learned in previous years are a critical component for the effective and efficient use of Commonwealth water for the environment. These learnings are incorporated into the way environmental water is managed.

Key findings from the MER (CEWO 2020) and VEFMAP (VEFMAP 2021) projects are summarised in Table VR4.

Table VR4 Key lessons learned in the Victorian Rivers

Theme	Outcomes and lesson learned
Native fish	*Goulburn River* • Species of conservation significance collected were Murray cod, trout cod, silver perch and Murray River rainbowfish. • Abundance of Murray cod increased in the 2020 surveys, following a decrease in abundance in 2017 after a blackwater event. • Silver perch abundance also increased in 2020, likely due to fish immigrating into the Goulburn River from the Murray River. • There was a marginal increase in abundance of Murray River rainbowfish in 2020, following a decrease in abundance from 2017 to 2019. • Two native (bony bream, flat-headed gudgeon) and two exotic (eastern gambusia, redfin perch) species collected in low numbers in previous surveys were not detected in 2020. • A fresh delivered in December 2020 resulted in the spawning of large numbers of golden perch and silver perch. *Campaspe* • Murray River rainbow fish, previously thought lost to the Campaspe system, observed at many sites and in abundance downstream of Elmore in reach 2. • Good numbers of Murray cod young-of-year. This may be a result of the 2019 winter high flow event, or reduced impact of intervalley transfers, due to smaller magnitude compared to previous years. *Loddon* • Combined Pyramid-Loddon spring fresh enhanced fish movement and populations in the Loddon River and Pyramid Creek. *Wimmera* • Fish monitoring in autumn 2018 showed that populations of small-bodied native fish have been maintained in all reaches of the Wimmera catchment that received environmental flows. *Lower Broken Creek* • The delivery of minimum low flows during the off-irrigation season provided refuge areas over winter, especially important for young-of-year fish. • Apart from during times when maintenance was being undertaken, fish ladders remained open providing fish connectivity throughout the system. • Freshes provided in spring encouraged native fish movement and spawning.
Macroinvertebrates	*Goulburn River* • The largest increase in the total number of macroinvertebrates (e.g. shrimps, water bugs, mayflies and caddisflies) happens from January onwards. However, it is not yet known the extent that this is attributed to seasonal increases in temperature and hours of daylight versus flow actions. Some increase also followed the spring fresh.
Stream metabolism	*Goulburn River* • Summer flows produced the most organic carbon (80 tonnes) followed by flows in spring (77 tonnes) winter (36 tonnes), and autumn (32 tonnes). • The total amount of organic carbon produced increases even with small increases in flow volume. • Increased in-channel flows increases the amount of organic carbon produced within the river channel which is an important food resource for macroinvertebrates and fish.
Vegetation	*Goulburn River* • Water dependant plants generally increased in cover after the spring freshes across the bank elevation influenced by the fresh. Grasses were restricted to higher bank elevations where inundation was shallower and for shorter duration.

Theme	Outcomes and lesson learned
	• IVT contributed to the absence/loss of vegetation on the banks and a narrowing of the band of water dependant plants. Modelling indicates that vegetation on the banks steadily declines if the total duration of IVT flows exceeds 55 days. • During winter and spring freshes submerged river and bank features received flow-delivered sediment and seeds. More sediment was deposited on low-level features such as bars and more seeds were deposited on both bars and higher-level features such as benches. *Lower Broken Creek* • The minimum low flows over winter retained water in the main creek channel inundating instream aquatic plants. • High and prolonged flows during winter and spring flushed accumulated Azolla and kept levels very low for the remainder of the year. • The spring freshes provided soil moisture for developing plants on the lower banks and benches.
Bank condition	*Goulburn River* • Moderate erosion (more than all other flow events) occurred primarily within bank zones corresponding to IVT flows between 1,500-3,000 ML/d. Minor notching occurred on some inside banks. No evidence of mass-failure was observed (in contrast to 2018–19 IVT delivery), so pulsing may have had a positive impact minimising excessive erosion and mass-failure. • Recession flows following natural freshes resulted in the largest volume of deposition and the second largest volume of erosion during 2019–20. Deposition was likely a result of increased % contribution of tributary flows to natural fresh events. Increased levels of erosion were largely a result of the events mimicking the shape of the earlier IVT flow, which appears to have prepared banks for increased erosion by surcharging upper banks. • Low-medium erosion and deposition occurred across lower and upper bank zones within the zone of bank inundated by the fresh at >3000 ML/d.

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14 River Murray Valley Water Plan

14.1 Region overview

14.1.1 River system

The River Murray is Australia's longest river, running a course of 2,500 km from near Mount Kosciuszko in the Australian Alps to the Southern Ocean at Goolwa, in South Australia. A mountain stream in its upper reaches, the river turns into a meandering river lined with magnificent river red gum forests and woodlands, before ending its journey flowing through the vast Lower Lakes and Coorong, and out through the small Murray Mouth. Many creeks and anabranches flow in and out of the River Murray, the largest being the Edward/Kolety-Wakool River system.

Water for the environment managed by the Commonwealth can be ordered for delivery to sites downstream of Hume Dam, near Albury, with water also supplied from Lake Victoria (west of Wentworth) and from its various tributaries, including from the Goulburn, Loddon and Campaspe rivers in Victoria, and from the Murrumbidgee and Darling rivers in NSW (Map RM1 and Map RM2). The Ovens and Kiewa Rivers are particularly valuable to the ecology of the River Murray given their limited regulation, which means they provide natural inflows into the River Murray.

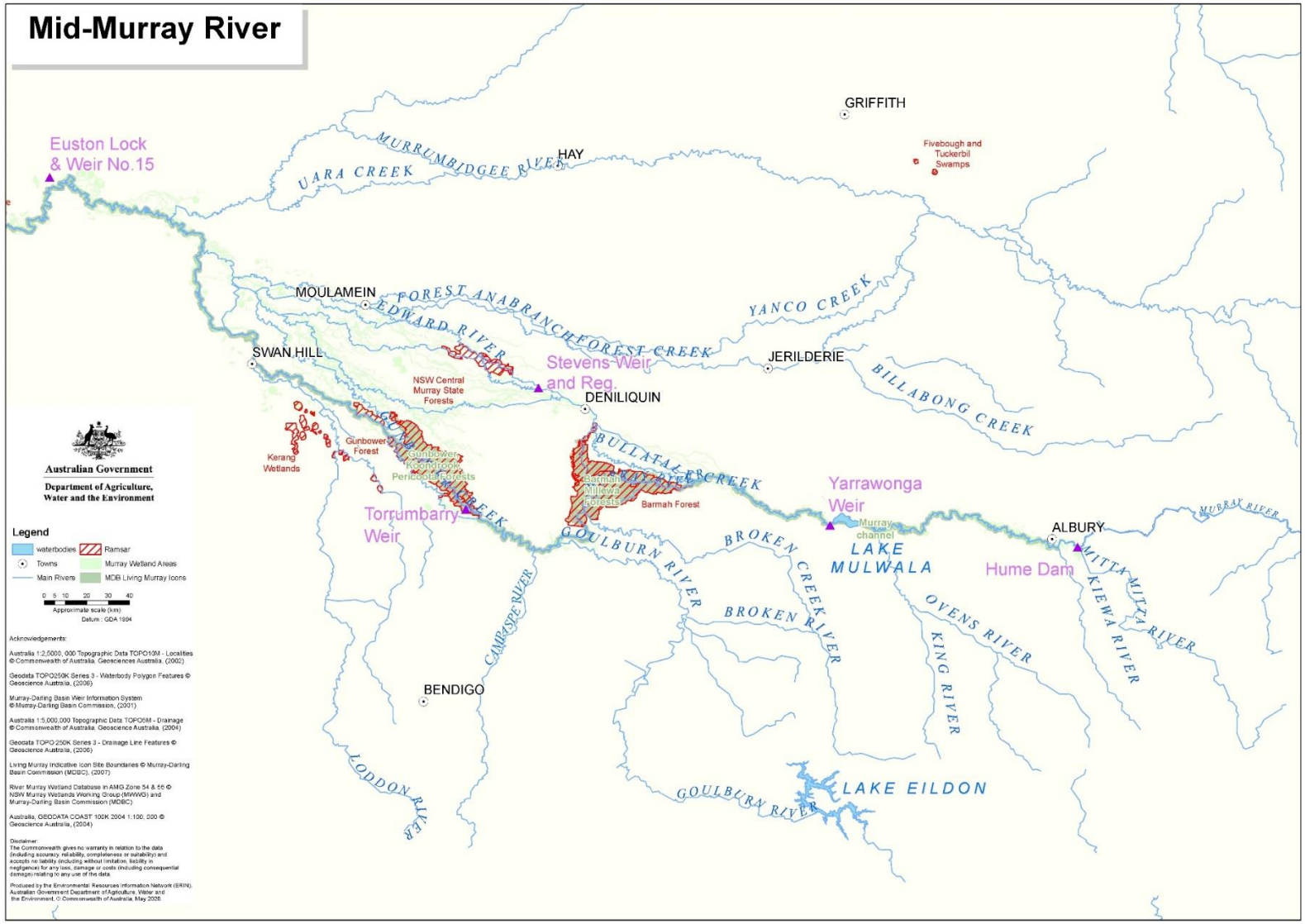
14.1.2 Traditional Owners

The River Murray flows through the traditional lands of many First Nations and the river and its floodplains have long been important for sustenance and spirituality (MDBA 2020). The upper Murray catchment includes the traditional land of the Dhudhuroa, Djilamatang, Ngarigo, Walgalu and Yaitmathang Aboriginal Nations. The Commonwealth Environmental Water Office (CEWO) respectfully acknowledges these Nations, their Elders past and present, as the Traditional Custodians of the lands on which this chapter is focused.

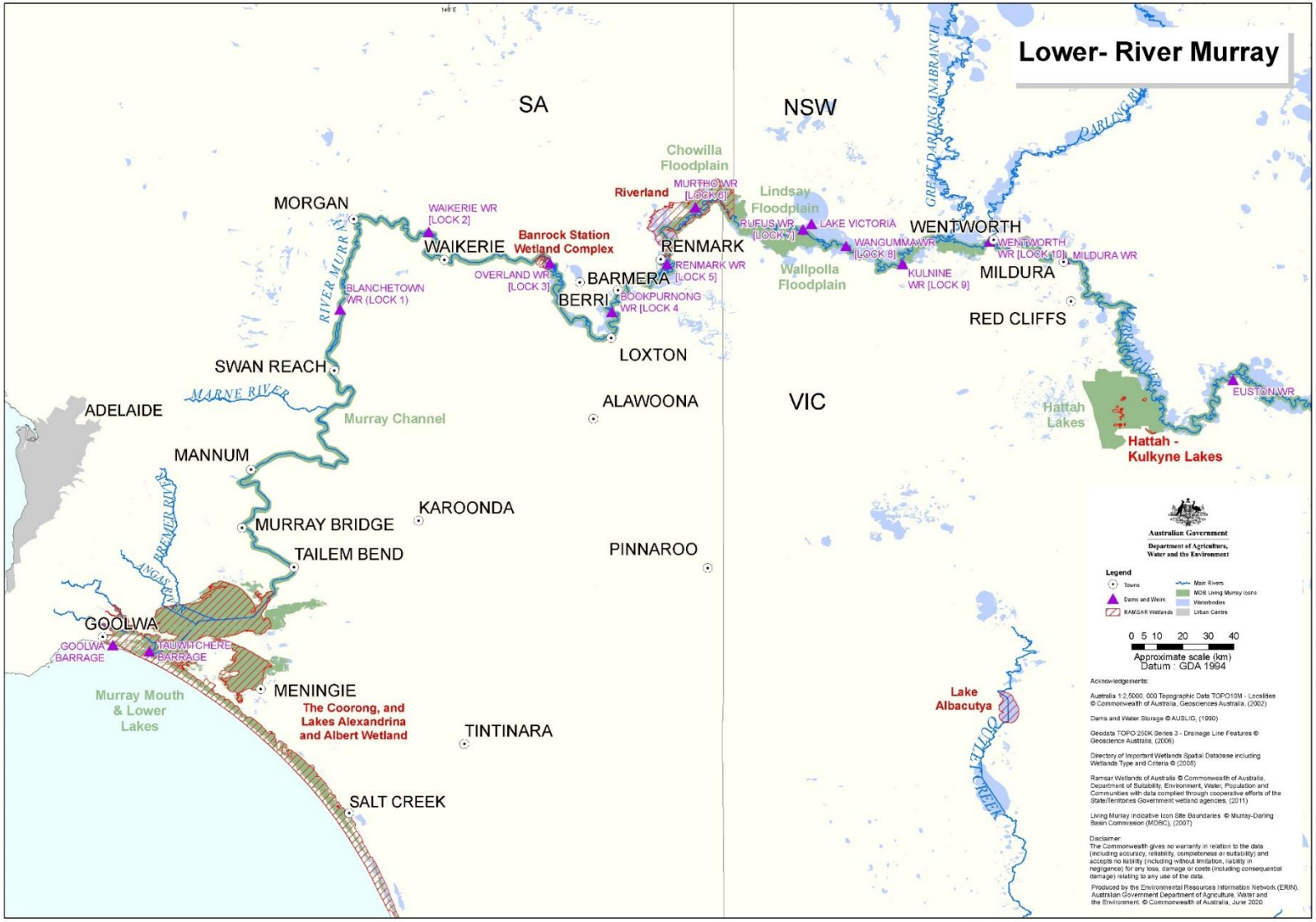
The Aboriginal Nations associated with the mid-Murray planning area include the Wiradjuri, extending from the River Murray to the Macquarie River in the north, and west to Balranald. The east, from the Murray and south into the Great Dividing Range, is the traditional land of the Dhudhuroa and Waywurru Nations. The region centred on Echuca, is the traditional land of the Barapa Barapa/Perepa Perepa, Wamba Wamba/Wemba Wemba and Yorta Yorta Nations. The lower stretch of the central Murray catchment includes the traditional land of the Barkindji, Maraura, Muthi Muthi, Nyeri Nyeri, Tati Tati, Wadi Wadi and Weki Weki Nations.

The Aboriginal Nations associated with land around the confluence of the Darling and Murray rivers include the Barkindji, Latji Latji, Maraura, Muthi Muthi and Nyeri Nyeri. Upstream of the confluence of the Darling and Murray includes the land of the Barkindji and Maraura nations. Along the River Murray, from about Mildura and into South Australia is also the traditional land of the Ngintait Nation. The First Peoples of the River Murray and Mallee Region are the Traditional Owners of the River Murray area from the Victorian border to Morgan. The land of the lower reaches of the Murray, the Lower Lakes and the Coorong is the traditional land of the Ngarrindjeri nation. The land west of the river and including the Mount Lofty Ranges, includes the country of the Kaurna and Peramanok Nations.

Map RM1 Mid-River Murray valley, including the Edward/Kolety-Wakool river system



Map RM2 Lower River Murray valley



14.1.3 Important sites and values

The River Murray valley supports a range of environmental values of local, regional, national and international significance. Examples are as follows.

Vegetation

The Mid-Murray reach includes over 90 000 ha of river red gum and over 40 000 ha of black box and extensive lignum shrublands, including Barmah-Millewa, Gunbower, Koondrook-Perricoota and Werai Forests. Together these comprise the largest complex of tree dominated floodplain wetlands in southern Australia and Australia's largest parcel of river red gum forests. Downstream, the woodlands of the Lower Murray (Hattah-Kulkyne Lakes, Lindsay-Mulcra-Wallpolla-Chowilla and Katarapko and Pike floodplains) and lignum shrublands are highly significant. There are also important non-woody vegetation communities including the Moira grasslands in the Barmah-Millewa Forest and *Ruppia tuberosa* in the Coorong.

Native fish

The River Murray, along with its anabranches, creeks and wetlands, provides habitat for a suite of native fish, including nationally listed threatened species, such as Murray cod, trout cod, silver perch and Murray hardyhead. The creeks through Barmah-Millewa Forest, the Edward/Kolety-Wakool system and Gunbower Creek (in the Mid-Murray) and the Lindsay-Mullaroo Creek system, Chowilla floodplain, Katarapko and Pike creeks and anabranches (in the Lower Murray) are also important habitat for native fish. Several small wetlands in the Lower Murray, along with the Lower Lakes, support some of the last remaining wild populations of threatened small-bodied native fish, such as Southern purple-spotted gudgeon, Southern pygmy perch and Murray hardyhead.

The Murray Mouth, the Coorong and the Lower Lakes region is a hot spot for native fish diversity, supporting marine, estuarine, freshwater and diadromous (move between both salt and freshwater) fish. This includes a range of recreational and commercial fish species such as black bream, greenback flounder, yellow-eye mullet, golden perch, and mulloway. Species like sandy sprat, small-mouthed hardyhead and congolli are also essential food sources for predatory fish and waterbirds in the region.

Birds

Floodplain ecosystems of the Murray-Darling Basin support a high diversity of migratory shore birds and waterbirds, as well as 108 species of floodplain dependent woodland birds. There are several wetlands recognised as having Basin-wide importance for waterbirds. These include the River Murray, Barmah-Millewa Forest (which includes wetlands that are significant to the nationally endangered Australasian Bittern), Gunbower-Koondrook-Perricoota Forest, Hattah Lakes, Chowilla-Lindsay-Wallpolla, Pyap Lagoon, and the Lower Lakes and Coorong (MDBA 2017). The Coorong and Lakes Albert and Alexandrina is recognised as a Wetland of International Importance for shorebirds (Paton et al. 2020), comprising the most important site in the Basin for shorebirds (MDBA 2017) and one of the most important sites in Australia. The site also supports the greatest waterbird species richness of the Murray–Darling Basin. In addition to waterbirds, the River Murray floodplain between Robinvale and Swan Reach has been identified as highly important to the nationally vulnerable regent parrot.

Ramsar Wetlands

The River Murray region contains several internationally important Ramsar listed wetlands: Barmah Forest, Gunbower Forest, New South Wales Central Murray Forests (consisting of

Millewa, Koondrook-Perricoota and Werai forests), Hattah-Kulkyne Lakes, the Riverland (including Chowilla floodplain), Banrock Station Wetland Complex and The Coorong, Lakes Alexandrina and Albert Wetland. These sites are recognised for their unique and diverse wetlands, support of species of conservation significance and biological diversity, their role in providing refuge during adverse conditions, and regularly supporting large numbers of waterbirds. This includes sites listed under international migratory agreements. The significance of these sites is documented in the ecological character descriptions.

14.1.4 Stakeholder engagement

Delivery partners

The planning, management and delivery of Commonwealth water for the environment throughout the Murray valley is undertaken in collaboration with a range of partners and stakeholder groups.

All Commonwealth environmental water delivery is coordinated with other government environmental water holders: NSW Department of Planning, Industry and Environment - Environment, Energy and Science (DPIE EES), the Victorian Environmental Water Holder (VEWH), the South Australian Department for Environment and Water (SA DEW), and the Murray-Darling Basin Authority (MDBA) in its role in coordinating The Living Murray programs. In most cases, Commonwealth environmental water is transferred to these agencies, who are responsible for ordering this water for delivery. The primary coordination body is the Southern Connected Basin Environmental Watering Committee (SCBEWC), which includes representatives from each of the federal and state government environmental water holders, as well as representatives from the Murray Lower Darling Rivers Indigenous Nations. Managers of The Living Murray (TLM) icon sites provide annual watering proposals that are considered by the committee in planning and delivering water for the environment. As part of this process, the Indigenous Partnerships Program supports First Nations contribution to the planning and management of key sites and environmental watering activities.

In addition to the above organisations, the delivery of environmental water is also supported by and coordinated with:

- river operators (MDBA, WaterNSW, Goulburn-Murray Water, SA Water)
- irrigation corporations (Murray Irrigation Limited, Renmark Irrigation Trust)
- regional natural resource management agencies (North Central Catchment Management Authority, Goulburn-Broken Catchment Management Authority, North East Catchment Management Authority, Mallee Catchment Management Authority, NSW Murray Local Land Services, South Australian Murraylands and Riverland Landscape Board), NSW DPI Fisheries
- land managers (such as Parks Victoria, NSW National Parks and Wildlife Service and Forestry Corporation NSW)
- private organisations (Murray-Darling Wetlands Working Group, Banrock Station/Accolade Wines, Calperum Station/Australian Landscape Trust, Nature Foundation Limited).

Stakeholder engagement

The CEWO plans for the use of water with input from, and or consultation from many partners. These include the delivery partners listed above as well as scientists engaged in monitoring the outcomes of environmental water use and various community groups and individuals.

There are several advisory groups that draw on the expertise and experience of community members to help inform our work. Advisory groups may include water managers, recreational fishers, landholders, First Nations groups, independent scientists, local government representatives and a variety of partner agencies. Key stakeholder advisory groups include:

- CEWO's Edward-Wakool Environmental Water Reference Group
- New South Wales Murray-Lower Darling Environmental Water Advisory Group
- Victorian Environmental Water Advisory Groups
- Coorong, Lower Lakes and Murray Mouth Community Advisory Panel.

14.2 Environmental objectives

Environmental watering objectives for the Murray valley (Table RM1) are based on long-term environmental objectives in the Basin Plan, state long-term watering plans, site management plans, and best available knowledge.

The objectives that are targeted in a particular year may vary, depending on available water, catchment conditions, operational feasibility, and demand for environmental water. These objectives will continue to be revised as part of the CEWO's commitment to adaptive management.

Table RM1 Summary of objectives for environmental watering in the River Murray valley

Basin-wide matters	In-channel assets	Off-channel assets	End of system
Vegetation	• Maintain riparian and in channel vegetation condition. • Increase periods of growth for nonwoody vegetation communities that closely fringe or occur within river corridors.	• Maintain the current extent of floodplain vegetation near river channels and on low-lying areas of the floodplain, including Moira grass. • Improve condition of black box, river red gum and lignum shrublands. • Improve recruitment of trees within black box and river red gum communities. • Maintain and improve condition of wetland vegetation.	• Ensure survival and promote growth and recruitment of *Ruppia tuberosa* in the south lagoon of the Coorong. • Maintain or improve the diversity, condition and extent of aquatic and littoral (on the shore or lakebed) vegetation at the Lower Lakes.

Basin-wide matters	In-channel assets	Off-channel assets	End of system
Waterbirds	• Provide habitat and food resources to support waterbird survival and recruitment and maintain condition and current species diversity.	• Provide habitat and food resources to support waterbird survival and recruitment and maintain condition and current species diversity. • Complete seasonally appropriate bird breeding events that are in danger of failing due to drying. • Support naturally triggered bird breeding events. • Provide habitat for migratory birds.	• Maintain habitat and food sources to support waterbird condition and populations within the Lower Lakes and Coorong lagoons (including curlew sandpiper, greenshank, red-necked stint and sharptailed sandpiper). • Complete seasonally appropriate colonial bird breeding events that are in danger of failing due to drying.
Native fish	• Provide flows to support habitat and food sources and promote increased movement, recruitment and survival/condition of native fish.	• Provide flow cues to promote increased movement, recruitment and survival/condition of native fish (particularly for floodplain specialists).	• Maintain or improve diversity, condition and population for fish populations (including estuarine-dependent and diadromous fish) through providing suitable habitat conditions within the Coorong lagoons and maintaining migration pathways that supports species recruitment and survival/condition. • Provide flow cues to promote increased movement, recruitment and survival/condition of native fish.
Invertebrates	• Provide habitat to support increased macroinvertebrate and macroinvertebrate survival, diversity, abundance and condition.	• Same as in channel assets.	• Same as in channel assets.
Other vertebrates	• Provide habitat to support survival, maintain condition and provide recruitment opportunities for other vertebrates, including frogs, turtles, platypus, reptiles.	• Same as in channel assets.	• Same as in channel assets.
Connectivity	• Maintain baseflows and increase overall flows in the River Murray. • Maintain longitudinal & lateral connectivity through contributing to an increase in the frequency of freshes, bankfull and lowland floodplain flows.	• Maintain lateral connectivity (within constraints) to wetlands, floodplains, creeks and anabranches by contributing an increase in the frequency of lowland floodplain flows.	• Improve the connection of the River Murray to the Coorong and the sea, through supporting increased barrage flows and Murray Mouth openness.

Basin-wide matters	In-channel assets	Off-channel assets	End of system
Aquatic food-webs and transport **Water quality** **Resilience**	• Increase primary productivity, nutrient and carbon cycling, biotic dispersal and movement. Increase transport of organic matter, salt and nutrients downstream. • Maintain water quality and provide refuge habitat from adverse water quality events. Increase mobilisation and export of salt from the River Murray system. • Provide drought refuge habitat and maintenance/condition of native biota.	• Same as in channel assets.	• Same as in channel assets.

Source: MDBA (2019 a); Department of the Environment (2011); MDBA (2012a-i); DELWP (2015); Department of Environment, Water and Natural Resources (2015)

14.3 First Nations environmental watering objectives

The CEWO is committed to working with First Nations groups to better understand their objectives. The CEWO will use environmental flows to contribute to these objectives where possible and where this is consistent with the Commonwealth Environmental Water Holder's statutory responsibility of protecting and restoring environmental assets in the Basin.

At the site scale, state government agencies have sought input from First Nations in the development of the annual watering proposals that feed into the Southern Connected Basin Environmental Watering Committee's annual planning process. This includes through The Living Murray's Indigenous Partnership Program.

At a broader scale, as part of planning for 2021–22, the CEWO and MDBA came together with Traditional Owners from many parts of the Southern Murray Darling Basin on Latji Latji Country, in Mildura. This forum aimed to share information about the health of Country and discuss preferred outcomes from the management of environmental water. This forum developed a statement on environmental water use which was used to guide planning for the 2021–22 water year. The Southern Connected Basin Environmental Watering Committee plans to map the alignment of environmental watering objectives with First Nations objectives identified in the forum. This work will help to guide future opportunities for strengthened alignment of water delivery to support First Nations objectives during 2021–22. At a more local scale the CEWO will also continue to work with First Nations groups and representatives to progress local watering actions. Our work with the Wamba Wamba and Perrepa Perrepa nations through Yarkuwa Indigenous Knowledge Centre, in the Edward/Kolety-Wakool River system, is an example of these partnerships.

Some of the identified First Nations objectives sit outside the scope of water for the environment to influence. Environmental flows will aim to contribute to identified objectives, where possible. The Commonwealth Environmental Water Holder is committed to continuing to strengthen engagement with all Southern Basin First Nations to support those Nations to share objectives for water management.

14.4 Recent conditions and seasonal outlook

14.4.1 Recent conditions and environmental water use

The health of rivers, wetlands and floodplains, and the plants and animals they support, can be influenced by flows and conditions in the past. In some cases, this can date back many years, with many parts of the natural environment still showing the effects of both the Millennium and more recent 2017–2020 drought.

Flows

Since the large-scale flooding of 2016–17, the River Murray has experienced three consecutive years of well below average inflows. In 2019–20, River Murray inflows were less than half the long-term average of 8,870 gigalitres and within the driest 12 per cent of years since 1891. Without water for the environment, several critical off-channel waterways would have otherwise remained dry over this three-year period. Water for the environment has supported variable flows in the River Murray, particularly in winter and spring, which were of critical importance to native fish populations. End-of-system flows have been highly dependent on water for the environment, which accounted for 100 per cent of flows through the barrages from January 2018 to August 2020, and prevented the Lower Lakes dropping below the critical threshold of 0.4 m (a trigger for the planning phase of the Drought Emergency Framework).

The dry conditions since 2016–17 continued throughout most of 2019–20, with a return to average and above average conditions in May and June resulting in higher streamflow through the mid-Murray region. This has been followed by above average rainfall over large parts of the southern Basin during 2020–21.

Vegetation

- Floodplain forests and woodlands:
  - The condition of river red gum forests at low elevation in the Mid-Murray (e.g., Barmah-Millewa and Gunbower Forests) has largely been maintained since the 2016–17 flood. Excellent red gum (and to a lesser extent, black box) tree canopy responding positively to environmental water delivery has been recorded (GB CMA 2020b, North Central CMA 2020). Due to dry conditions and delivery constraints, woodlands at higher elevation and throughout Koondrook-Perricoota Forest, have continued to show declining health since the 2016–17 floods (New South Wales Forests 2020).
  - The internationally important Moira grass plains of Barmah-Millewa Forest have seen excellent growth during periods where environmental water has been delivered and grazing pressure has been managed. Overall, the Moira grass plains are in good condition with the extent of coverage increased through the addition of six new grazing exclusion fences (BMF SWP, 2020–21; BMF SWP, 2021–22).
  - Aquatic vegetation in wetlands that have received sufficient water is generally in good condition along the length of the River Murray. Further, the increased variability of weir pool levels has provided benefits for vegetation fringing the main river channel, anabranches and low-lying wetlands for several reaches of the River Murray (Gehrig 2018, Ye et al. 2021). Wetland vegetation condition in other locations, such as those more exposed to drought conditions, heat stress or grazing pressure, is poorer.
  - Further downstream, the condition of river red gum and black box woodlands such as at Hattah Lakes and Chowilla Floodplain has largely been maintained in areas where

infrastructure has enabled the delivery of water (Mallee CMA 2020). In higher elevation sites where water has not been delivered, particularly at Chowilla, black box is showing signs of stress following three years of dry conditions (MDBA 2019 b).

- Coorong and Lower Lakes:
  - Fringing vegetation in the Lower Lakes has become more diverse and the abundance of key taxa has increased in recent years. This represents ongoing recovery from the millennium drought as the lakeside vegetation community re-establishes. Improvements have likely been driven by seasonally appropriate water levels varying between higher levels in spring (approx.0.85 m) and lower levels in autumn (approximately 0.5 m) (Nicol et al. 2019, Ye et al. 2021).
  - Researchers and community members have reported improvement in *Ruppia* distribution and abundance in the southern part of Coorong North Lagoon and in certain areas in the South Lagoon.

Native fish

The 2016–17 flood was beneficial to wetland and floodplain vegetation and waterbird populations in many areas. However, the natural floods also generated a significant hypoxic blackwater event as organic material, accumulated by the lack of frequent, natural, flushing flows, was washed off the floodplain. While environmental flows were used to mitigate the impacts on native fish populations in some localities, the hypoxic blackwater still resulted in large-scale fish kills throughout the Mid-Murray and through parts of the Lower Murray. There have since been mixed outcomes for fish species across the Murray system, however achieving sustained breeding success across the various key fish species remains a challenge.

- Fish species that occupy flowing river habitats and breed independently of particular flow events are perhaps the best faring native species across the Murray. Murray cod and trout cod have bred successfully in the Mid-Murray river channel during the spring and summer of most recent years (GB CMA 2020a, Raymond 2018). The Edward/Kolety-Wakool River systems continue to be a nursery area for Murray cod, with the species' population slowly recovering since the 2016 flood (Watts et al., 2018 and 2019). Similarly, in the Lower River Murray, Murray cod successfully bred for six consecutive years following an extended period of unsuccessful breeding, considerably improving the structure of the Murray cod population in the Lower Murray (Ye et al. 2020).
- Iconic fish species that are dependent on a distinct flow 'pulse' during warmer spring or summer months for their breeding success, such as golden and silver perch, have bred in the Mid-Murray (Raymond et al. 2019., GB CMA 2020a). In the Edward/Kolety-Wakool River systems, silver perch are benefitting from nursery habitat and winter flows that allow movement throughout the year (Watts et al. 2019). Silver perch eggs and larvae were detected in the Lower Murray during the 2020 spring pulse; however no recruitment has been observed. There has been a sustained lack of breeding success for golden perch in both the Edward/Kolety-Wakool and Lower River Murray areas for several years (Ye et al. 2021, Watts et al. 2019), which is a concerning trend.
- The condition of species that occupy lakes and floodplain wetland sites is variable, dependent on location. Overall, this category of fish species has been heavily affected by reduced flows to floodplain wetland sites and introduced species, such as carp. For example, monitoring of the Lower Lakes in late 2018 failed to detect Yarra pygmy perch, which is

now considered likely to be extinct in the Murray-Darling Basin (Wedderburn et al. 2019). However, there have been some success stories resulting from the delivery of water for the environment.

  - Populations of the nationally endangered Murray hardyhead have been maintained at several locations, with two new populations established in recent years.
  - Increased variability in water levels in the Lower Lakes has benefited fringing and submergent vegetation (Nicol et al. 2019). In turn, small-bodied fish species have also demonstrated positive responses. Murray hardyhead have become more abundant and expanded in range after successful spawning and recruitment in the Lower Lakes in 2018–19 and 2019–20. For southern pygmy perch, high spring lake levels and improved submergent vegetation habitat have favoured spawning and after several years at stable low levels, the population quadrupled in 2020–21 (Wedderburn pers. comm.).

- Diadromous fish species spend portions of their life cycles partially in fresh water and partially in salt water. Water for the environment has been solely responsible for maintaining the connection between the River Murray and its estuary, the Coorong, for extended periods since the Millennium drought. This connection is having clear benefits for diadromous fish species.

  - For example, monitoring undertaken in the Lower Lakes in late spring 2019 recorded the native congolli as the most abundant fish species for the first time since surveys began in the mid-2000's. Congolli are a key part of the Coorong and Lower Lakes food web as a major prey item for larger predators including mulloway, pelicans, cormorants and golden perch, thus the high abundance of congolli is a strong positive indicator of available food resources for other species (DEW 2020).
  - Sustained connection has supported increasing abundances of congolli and common galaxias, which need connection but are not particularly flow dependent.
  - Pouched lamprey have also been detected moving upstream during winter/spring for several consecutive years, and for the last three years short-headed lamprey were also recorded. Numbers of migrating lamprey captured during monitoring are generally increasing over time, suggesting that populations are gradually recovering (Bice et al. 2020). Recordings in winter/spring 2021 were the highest since the Millennium Drought.

- Outcomes for estuarine fish species in the Coorong have been variable, influenced by both the continuous connection between the lakes and the Coorong and low flows in ongoing drought conditions. While black bream spawned and recruited in early 2018 during a small flow pulse, recruitment has not been detected in the following years. (Ye et al. 2019, Ye pers. comm. 2020). Autumn 'pulsing' of flows from the barrages in line with tide and storm conditions has been linked to improvements in range and condition in commercial Coorong fish such as Coorong mullet.

Waterbirds

Basin scale monitoring of waterbirds in the Murray-Darling Basin indicates waterbird numbers are declining over the long term (since the 1980s). Waterbird breeding has generally been limited across the Murray system for several consecutive years. This may be due to a lack of

natural breeding cues resulting from below average rainfall conditions through most of winter and spring, as well as limited foraging and nesting habitat availability and condition.

Aerial waterbird surveys indicate a significant proportion of the waterbird breeding in 2018 and 2019 in the Murray valley (and more broadly) had occurred at the Coorong and Lower Lakes and Chowilla-Lindsay-Wallpolla (Kingsford et al. 2019). Murray-Darling Basin waterbird survey results for 2020 indicate waterbird abundance has grown by 80-100% over 2019 numbers, though waterbird numbers are down overall across south-eastern Australia (Porter et al. 2020).

Other notable points in relation to waterbirds in the Murray valley include:

- Barmah-Millewa Forest continues to provide a haven for bitterns, a species where survival is threatened by habitat loss, drought, and fire (pers. comms. NSW NPWS, 2019). Up to twenty five percent of the estimated remaining population are thought to rely on use of the Barmah-Millewa wetlands (Belcher et al. 2018).
- The nationally vulnerable regent parrot has experienced a 12 per cent population decline in recent years due to a decline in river red gum health. Survey results from 2019–20 have shown a further decrease in nesting, but there are some indications that birds are moving into areas that are receiving environmental water as this is helping to maintain or restore tree condition (SA Regent Parrot Recovery Team, pers. comm.).
- The annual summer census (January 2020) of waterbirds in the Coorong and Lower Lakes observed similar numbers of waterbirds and shorebirds (including migratory waders) to the previous two years. Abundance for many species are below long-term medians and below long-term threshold ecological targets. Birds that were present spent over 70% of time foraging, potentially indicating low food abundance within the mudflats, a consistent observation in recent years (TLM site manager pers. comm. 2020; Paton et al. 2020). The 2021 survey reported a significant reduction in abundances compared to the previous 3 years, with 8 out of 12 key migratory species below their long-term median annual abundances (TLM site manager pers. comm. 2021).

Learn more about use of water for the environment in the River Murray.

14.4.2 Seasonal outlook

According to the Bureau of Meteorology outlook (BoM 2021) above median rainfall between July and September is likely in both the River Murray valley and key other southern catchments that provide inflows to the River Murray valley.

This forecast indicates that dry conditions have somewhat eased, catchments are becoming more saturated and storage levels are improving. However, several months of above average rainfall are needed to see continual recovery from the drought.

14.4.3 Water availability

The volume of Commonwealth environmental to be carried over in the River Murray valley for use in 2021–22 was 261.6 gigalitres. Total carryover in the Southern-connected Basin was 538 gigalitres.

Allocations will vary depending on conditions. In the Murray, allocations against Commonwealth entitlements in 2021–22 (including carryover from 2020–21) could range from 688.1 gigalitres under very dry conditions, to 1,127.9 gigalitres in very wet conditions.

14.4.4 Environmental demands

For the environmental water demands for assets in the Murray valley, see Tables RM2 to RM4. The extent to which these environmental demands can be contributed to is contingent on several factors described in the table.

Table RM2 Environmental demands and priority for watering, 2021–22, and outlook for coming year, Mid-Murray

Environmental asset	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
	Flow/Volume	Required frequency (maximum dry interval)		Environmental demands for water	Potential Commonwealth environmental water contribution	Likely environmental demand in 2022–23 if watering occurred as planned in 2021–22
River Murray from Hume Dam to Euston and Barmah-Millewa Forest	2 000-5 000 ML/day at Yarrawonga Weir throughout the year for native fish habitat to improve recruitment and population structures, and water quality in main river channel and Barmah-Millewa creeks.	Annual	Continuous requirement, therefore the environmental demands have been assessed as High.	High	High priority for Commonwealth environmental watering (likely to receive water even under a very low water resource availability)	High
	Variable flows between 5 000 and 9 500ML/day at Yarrawonga Weir from July to November for fish condition, spawning, dispersal, in-channel non-woody vegetation and ecosystem function/productivity.	Annual	In-channel variability in 2018–19 was limited due to operational deliveries. Met in 2019–20 and 2020–21.	High	High priority for Commonwealth environmental watering (likely to receive water even under a very low water resource availability)	High
	Freshes 12 000-18 000 ML/day variable flow rate for at least 5 days, measured d/s Yarrawonga Weir during the period July to November for native fish habitat to improve recruitment and population structures (in-channel outcomes and anabranches) and for core wetlands, including Australasian bittern habitat. Would also provide carbon/productivity benefits to Edward/Kolety-Wakool system during the cooler time of the year.	5–10 in 10 years (2 years)	Has been met in 6 of the last 7 years. Therefore, the environmental demand has been assessed as Moderate.	Moderate	Option to be considered under a low to high water resource availability. Flows above a rate of 15 000ML/d at Yarrawonga are currently constrained by potential third-party effects.	Moderate
	Small overbank of 12 000-15 000 ML/day for a minimum of 45 days measured d/s Yarrawonga between August to November, to improve native fish recruitment and population structures (in-channel outcomes and giant rush wetlands). Would also provide carbon/productivity benefits to Edward/Kolety-Wakool system during the cooler time of the year.	4-8 in 10 years (2 years)	Has been met or partially met in 5 of the last 7 years. Therefore, the environmental demands have been assessed as Moderate.	Moderate	Option to be considered under a low to high water resource availability.	Moderate
	> 25 000 ML/day at Yarrawonga Weir (unregulated flow) for at least 7 days (river red gum forest) and followed by flows of up to 18 000 ML/day or greater for three to five months targeting Moira grassland.	6-8 in 10 years (2-3 years) Annual (2 years) for Moira grass	For river red gum, the target has been met or partially met 2 in 6 years. For Moira grass the target has been met fully 2 in 6 years.	High	Currently reliant on large, unregulated flows. Commonwealth environmental water may extend the depth and duration of natural floods within current constraints (i.e., 15 000 ML/day), subject to ecological need, water availability and assessment of risk and potential, adverse third-party effects.	High
Gunbower Creek	Winter low flow and summer ramp down to support juvenile fish and maintain habitat connectivity during off-irrigation season: Winter base flows (200 ML/day for 5 months).	Annually	Met or partially met every year in the last 6 years. Watering required on an annual basis therefore the environmental demand has been assessed as High.	High	Winter baseflow will not be delivered due to construction of Cohuna and Koondrook weir fishways.	High

Environmental asset	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
	Flow/Volume	**Required frequency (maximum dry interval)**		**Environmental demands for water**	**Potential Commonwealth environmental water contribution**	**Likely environmental demand in 2022–23 if watering occurred as planned in 2021–22**
	Spring pulse and stable summer flows for fish breeding: Small fresh up to 400 ML/day in spring, reducing to 300 ML/day in summer.	Annually Spring fresh September to December for 122 days Summer flows Jan to March for 74 days	Met or partially met every year in the last 6 years. The environmental demand has been assessed as High.	High	Priority for Commonwealth environmental watering (likely to receive water even under low water resource availability, subject to flow constraints)	High
Gunbower Forest	Small-moderate actions (~ 100-1 000 ML/day in late winter/early spring – duration dependant on inflow rate) targeting permanent and semi-permanent wetlands, or targeted infrastructure use at the sites. Up to 2 500 ha via Gunbower Forest infrastructure.	6-9 in 10 years (2 years)	Significant watering action in 2014–15 and 2015–16 and natural flood event in 2016–17 inundated various parts of the Forest. Drying phase in 2017–18, with the exception of high value permanent wetlands. Watering action in 2018–19. Small throughflow event to targeted wetlands in 2019–20 and 2020–21. Environmental demand has been assessed as High.	High	It is anticipated that demands in Gunbower Forest will be met by other water holders in 2020–21.	High
	Infrastructure delivery to Gunbower Forest targeting river red gum forest (~1 600 ML/day for 90 days in winter/spring) Up to 4 700 ha via Gunbower Forest infrastructure.	6-7 in 10 years (3 years)	Met or partially met in 6 of the past 7 years. The environmental demand has been assessed as Moderate.	Moderate	It is anticipated that demands in Gunbower Forest will be met by other water holders in 2020–21.	Moderate
Mid-Murray Off-Channel Wetlands and ephemeral creeks Hume to Euston	Infrastructure and/or weir pool delivery targeting permanent off-channel wetlands.	Annually	Annual requirement therefore the environmental demand has been assessed as High.	High	Mid-Murray wetlands are generally watered using other water portfolios, however if additional water is required for priority wetland sites, a Commonwealth environmental water contribution will be considered. The Lock 15 weir pool is likely to be raised during spring 2021 for environmental purposes, underwritten by Commonwealth environmental water. The raising is expected to connect the River Murray with low-lying creeks and wetlands such as a portion of the Euston Lakes complex (portions of which have not received substantial inundation since the 2016 flood).	High
	Infrastructure and/or weir pool delivery targeting semi-permanent off-channel wetlands.	3-7 in 10 years (5 years)	Variable across sites with last natural watering event in 2016. Therefore, the environmental demand has been assessed as Moderate.	Moderate		Moderate
	Infrastructure and/or weir pool delivery targeting ephemeral off-channel wetlands.	1 in 5 years				

Note: References include Murray and Barmah-Millewa Forest indicators adapted from Department of the Environment (2011), MDBA (2012c). Gunbower Creek indicators sourced from North Central CMA (2021). Gunbower-Koondrook-Perricoota Forest indicators adapted from MDBA (2012a) and MDBA (2012 g and h). Mid-Murray Off-Channel Wetlands and ephemeral creek indicators sourced from North Central CMA (2021).

Key

Potential watering in 2021–22

High priority for Commonwealth environmental watering (likely to receive water even under low water availability)

Secondary priority for Commonwealth environmental watering (watering to occur only if natural trigger is met, or under moderate – high water resource availability); or water demand likely to be met via other means

Low priority for Commonwealth environmental watering (under high – very high water resource availability); or unable to provide water because of constraints or insufficient water

Environmental demands (demand is considered at a generalised scale; there may be specific requirements that are more or less urgent within the flow regime)

High to critical demand for water (needed in that particular year or urgent in that particular year to manage risk of irretrievable loss or damage)

Moderate demand for water (water needed in that particular year, the next year, or both)

Low demand for water (water generally not needed in that particular year)

Table RM3 Environmental demand and priority for watering, 2021–22, and outlook for coming year, Edward/Kolety-Wakool River system

Environmental assets	Indicative demand (for all sources of water in the system)		Watering history	2021–22		Implications for future demands
	Flow/Volume	Required frequency (maximum dry interval)	(from all sources of water)	Environmental demands for water	Potential Commonwealth environmental water contribution	Likely environmental demand in 2022–23 if watering occurred as planned in 2021–22
Yallakool - Wakool Maintenance of native fish habitat and instream aquatic vegetation Longitudinal connectivity Fish spawning, recruitment, and movement Nutrient cycling Water quality	~200 ML/day base flow for ~295 days during late winter to late Autumn (~59 GL). Note: winter base flows are a separate flow component and is included below.	Annual	Has been met 5 out of the past 5 years	Low	Likely to be met by operational flows except in **a very dry year** when CEW may be use to prevent system from being cut off subject to NSW Extreme Events Policy	Low
	~580 ML/day peak for 10 days fresh over ~25 days in early spring with gradual recession (~11 GL, includes ~200 ML/day base flow. To assist in providing the spring pulse an additional ~3-4 GL through the Wakool escape may need to be needed).	Annual	Has been met 5 out of the past 5 years. Annual requirement therefore the environmental demand has been assessed as High.	High	Priority for Commonwealth environmental water to continue ecosystem recovery	High
	~430 ML/day for 41 days to maintain minimum flow for fish nesting habitat, and inundation for aquatic vegetation growth (~17.6 GL in total, includes ~200 ML/day base flow)	Annual	Has been met 5 out of the past 5 years. Annual requirement therefore the environmental demand has been assessed as High.	High	Priority for Commonwealth environmental water to continue ecosystem recovery	High
	~600 ML/day peak for 5 days undertaken as 1 to 3 freshes in late spring/early summer to stimulate silver perch breeding with a gradual recession down to 220 ML/day at end of fish nesting period (from min. 20 days to max. 84 days) (~10.5 GL min to 38 GL max., includes ~200 ML/day base flow).	Annual	Has been met 3 times for 1 fresh out of the past 5 years and has not been met for 3 freshes.	Moderate	Option to be considered under a moderate to high water resource availability.	Moderate
	~510 ML/day peak for 4 days over 51 days fresh in autumn with a gradual recession (~16 GL, includes ~200 ML/day base flow).	2 in 3 years (2 years)	Has been met 3 out of the past 5 years	Moderate	Option to be considered under a moderate to high water resource availability.	Moderate
	~170 ML/day winter base flow from early-May (irrigation shut down) until first week of July (system restarts) (~10 GL). Needs minimum of 4,000 ML/day at Yarrawonga to meet all Edward/Kolety system winter base flow requirements.	Annual	Has been met 2 out of the past 5 years. Subject to Stevens weir pool being kept in over winter to enable connection to Colligen and Yallakool regulators.	High	Priority for Commonwealth environmental water to continue ecosystem recovery.	High
	Upper Wakool over summer and autumn to maintain water quality. 14 day increase stepwise of 30 ML/day up to a peak of ~110 ML/day for 14 days followed by stepwise decrease of 30 ML/day down to 50 ML/day for 14 days, then repeat to watering season end in early May.	Annual	Has been met 1 out of the past 5 years. Annual requirement therefore the environmental demand has been assessed as High.	High	Priority for Commonwealth environmental water to continue ecosystem recovery.	High
Colligen – Niemur As per Yallakool-Wakool above	The potential flow components for the Colligen-Niemur during 2021–22, and related assessment of demands & urgency of demands are like the flow components outlined for the Yallakool-Wakool above. The primary difference is that the flows planned for the Colligen-Niemur have been scaled to fit within its constraint for environmental flows of up to 450 ML/day.	As above.	As above.	As above.	As above.	As above.
Edward/Kolety River downstream of Stevens Weir	Above 2700 ML/day (constraint downstream of Stevens Weir) early spring pulse targeting Werai Forest (~15 GL) and late spring/summer pulse (~15 GL). Will need to align with delivery of RMC	Annual	Single fresh has been met 3 out of the past 5 years by unregulated flows. Annual requirement therefore the environmental demand has been assessed as High.	High	Flows up to constraint of 2700 ML/day are likely to be met by RMC operational flows during early spring and late spring/early summer.	High

Environmental assets	Indicative demand (for <u>all sources of water</u> in the system)		Watering history	2021–22		Implications for future demands
	Flow/Volume	Required frequency (maximum dry interval)	(from all sources of water)	Environmental demands for water	Potential Commonwealth environmental water contribution	Likely environmental demand in 2022–23 if watering occurred as planned in 2021–22
	flows into Yallakool-Wakool and Colligen-Niemur systems.					
Tuppal Creek	~5,500 ML in total spring fresh with variability flow during August to April (~2.75 GL of CEW + ~2.75 GL NSW).	Annual	Has been met 1 out of the past 5 years	Moderate	Priority for Commonwealth environmental water to maintain ecosystem health - undertaken in partnership with NSW.	Moderate
Merran Creek	~460 ML/day preferably in spring and comprised of: Merran Creek at Franklings Bridge (~250 ML/day), Waddy Cutting (~150 ML/day) and St Helena Creek (~60 ML/day).	Annual	Has been met 5 out of the past 5 years	Low	A low priority for watering in 2021–22. Demand may be met by other means.	Low
Jimaringle, Cockran and **Gwynnes Creeks**	Total flow of ~10 GL deliverable preferably in August to November. May also require high flows in receiving Niemur system to dilute potential poor water quality outflows from these systems.	1 in 2 years (2 years)	Has been met 1 (65%) in 5 years. Last significant flow was the 2016 flood event.	Moderate	Option to be considered under a moderate to high water resource availability.	Moderate
Werai Forest	Linked to Edward/Kolety River action above. May need to call on MIL Edward Escape for ~15 GL to push flows over 2,700 ML/day D/S of Stevens Wier.	2-3 in 5 years (2 years)	First fresh has been met 5 out of the past 5 years. Second fresh has not been met in past 5 years. Forest in poor health therefore the environmental demand has been assessed as High for successive years.	High	Priority for Commonwealth environmental water to maintain ecosystem health – likely to be undertaken as part of the River Murray watering action (Table RM2).	High
Koondrook-Perricoota Forest	Annual watering proposals for this site are developed by Forestry NSW and can be contributed to by a number of water holders.	2-3 in 5 years (2 years)	Minimum flow has been met twice (provided in 2019–20, similar to 2014–15 commissioning event). Forest in poor health therefore the environmental demand has been assessed as High for successive years.	High	Use of CEW in scope subject to support from local stakeholders and potentially affected landholders.	High
Pollack Swamp	~3 GL per year watering proposals for pumping to this site during late spring and summer developed by Forestry NSW and DPIE.	Annual	Has been met 5 out of the past 5 years. Annual requirement therefore the environmental demand has been assessed as High.	High	Priority for Commonwealth environmental water to maintain ecosystem health - undertaken in partnership with NSW.	High
Thule Creek	~750 ML top up to maintain water quality in Aug to April.	Annual	Has been met 2 out of the past 5 years	High	Priority for Commonwealth environmental water to maintain ecosystem health - undertaken in partnership with NSW.	High
Murrain-Yarrein	Up to ~3 GL in total August to April	5 to 10 years in 10 years (75%)	Has not been met since 2016 flood.	High	Priority for Commonwealth environmental water to maintain ecosystem health - undertaken in partnership with NSW.	Moderate
Yarrein Creek	~5 GL to 10 GL total August to November	5 to 8 years in 10 years (65%)	Has not been met since 2016 flood.	High	Priority for Commonwealth environmental water to maintain ecosystem health - undertaken in partnership with NSW.	Moderate
Whymoul Creek	~500 ML in total August to April. Maintain for native fish particularly if threatened species are released into it.	Annual (100%)	Has been met once in 2021. Prior to that was the 2016 flood.	High	Priority for Commonwealth environmental water to maintain ecosystem health - undertaken in partnership with NSW.	Moderate
Buccaneit-Cunningyeuk Creeks	~2 GL in total August to April for refuge pools.	Annual (100%)	Has been met 2 out of the past 5 years. Prior to that was the 2016 flood.	High	Priority for Commonwealth environmental water to maintain ecosystem health - undertaken in partnership with NSW.	Moderate
Lake Agnes	~1 GL in total September to December.	5 to 10 years in 10 (75%)	Has been met once in 2021. Prior to that was the 2016 flood.	High	Priority for Commonwealth environmental water to maintain ecosystem health - undertaken in partnership with NSW.	Moderate
Mortons swamp	~800 ML in total September to December	5–8 years in 10 (65%)	Has not been met since 2016 flood.	High	Priority for Commonwealth environmental water to maintain ecosystem health - undertaken in partnership with NSW.	Moderate

Environmental assets	Indicative demand (for all sources of water in the system)		Watering history	2021–22		Implications for future demands
	Flow/Volume	Required frequency (maximum dry interval)	(from all sources of water)	Environmental demands for water	Potential Commonwealth environmental water contribution	Likely environmental demand in 2022–23 if watering occurred as planned in 2021–22
Southern Bell frog private wetlands	~4 GL in total September to December	Annual (100%)	Has been met 10 out of the past 10 years. Not all sites are watered annually black box sites are watered around 5 years in 10 depending on conditions	High	Priority for Commonwealth environmental water to maintain ecosystem health - undertaken in partnership with NSW.	High
Private wetlands supporting Wanganella waterbird habitat	~500 ML in total September to December. Black box wetlands in area south of Wanganella	3–4 years in 10 (35%)	Has not been met in past 3 years	High (Contingency: bird breeding)	Depending on timing, option to be considered if breeding event is triggered. However more likely to occur under moderate or high water resource availability	High (Contingency: bird breeding)
Private wetlands supporting KP/Pollack waterbird habitat	~1 GL in total September to December. Red gum wetlands adjoining KP forest.	5–8 years in 10 (65%)	A couple watered last season, most not watered since 2016 flood	High (Contingency: bird breeding)	Depending on timing, option to be considered if breeding event is triggered. However more likely to occur under moderate or high water resource availability	High (Contingency: bird breeding)
Edward/Kolety Wakool System - Refuge Flows Habitat flows Water quality Provision of refuges for native fish	~30-120 GL a year to manage hypoxic water quality events and other critical habitat needs.	As required - usually triggered once dissolved oxygen levels reach 4.0 mg/l in line with Basin Plan water quality requirements.	Has been met when required	High (Fish refuge flows)	High priority for Commonwealth environmental water to abate the impact of potential fish kills if triggers are met.	High (Fish refuge flows)

Note: The majority of flows listed in this table will be synchronised with flows in the River Murray (Table RM2).

Key

Potential watering in 2021–22

- High priority for Commonwealth environmental watering (likely to receive water even under low water availability)
- Secondary priority for Commonwealth environmental watering (watering to occur only if natural trigger is met, or under moderate – high water resource availability); or water demand likely to be met via other means
- Low priority for Commonwealth environmental watering (under high – very high water resource availability); or unable to provide water because of constraints or insufficient water

Environmental demands (demand is considered at a generalised scale; there may be specific requirements that are more or less urgent within the flow regime)

- High to critical demand for water (needed in that particular year or urgent in that particular year to manage risk of irretrievable loss or damage)
- Moderate demand for water (water needed in that particular year, the next year, or both)
- Low demand for water (water generally not needed in that particular year)

Table RM4 Environmental demands and priority for watering, 2021–22, and outlook for coming year, Lower Murray

Environmental assets	Indicative demand (for all sources of water in the system)		Watering history	2021–22		Implications for future demands
	Flow/Volume	Required frequency (maximum dry interval)	(from all sources of water)	Environmental demands for water	Potential Commonwealth environmental water contribution?	Likely environmental demand in 2022–23 if watering occurred as planned in 2021–22
River Murray from Euston to Lower Lakes, including pool level wetlands	Elevated river baseflow of at least 10 000 ML/d at SA Border for up to 60 days in spring/summer for in-channel aquatic vegetation, fish, and water quality.	9 in 10 years (2 years)	All indicators met in 2011–12, 2012–13 and 2016–17 (high flow years during the last decade). 2013–14 and 2017–18 also saw high baseflows and moderate freshes. The drier years (2014–15, 2015–16, 2018–19, 2019–20 and 2020–21) saw contributions to the baseflows and moderate freshes in 2019–20 and 2020–21 of 15 000 ML/day and 18 000 ML/day (respectively) but only for a short duration. All indicators have a high demand for 2021–22.	High	A very high priority for watering in 2021–22, even in low resource availability.	High
	Moderate fresh of 15 000–25 000 ML/day at SA Border for up to 90 days in spring/summer for perch spawning and survival and other ecological benefits.	2 in 3 years (2 years)		High	A very high priority for watering in 2021–22, noting that at least moderate resource availability (and multiple water holder contributions) would be required. Meeting the upper end of the flow rate and the duration is not possible with water for the environment alone and will depend upon unregulated conditions.	High
	Large fresh of 25 000-35 000 ML/day at SA Border for up to 60 days in spring/summer for fish populations and other in-channel biota.	1 in 2 years (3 years)		High	High resource availability and coordination with unregulated tributary inflows would be required to deliver flows of this magnitude and duration, with water for the environment used to supplement the flow.	Moderate
Hattah Lakes	Small action targeting temporary wetlands (inundation to 42-43 m AHD in winter/spring) - up to 22 000 ML via infrastructure equivalent to natural event of 40 000-50 000 ML/day at Euston for 26-60 days.	1 in 2-3 years (4 years)	All indicators met in 2016–17 (flood), followed by environmental water delivery to 44.85 m AHD in spring 2017. Apart from a small watering event at Lake Kramen in 2019–20, much of the lakes complex has had a drying phase or been completely dry since 2017. Environmental water delivery in April-May 2021 has targeted 11 of the 18 lakes in the complex, to prime the system for further planned delivery in spring 2021.	High	High priority for Commonwealth (and Victorian) environmental water contribution in spring 2021.	High
	Moderate action targeting wetlands and fringing river red gums (inundation to 43.5 m AHD for 90 days in winter/spring) - up to 40 000 ML via infrastructure equivalent to natural event of 85 000 ML/day at Euston for 7-30 days.	1 in 3 years (7 years)		High to Critical		
	Large event targeting wetland and river red gum/black box woodlands on floodplain (inundation to 45 m AHD for 90 days) - up to 120 000 ML via infrastructure equivalent to natural event of 150 000 ML/day at Euston for 7 days anytime in the year.	1 in 8 years (12 years)		Low	Environmental water will be contributed only to extend a large natural overbank flow.	
Floodplain and wetlands from Euston to South Australian border	30 000 ML/day at Lock 8 for 30-60 days targeting low lying wetlands and anabranches, or priority areas via infrastructure or weir pool raising.	2 in 5 years (4 years)	All indicators met in 2016–17 (flood). Environmental water delivered to targeted wetland sites in the following four years, however the majority of sites	High	Commonwealth environmental water is able to contribute to overbank flows only in high resource availability years with significant tributary inflows. Water is likely to be delivered to priority wetland sites via infrastructure and temporary pumps	High (unless natural flooding occurs)

Environmental assets	Indicative demand (for all sources of water in the system)		Watering history	2021–22		Implications for future demands
	Flow/Volume	Required frequency (maximum dry interval)	(from all sources of water)	Environmental demands for water	Potential Commonwealth environmental water contribution?	Likely environmental demand in 2022–23 if watering occurred as planned in 2021–22
	50 000-60 000 ML/day at Lock 8 for 60-120 days targeting river red gum forest, lignum shrubland and associated wetlands, or priority areas via infrastructure.	1 in 5 years (5 years)	have not received water since 2016–17. As such, the environmental water demand has been assessed as high.		during 2021–22. Raising of weir pools 7, 8 and 9 (which is underwritten by Commonwealth environmental water) is also expected to connect the River Murray with low lying wetlands and provide freshes down creek systems, such as the Lindsay River and Potterwalkagee and Mullaroo Creeks. Mulcra Island floodplain is very high priority and will be fed via weir pool raising and infrastructure.	
Floodplain and wetlands from South Australian border to Lower Lakes	Small overbank flow of 45 000-55 000 ML/day at SA border for at least 30 days between Sept-Dec targeting river red gum forest, tea tree, lignum, river cooba and associated wetlands, or priority areas via infrastructure	1 in 2 years (5 years)	Small and moderate flow requirements were last met in 2016–17 and 2011–12 natural flows. Small overbank flow also occurred in 2012–13 for <30 days. All overbank flow requirements were last achieved in 2010–11. Environmental water has also been delivered to some priority wetland sites each year, across all floodplain elevation levels. First operations of new floodplain regulators raised water levels across parts of the floodplain to the equivalent of a 45,000 ML/d flow at Katarapko and 55,000ML/d at Pike in spring 2020. The broader floodplain however is in poor condition with significant tree canopy loss. There is a critical to high demand for overbank flows in 2021–22.	Critical	In the absence of overbank flows, water use will be limited to delivery via infrastructure to priority wetland sites and the Pike and Katarapko floodplains. Chowilla floodplain will also receive environmental water, most likely from other sources. The Lower River Murray is expected to be connected to low-lying floodplain areas via proposed raising of weir pools 2, 4, 5 and 6 (depending on the climate scenario). Commonwealth water can only contribute to overbank flows in high resource availability years with significant tributary inflows.	High/critical (unless natural flooding occurs)
	Moderate overbank flow of 55 000-65 000 ML/day at SA border for at least 30 days between Sept-Dec targeting river red gum forest, tea tree, lignum, river cooba and associated wetlands, or priority areas via infrastructure	1 in 2 years (5 years)				
	Large overbank flow of 65 000-75 000 ML/day at SA border for at least 30 days between Sept-Dec targeting black box, cooba, lignum and chenopod and associated wetlands, or priority areas via infrastructure	1 in 3 years (5 years)		High	Water is likely to be delivered to priority wetland sites via infrastructure. Commonwealth environmental water can contribute to overbank flows only in high resource availability years with significant tributary inflows.	
Coorong, Lower Lakes and Murray Mouth	Minimum barrage flow of 650 GL/yr. (and lake water levels maintained above 0.4 m AHD) to provide suitable conditions and refuge habitat in the lakes and north lagoon for native fish, plants and internationally important migratory birds.	Annually	Lower Lakes and Coorong north lagoon in generally good condition, with salinity levels and signs of stress increasing with distance from the barrages along the north lagoon. Minimum flow (1 in 1 year) was not met in 2015–16 or 2018–19. The period in which the three-year rolling average was last met was 2016–18.	High	A very high priority for watering in 2021–22, even in low resource availability.	High
	Barrage flows of 2 000 GL/yr. required to provide suitable conditions and refuge habitat for native fish, plants and internationally important migratory birds.	Rolling 3-year average		High	A high priority for watering in 2021–22, even in low resource availability. Average barrage flows over the past four years are less than half of the rolling three-year average target. Commonwealth water likely to contribute significantly. However the three-year average target cannot be met by Commonwealth water alone.	Moderate
	Barrage flows of 6 000 GL every three to five years to maintain and improve habitat conditions within the Coorong. Lake water level range between 0.4 and 0.83 m AHD to maintain healthy lake ecology.	1 in 3 years (5 years)	Coorong south lagoon still in poor health, with a trend of increasing salinity over the past four years. While Commonwealth environmental water can help to slow the decline and minimise further damage, strong recovery in	High (last met in 2016–17)	Commonwealth water will contribute to meeting this demand. However the targets cannot be met by Commonwealth water alone and will depend upon unregulated flow event/s.	Low

Environmental assets	Indicative demand (for all sources of water in the system)		Watering history	2021–22		Implications for future demands
	Flow/Volume	Required frequency (maximum dry interval)	(from all sources of water)	Environmental demands for water	Potential Commonwealth environmental water contribution?	Likely environmental demand in 2022–23 if watering occurred as planned in 2021–22
	Barrage flows of 10 000 GL every seven to seventeen years to improve habitat conditions within the Coorong. Lake water level range between 0.4 and 0.9 m AHD to maintain healthy lake ecology.	1 in 7 years (17 years)	the Coorong South Lagoon requires significant volumes of water and/or complementary measures and will likely only occur in high resource availability years. Large flow events in the last decade include 2010–11 (15,000+ GL), 2012–13 (6797 GL) and 2016–17 (6484 GL).	Moderate (met in 2010–11)		Low

Note: References include River Murray Channel indicators sourced from Wallace et al. (2014), Ecological Associates (2015), Ecological Associates (2010), DEWNR (2015) and MDBA (2012f). Hattah Lakes indicators sourced from MDBA (2012e), (2012f); Roberts and Marston (2011). Floodplain from Euston to SA indicators sourced from MDBA (2012b). Floodplain from SA to Lower Lakes indicators sourced from Kilsby and Steggles (2015), MDBA (2012d) and DEWNR (2015). Coorong, Lower Lakes and Murray Mouth indicators sourced from MDBA (2014) and DEWNR (2015).

Key

Potential watering in 2021–22

- High priority for Commonwealth environmental watering (likely to receive water even under low water availability)
- Secondary priority for Commonwealth environmental watering (watering to occur only if natural trigger is met, or under moderate – high water resource availability); or water demand likely to be met via other means
- Low priority for Commonwealth environmental watering (under high – very high water resource availability); or unable to provide water because of constraints or insufficient water

Environmental demands (demand is considered at a generalised scale; there may be specific requirements that are more or less urgent within the flow regime)

- High to critical demand for water (needed in that particular year or urgent in that particular year to manage risk of irretrievable loss or damage)
- Moderate demand for water (water needed in that particular year, the next year, or both)
- Low demand for water (water generally not needed in that particular year)

14.5 Water delivery in 2021–22

The use of water for the environment will be responsive to prevailing conditions, water availability, and any emergent opportunities or risks. As such, our plans are flexible (as opposed to being prescriptive) and we may deviate from them in order to maximise the achievement of environmental outcomes throughout the Basin.

Where possible, water for the environment will be managed to benefit multiple sites along the entire River Murray and will be coordinated with other sources of water. This will include other environmental water portfolios (such as The Living Murray program), consumptive and operational deliveries, natural flows, and inflows from key tributaries such as the Ovens and Kiewa Rivers.

The following summary indicates how we may manage Commonwealth environmental water deliveries under various scenarios, with a focus on scenarios that reflect current and forecast climate conditions.

14.5.1 Dry to moderate (a year that is in the driest 10–50% of years)

A combination of forecast water availability (see Section 1.4.3), carryover of allocations from 2021–22 and strong opening allocations has enabled planning for the following events (even in a very dry scenario:

- Maintain winter baseflows to support in-channel species (including native fish), provide drought refuge, maintain water quality and riverine functions
  - main river channel flows in winter (4 000 ML/day at Yarrawonga) and spring (8 000 ML/day at Yarrawonga)
  - flows through creeks and key wetlands of Barmah-Millewa Forest
  - flows through Gunbower Creek to promote connectivity with Gunbower forest, provide native fish habitat, and maximise spawning potential
  - flows through the Edward/Kolety-Wakool River system, including the Yallakool-Wakool and Colligen-Niemur Creek systems
  - provide continuous connection through the Lower Lakes and into the Coorong and maintain water levels in the Lower Lakes above 0.4 m (to avoid the risk of acidification).
- Provide spring freshes
  - through the River Murray to support a broad range of environmental outcomes (see Tables RM1 to RM4 above). The timing, size, duration and number of freshes will depend on water availability. Under drier scenarios, the fresh is likely to be smaller and delivered later in spring to early summer. With increasing water availability, the targeted flow height and duration is likely to increase and may start in late winter to early spring.
  - that are coordinated with tributaries flows from the Goulburn, Murrumbidgee and Baaka (Lower-Darling) and Great Darling Anabranch to support large-scale connectivity and support carbon and nutrient transport throughout the southern connected basin.

  - which, where possible are coordinated to reach targeted flow rates (>20 000 ML/d) in the Lower Murray river channel to enable 'faster flowing habitat' to support breeding and recruitment of golden and silver perch.
  - through Gunbower Creek.
  - in the Edward/Kolety-Wakool River system, with a minimum flow target during fish nesting period as a priority, followed by increase flow variability in summer and autumn and winter flows from May to August 2021 subject to water availability.
  - Maximise end-of-system flows to
    - connect the River Murray to its estuary and the ocean to allow for native fish movement between fresh and saltwater habitats to successfully reproduce
    - provide suitable food and habitat for migratory shorebirds
    - export salt out of the Basin and reduce salt import into the Coorong and reduce salinity concentrations in the Coorong
    - maintain water levels in the Lower Lakes support improved diversity and extent of fringing and submergent vegetation, improve population size of small-bodied native fish species and increase habitat for waterbirds and migratory shorebirds.

- Deliver sufficient water to SA during summer/autumn to maintain end of system flows and connection between the Lower Lakes and the Coorong.
- Use infrastructure, pumps and/or weir pool manipulation to provide water to key wetlands throughout the valley, including Koondrook-Perricoota Forest, Hattah-Kulkyne Lakes, Chowilla, Pike and Katarapko floodplains.
- Respond to poor water quality events that may result from low flows.

Wet (a year that is in the wettest 25% of years)

- Contribute to the above outcomes, where not achieved by natural flows.
- Extend the peak, duration and/or recession of natural flows (within allowable operational limits), including with 'top-up' watering for wetlands in autumn.
- Provide refuge flows in response to hypoxic blackwater events.
- Support end-of-system flows.

14.6 Monitoring and lessons learned

14.6.1 Monitoring

Operational monitoring is undertaken for all Commonwealth environmental watering actions. It involves collecting on-ground data on environmental water delivery such as volumes delivered, impact on the river systems hydrograph, area of inundation and river levels. It can also include observations of environmental outcomes. Monitoring activities for the River Murray are funded by CEWO or The Living Murray Program.

The Commonwealth Environmental Water Monitoring, Evaluation and Research program has the Lower Murray and Edward/Kolety-Wakool region as focus areas. It aims to understand the environmental response from Commonwealth environmental watering with respect to the targeted objectives by carrying out monitoring of site condition and ecological response over many years. Learn more about the Commonwealth Environmental Water Office's monitoring activities in the Mid-Murray and Lower Murray-Darling.

The Living Murray program funds complementary monitoring for—Barmah-Millewa Forest, Koondrook-Perricoota Forest, Gunbower Forest, Hattah Lakes, Chowilla–Lindsay–Wallpolla Floodplain and the Lower Lakes and Coorong. Monitoring results from The Living Murray icon sites are available at the MDBA's water for the environment outcomes page.

In addition to site-based monitoring, during 2019–20 and 2020–21 a system-scale monitoring approach for the River Murray Channel was undertaken. These projects investigated changes in productivity (aquatic food-webs) resulting from the 'Southern Spring Flow'. Reports from 2019–20 include Zooplankton response to a multi-site environmental watering event during spring 2019 in the River Murray and 2019 Southern Spring Flow – Productivity Monitoring (2020–21 reports to be published in coming months).

During 2020–21, River Murray state and Commonwealth jurisdictions collaborated to develop a five-year monitoring plan for the River Murray Channel. The plan was developed with a focus on building on existing monitoring programs to fill gaps so that fish and productivity response can be evaluated at a whole of River Murray scale. Implementation of the Monitoring Plan for the first year in 2021–22 is expected to significantly improve monitoring coverage in the River Murray, focusing on productivity and fish indicators that will directly inform improved management and coordination of flows.

14.6.2 Lessons learned

Outcomes from monitoring and lessons learned in previous years are a critical component for the effective and efficient use of Commonwealth water for the environment. These learnings are incorporated into the way environmental water is managed.

Landscape-scale environmental water delivery is still relatively new, which means trialling and learning by doing (informed by science) from various events and outcomes. These learnings continue to be incorporated into the way environmental water is managed. While there are many learnings relating to particular locations, types of watering actions or subsets of the Murray's ecology (some are described in Table 6), key learnings that apply throughout the River Murray valley are summarised as follows.

Environmental water coordination

- Coordinating releases of water for the environmental across multiple river systems is complex. Factors such as delivery constraints, notification requirements and site-specific environmental demands or risks make it challenging to align releases of water in multiple tributaries to achieve coordinated flows downstream, however progress is being made.
  - In spring 2019, the 'Southern Spring Flow' provided extensive environmental benefit along the River Murray, from Hume Dam to the Coorong in South Australia, enhanced by its timing aligning with a spring fresh in the Goulburn River. Full details, including environmental outcomes, are described in the 'Southern Spring Flow Wrap-up' (CEWO 2020a).
  - A similar event was undertaken in 2020, including coordinated Murray, Goulburn and Murrumbidgee pulses and additional releases from Lake Victoria. Details are described in the flow updates on the CEWO website (CEWO 2020b).
- The 2019 and 2020 Southern Spring Flows, along with previous coordinated flow events and associated monitoring activities, have shown there are multiple benefits of flows

moving through the length of the river system. However, it is also becoming clear that some important environmental outcomes are challenging to achieve and likely depend upon flows being higher and/or continuing for longer than what has been delivered to date. Thus, these outcomes require delivery constraints being relaxed, significant environmental releases combined from multiple tributaries and/or natural flows. For example:

- At a maximum flow rate of 15 000 ML/day downstream of Yarrawonga, satellite images show that only 25 per cent of Barmah-Millewa Forest was inundated as a result of the Southern Spring Flow (CEWO 2020a). Though only a small proportion of the total forest is watered, benefits from this extent of inundation are significant. For example, flows at this rate enable Moira grass growth, flowering and seed-set, improved river red gum condition, and generation of food for native fish in watercourses downstream of the forest as far as South Australia (CEWO 2020a, GB CMA 2020a). However, additional benefits such as to vegetation in the remaining majority of Barmah-Millewa Forest, remains unattainable at current flow constraints.
- Sustained flows of >20 000 ML/d are important for shifting a noticeable proportion of the Lower River Murray from still water to flowing water habitat, which benefits native plants and animals that are adapted to a flowing riverine environment (Ye et al. 2020). However, despite previous success of coordinating tributary flows, outside of unregulated conditions, flow rates of this magnitude are yet to be achieved. The combined Murray and Goulburn releases in 2019 achieved a peak flow at the South Australian border of around 15 000 ML/day. In 2020, Murray and Goulburn spring flows were enhanced with Murrumbidgee return flows and a direct order at the SA border which supplemented river flows with releases from Lake Victoria, achieving a brief flow peak of around 18,000 ML/d at the SA border.
- The diverse hydraulic conditions that occur above the 20 000 ML/d flow threshold, along with water temperature >18 degrees, are expected to trigger and support spawning and recruitment of golden and silver perch. While silver perch spawned in the Lower Murray during the 2020 spring pulse, there has been negligible recruitment of silver or golden perch detected in the last seven years, resulting in a lack of fish <6 years of age (Ye et al. 2021). This result is a concern for the population health of these iconic native perch.

End of system flows

The importance of delivering water for end of system flows is significant and remains among the highest priorities in the River Murray. Lessons learned regarding flows to the end of the River Murray are as follows:

- Flows through the barrages to the Coorong have been almost continuous since the Millennium Drought because of environmental flows (Ye et al. 2021). Without water for the environment, barrages would need to have been closed for extended periods, effectively disconnecting the River Murray from its estuary. Connection to the estuary and sea is vitally important for many fish species to move between fresh and saltwater habitats to successfully reproduce, and for providing suitable food and habitat for migratory shorebirds.
  - If flows are reduced to fishways-only at the barrages for extended periods (e.g., 3 months during 2019–20 summer), releases are insufficient to prevent North Lagoon salinities increasing above 45 grams per litre (g/L). This is a maximum

management threshold as salt levels above this rate are lethal for some estuarine plants and animals (Taylor 2010). Higher flows in 2020–21, with minimal periods of fishways-only deliveries, ensured salinity generally remained below 45 g/L.

- Environmental flows substantially increased salt export out of the Basin, reduced salt import into the Coorong and reduced salinity concentrations in the Coorong. Flows have prevented around 5.5 million tonnes of salt building up in the Coorong from 2017 to 2020, avoiding catastrophic impacts that would have been reminiscent of those experienced during the Millennium Drought (Ye et al. 2021). In some years, environmental water has contributed to over 500 000 tonnes of salt being exported from the river and out the Murray Mouth (Ye et al. 2021). This is the equivalent of 25 000 semi-trailers each carrying a full load of salt (around 20 tonnes).
  - While water for the environment has to-date prevented catastrophic impacts re-occurring in the Coorong, there is still a year-on-year trend of gradual salt build-up in the South Lagoon over the past 4 years. Extensive recovery of *Ruppia* has also not occurred. Current volumes of water for the environment are not sufficient to 'reset' and maintain appropriate salinities and water levels in the South Lagoon during low flow conditions. High natural flows from the river, from the South-East and/or infrastructure solutions being investigated by the Healthy Coorong, Healthy Basin project are likely required to alleviate the threat of escalating salinity and encourage a strong recovery trend.
- While large volumes of freshwater are required to manage the health of the entire Coorong, new approaches to managing small releases of water through the barrages to the Coorong can have significant benefits. For example:
  - Strategically releasing pulses of water through Tauwitchere barrages to coincide with favourable wind, tide and swell conditions has proven effective in reducing Coorong salinity levels along the full length of the North Lagoon (CEWO 2020c).
  - Lamprey have been detected migrating even under low flow conditions (e.g., 2018). As such they remain a legitimate objective in similar conditions during winter/early spring, though more moderate flows are likely to enhance attraction to barrages and passage upstream (Bice et al. 2020).
- Without water for the environment water, water levels in the Lower Lakes would have dropped to levels that are ecologically devastating several times since the Millennium Drought. Environmental water stored temporarily in the Lower Lakes, prior to its release into the Coorong, has provided significant benefits to the health of the Lower Lakes. Environmental water has increased variability in the water levels of the Lower Lakes, improving diversity and extent of fringing and submergent vegetation, boosting populations of some small-bodied native fish species and increasing habitat for waterbirds and migratory shorebirds (SA DEW, 2020).

Value of flows all year round

Over the last 10 years environmental flows have moved from having a single-site focus for limited times (during drought and when environmental water holdings were relatively small) to large-scale deliveries that aim to provide multiple benefits along the entire length of river systems. Recent experience has also demonstrated the benefit of delivering water through the

entire year, particularly when ecological needs would otherwise not be met due to limited demand for operational flow resulting in flows ceasing unnaturally. For example:

- Several consecutive years of stable winter flows in Gunbower Creek, along with a spring rise, are considered to have been key to the observed improvement in the structure of Murray cod populations (Bloink et al. 2019).
- Winter flows, supported by water for the environment, in the Edward/Kolety-Wakool River system have prevented cease to flow conditions (caused by the winter shut down of the irrigation season). This has resulted in in over a hundred kilometres of perennial instream habitat throughout Yallakool Creek-Wakool River and Colligen Creek-Niemur River systems. The provision of winter flows has assisted with the movement of native fish, such as silver perch, throughout the system (Watts et. al., 2019). It is also expected that winter flows into the Edward/Kolety-Wakool River system will protect aquatic plants from frost damage and improve their rate of recovery in the following spring, this will require further monitoring over multiple seasons to confirm (Watts et al. 2018).
- Further downstream, flows through the barrages and through fishways to the Coorong in winter are essential for allowing pouched lamprey to complete their life cycle. Peak migration for pouched lamprey is understood to occur in August, however monitoring of lamprey in winter-spring of 2019 and 2020 demonstrated that the migration season for lampreys extends into late spring with peak migrations of short headed lamprey in September and October (Bice et al. 2020). During periods of limited water availability, releases through Goolwa and Mundoo barrages may elicit greater outcomes in relation to lamprey migrations compared to Tauwitchere, given the proximity of these barrages to the Murray Mouth and fresher environment downstream of these barrages (Bice et al. 2020).
- In late summer and autumn, at a time when most of the flow in the river is used for consumptive purposes, limited flows reach the end of system. Providing environmental water targeting the 'end of system' during this period is highly important, however at times, system constraints have made this difficult to achieve. Environmental flow at this time of year has been critical in maintaining Lower Lakes water levels above 0.5 m AHD while still providing some connectivity to the Coorong through fishway flows. A sharp drop in lake levels over summer and autumn 2020 may have limited recruitment and health of small bodied fish in the Lower Lakes, which had spawned strongly during the 2019 spring pulse (Wedderburn pers. comm. 2020).

Additional key findings from fish, aquatic habitat and flow monitoring in the River Murray valley are summarised in Table RM5.

Table RM5 Key lessons learned in the River Murray valley

Theme	Lessons learned
Native fish	• Maintaining connectivity between the River Murray and its anabranch systems during hypoxic blackwater events is crucial—prior to, during and after—to allow fish to disperse and seek refuge and then return to the anabranch after the event has passed (Watts et al. 2019). • Small flows rates, at the right time of year can make a difference for Murray cod. Delivery constraints prevented planned flows to support large bodied native fish in Gunbower Creek in 2018. Monitoring revealed that a reduced flow rate of 200 ML/day still provided adequate habitat and connectivity for Murray cod (NCCMA, 2020).

Theme	Lessons learned
	• Delivering water for the environment at the right flow rates and time of year has successfully stimulated spawning of native fish in several river systems. In the Mid-Murray, excellent recruitment has been observed across several native species over multiple years (Raymond et al. 2018). • Very slow flow habitats, or river reaches with less permanently flowing water show limited evidence of recruitment for large-bodied native fish (Watts et al. 2019, Ye et al. 2020). • Recovery of native fish populations following drought and other fish kill events is slow. It is important to seek opportunities to support re-colonisation and immigration of native fish into areas which have seen declines. Key nursery areas in the mid-Murray should be considered for reconnection (with the Darling, Murray and Goulburn) to support immigration and dispersal of species such as silver and golden perch (Watts et. al. 2018, Watts et al. 2019).
Native vegetation	• Several consecutive years of inundation area beneficial for floodplain and wetland vegetation communities: – In Barmah Forest, low-level overbank spring flows resulted in exceptionally good Moira grass growth and flowering since 2018, particularly within grazing exclusion zones (GB CMA 2021). – Improved cover and diversity of wetland vegetation in Gunbower Forest, indicates that environmental water has enabled wetland plants to germinate, flower and set seed (NCCMA 2020). – River red gums that have received water following the 2016–17 flood have healthier canopies than river red gums in areas that remained dry (Mallee CMA 2020, North Central CMA 2020). • Vegetation located at higher elevation floodplain and wetlands, or vegetation that has not been able to have follow-up water delivered, are more stressed and continue to decline in condition. • Providing a slow rate of recession to flows enables native water plants to avoid being stranded and drying out prior to completing their life-cycle (Watts et al. 2015).
Waterbirds	• During dry and moderate years water for the environment can assist in maintaining foraging and breeding habitat and supporting small-scale bird breeding events. While unlikely to contribute to population growth, these localised breeding events provide a regular input of new recruits into the population and are important in maintaining genetic diversity (McGuinness et al. 2019).
Water quality	• At small scales, targeted deliveries of environmental water may be used to maintain viable oxygen levels for aquatic organisms during hypoxic blackwater conditions in localised areas (Ye et al. 2018, Watts et al. 2019).
Connectivity and water delivery	• Monitoring results show that environmental watering which returns flows from major floodplain forests (e.g., Barmah-Millewa Forest) results in significant mobilisation and transport of carbon and nutrients into river systems (Watts et al. 2016, CEWO 2020a, Furst et. al. 2020, Rees et al. 2021). This is a fundamental ecological process that is crucial for supporting and maintaining aquatic food-webs and reducing floodplain carbon loads, which reduce the risk of hypoxic black water events. • Early season delivery of environmental water assists in avoiding delivery constraints that arise during the irrigation season (spring-summer). • Two successful trial delivery flows of 800 ML/day (the existing limit is 600 ML/day) in the Yallakool Creek-Wakool River system during spring have highlighted: – the importance of a long lead in time to planning with local land holders, agencies, community members and monitoring providers

Theme	Lessons learned
	– the need to have alternative delivery arrangements (i.e., Murray Irrigation network) to deliver target flows if WaterNSW infrastructure is unable to meet those flow rates – the flow inundated one low level bridge near Bookit Island (mid Wakool River) and another on Black Dog Creek, but did not limit landholders' access to their properties – the flow trial increased lateral connectivity within the river system. • Fishways at the barrages (rock ramp and trapezoidal) continued to operate when Lower Lake levels fell below 0.6 m AHD, when previously thought to become non-functional. This provides future option of managing water levels below 0.6 m while continuing releases through the fishways.

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