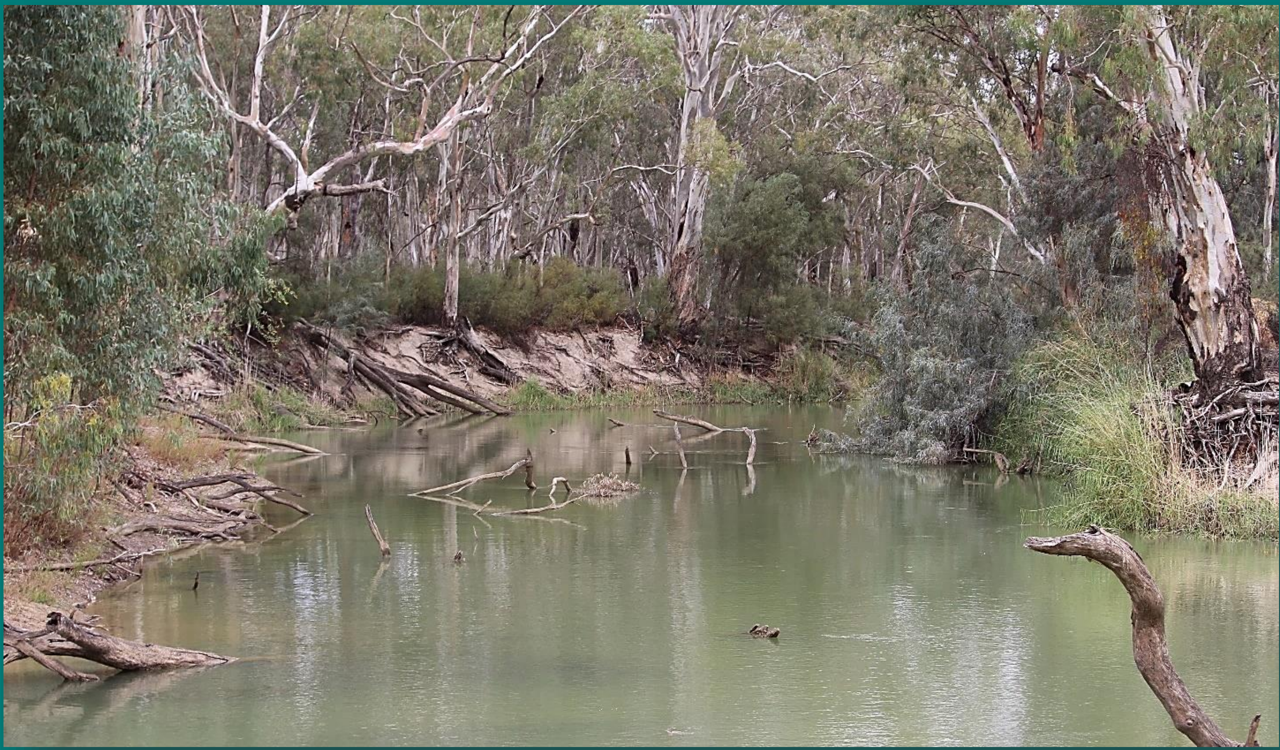

Lindsay–Mulcra–Wallpolla Islands

Environmental Water Management Plan

Mallee Catchment Management Authority
Looking after our environment together
www.malleecma.com.au

For further information contact:

Mallee Catchment Management Authority
Corner Eleventh Avenue and Koorlong Ave,
Irymple, Victoria.
Phone: 03 5051 4377
Email: reception@malleecma.com.au

Cover Image: Mullaroo Creek (Lindsay Island) (Source: MCMA).

Version Control

Version/Review type	Review date	Reviewer

Acknowledgement of Country

Mallee Catchment Management Authority (CMA) acknowledges and respects Traditional Owners, Aboriginal communities and organisations. We recognise the diversity of their cultures and the deep connections they have with Victoria's lands and waters.

We value partnerships with them for the health of people and country.

Mallee CMA Board, management and staff pay their respects to Elders past, present and emerging, and recognise the primacy of Traditional Owners' obligations, rights and responsibilities to use and care for their traditional lands and waters.

Funding Acknowledgement

Development of this document was funded through The Living Murray Initiative. The Living Murray is a joint initiative funded by the New South Wales, Victorian, South Australian, and Commonwealth governments, coordinated by the Murray-Darling Basin Authority.

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About this plan

The Lindsay-Mulcra-Wallpolla (LMW) Islands Environmental Water Management Plan (EWMP) establishes priorities for the use of water within the icon site. It identifies ecological objectives which are consistent with the Basin Plan Environmental Watering Plan Framework (Chapter 8), and associated targets, water delivery options and regimes for the site.

This revision builds on previous iterations of the Lindsay-Wallpolla Environmental Water Management Plan, most recently the 2012 document (MDBA 2012). The most significant change since the last iteration has been the completion of The Living Murray (TLM) water infrastructure at this site and, in 2012, the Murray-Darling Basin Plan (Basin Plan) coming into effect.

This EWMP has been revised to reflect learnings from over 10 years of water delivery to the site and improve the alignment of TLM icon site ecological objectives with the Basin Plan's Environmental Watering Plan Framework.

The previous EWMP for Lindsay-Wallpolla Islands (MDBA 2012) has been used as the guiding document during the initial stages of water delivery using TLM infrastructure at the Lindsay-Mulcra-Wallpolla Icon Site. Monitoring during delivery of water to the icon site since 2013 has improved our understanding of the operational and ecological considerations of delivering water to the Lindsay-Mulcra-Wallpolla Icon Site through the TLM infrastructure. This document incorporates findings from past monitoring, targeted research of icon site key species and communities, and outcomes from previous environmental watering.

More detailed information than is included in this EWMP is captured in three main supporting documents, which are considered schedules to this EWMP:

- **Lindsay-Mulcra-Wallpolla Icon Site Operating Plan** – provides the framework for the operation of existing environmental structures to meet key ecological objectives within the broader context of legislative requirements and governance.
- **Lindsay-Mulcra-Wallpolla Watering Guide** – contains key ecological and hydrological information to inform environmental water management.
- **Lindsay-Mulcra-Wallpolla Icon Site Condition Monitoring Plan –** describes how to undertake annual condition monitoring (i.e. the method).

The revision of this EWMP has been coordinated by the Mallee Catchment Management Authority in consultation with the Department of Environment, Land, Water and Planning (DELWP) and the Murray-Darling Basin Authority (MDBA) to ensure a consistent approach to planning and management across the icon sites. We also endeavour to align environmental water management in the Mallee (where appropriate) with developing 'holistic' environmental water planning at the landscape scale (i.e. in the River Murray and its tributaries and the Darling-Baaka River).

Although this EWMP deals specifically with the Victorian component of the Chowilla-Lindsay-Wallpolla Icon Site (Lindsay-Mulcra-Wallpolla Islands), there will be opportunities to maximise environmental outcomes locally and more broadly through collaborative planning with environmental water planners and river operators in NSW, SA and federally (i.e. the MDBA and Commonwealth Environmental Water Office).

Executive summary

The Lindsay-Mulcra-Wallpolla (LMW) Islands Environmental Water Management Plan (EWMP) establishes priorities for the use of water for the environment within Lindsay-Mulcra-Wallpolla Islands water management region as part of The Living Murray (TLM) icon site.

The Living Murray initiative is one of Australia's most significant river restoration programs aimed at improving the health of the River Murray system. The program is delivered by governments and is coordinated by the Murray-Darling Basin Authority (MDBA). The Chowilla-Lindsay-Wallpolla Icon Site is one of six icon sites under TLM recognised for their ecological, cultural, recreational, heritage and economic significance. The Lindsay-Mulcra-Wallpolla Islands form the Victorian part of the Chowilla-Lindsay-Wallpolla Icon Site under TLM initiative.

Lindsay-Mulcra-Wallpolla Islands form a major floodplain and anabranch system in northwest Victoria, spanning from Lock 10 to the South Australian border. The border of the LMW Islands is defined by the Lindsay River, Potterwalkagee and Wallpolla creeks, respectively, and the River Murray to the north. They cover approximately 26,000 ha within the Murray-Sunset National Park and are managed by Parks Victoria.

The LMW floodplain is an area of high ecological significance characterised by a network of anabranches, small creeks and permanent and ephemeral wetlands. Lindsay Island, Wallpolla Island and Lake Wallawalla are listed as nationally important wetlands. The region is relatively flat, with much of the floodplain situated at higher elevations, and requires larger floods for inundation). The region supports a large variety of flora and fauna species, many which rely on regular flooding to support productivity, and terrestrial and aquatic food. This includes threatened mammals, fish, reptiles, birds and plant species, listed as having conservation significance at both state and national level. During dry periods, strategic delivery of environmental water is critical in providing refuge for these species.

For thousands of years, the rivers and floodplains of LMW Islands have supported First Nations communities, who continue to maintain a strong connection to Country.

The LMW region also provides important socio-economic value by supporting tourism and recreational activities such as camping, boating, birdwatching and fishing.

Since the construction of locks and weirs in the River Murray (in the mid 1900's), the hydrology (seasonal flow regime) and hydraulics (dynamics of flow at a finer scale) of the River Murray and surrounding floodplain waterways and wetlands has been significantly altered. These alterations, together with changing climatic conditions, have led to reductions in the frequency, extent and duration of flooding, and subsequently resulted in a decline in the health of the river and floodplain. At LMW, there is currently a range of water management infrastructures that assist with the delivery of water for the environment to creeks, wetlands and floodplain features. Watering actions are prioritised annually for different water availability scenarios and priority environmental outcomes. Currently, the most feasible options for delivering water for the environment to many wetlands and creek lines is via temporary pumping. Additional on-ground infrastructure works and measures planned at Lindsay and Wallpolla Islands under the Basin Plan Sustainable Diversion Limit Adjustment Mechanism, and scheduled for completion in 2024, will allow managed inundation of larger areas (an additional 5,152 ha) of the floodplain than has previously been possible at these locations. Efforts to relax delivery and supply constraints in the wider southern Murray-Darling Basin (MDB) by the Commonwealth and Basin states may provide future opportunities for watering of these areas to be accomplished in synchrony with larger River Murray flow events (supported by environmental water), intending to mimic more natural hydrology and inundation.

Ecological objectives for LMW were first established in 2003 as part of The Living Murray First Step Decision. Since then, ongoing refinement of the vision and objectives has occurred, with the most recent vision for LMW, to:

> *'Improve biodiversity values of Lindsay, Mulcra and Wallpolla Islands, with environmental conditions in anabranches and floodplains to be representative of those which would be expected under natural flow conditions.'*

Ongoing refinement of site-specific ecological objectives intends to improve alignment of the objectives with the Basin Plan, and associated planning documents such as the Victorian Long-term Watering Plan. These refinements include defining a set of SMART (Specific, Measurable, Achievable, Realistic and Timely) targets under each objective. A set of nine objectives have been defined for LMW.

Objectives for the Lindsay-Mulcra-Wallpolla Icon Site	
LMW1 Diversity of ecosystem type	By 2030, maintain diversity of freshwater ecosystem types at the Lindsay-Mulcra-Wallpolla Icon Site, including palustrine, riverine and floodplain ecosystems with temporary and permanent water regimes.
LMW2 Species richness and abundance of aquatic vegetation	Improve the species richness and abundance of native wetland and floodplain aquatic vegetation functional groups by 2030.
LMW3 Condition and extent of floodplain vegetation	Improve condition and maintain extent (ha) from baseline (2006) levels of river red gum (*Eucalyptus camaldulensis*), black box (*E. largiflorens*) and lignum (*Duma florulenta*) to sustain communities and processes typical of such communities at the Lindsay-Mulcra-Wallpolla Icon Site by 2030.
LMW4 Limit *Typha*	By 2030, limit the spread of *Typha* and other invasive species.
LMW5 Support threatened species	Improve or maintain the populations of threatened flora and fauna that are flow dependent at the Lindsay-Mulcra-Wallpolla Icon Site by 2030.
LMW6 Create vital habitat – feeding habitat for waterbirds	By 2030, protect and restore vital feeding habitats that support sustainable communities of colonial nesting waterbirds, waterfowl, waders and piscivores to maintain the current species diversity at the Lindsay-Mulcra-Wallpolla Icon Site.
LMW7 Lateral connectivity to support off-stream productivity	By 2030, improve ecosystem functions of water-dependent ecosystems by maintaining or improving productivity linkages between the river and floodplain habitats (on and off) at the Lindsay-Mulcra-Wallpolla Icon Site by achieving variable extents of lateral connectivity.
LMW8 Waterbird breeding	By 2030, protect and restore breeding habitat for colonial nesting waterbirds at Lake Wallawalla and non-colonial waterbird breeding at Mulcra Horseshoe and Wallpolla Horseshoe.
LMW9 Native fish recruitment	By 2030, improve native fish populations (large- and small-bodied fish) across the Lindsay-Mulcra-Wallpolla Icon Site and their relative abundance and diversity; assessment to include comparison with 2006-2012 levels for short-lived species and the spread of age-classes for long-lived fish.

To assess progress toward objectives set out for LMW, an extensive monitoring program has been in place for more than 15 years. Three main types of monitoring have been undertaken: Basin-Scale monitoring, condition monitoring and intervention monitoring. Basin-Scale monitoring, such as the Murray-Darling Basin aerial waterbird survey, informs changes at the basin scale, while condition and intervention monitoring are specifically site-based. Annual icon site condition monitoring has been undertaken at LMW since 2005 using standard methodologies investigating vegetation, fish and waterbirds. Results from this monitoring assess long-term shifts in populations and communities, and are used to determine the 'health' of the icon site and assess progress against site ecological objectives. Intervention monitoring assesses the ecological response to water delivery or other interventions, and also includes monitoring of potential risks.

Management of potential risks associated with on-ground operations at the icon site is an important consideration of any management plan. These risks come in various forms, and include environmental, community, management and legal risks. Only environmental risks associated with water delivery are presented here. Other risk-types are identified within the LMW Operational Plan; however, risk identification and assessment are continually undertaken throughout the program life-cycle. This includes formal workshops such as the Victorian Environmental Water Holder annual watering risk workshop, and during the development of watering proposals and monitoring activities being proposed under the TLM program. Many of these risks can be appropriately managed though monitoring, consultation and adaptive management to reduce the actual or perceived risk.

This plan supersedes the Lindsay-Wallpolla Environmental Management Plan 2012, and following the Basin Plan coming into effect in 2012, reflects aligning of TLM site ecological objectives with the Basin-Wide Environmental Watering Strategy (MDBA 2019a). Development and integration of Sustainable Diversion Limit projects into the EWMP will be ongoing and align with reviews to high level planning documents such as the Basin-Wide Environmental Watering Strategy.

Darling lily (**Crinum flaccidum*****), Mulcra Island (Source: MCMA).***

1. The Living Murray

The Living Murray (TLM) initiative is one of Australia's most significant river restoration programs. It was established in 2002 via a partnership between the Commonwealth, New South Wales, Victorian and South Australian governments, and is coordinated by the Murray-Darling Basin Authority (MDBA). The initiative's long-term goal is to achieve a healthy working River Murray system for the benefit of all Australians, and in doing so contribute to the delivery of the Basin Plan objectives and outcomes.

The Living Murray aims to improve the environmental health of six icon sites (Figure 1.1) chosen for their significant ecological, cultural, recreational, heritage and economic values. The six icon sites are:

- Barmah-Millewa Forest
- Gunbower-Koondrook-Perricoota Forest
- Hattah Lakes
- Chowilla Floodplain and Lindsay-Wallpolla Islands (including Mulcra Island)
- Lower Lakes, Coorong and Murray mouth
- River Murray channel

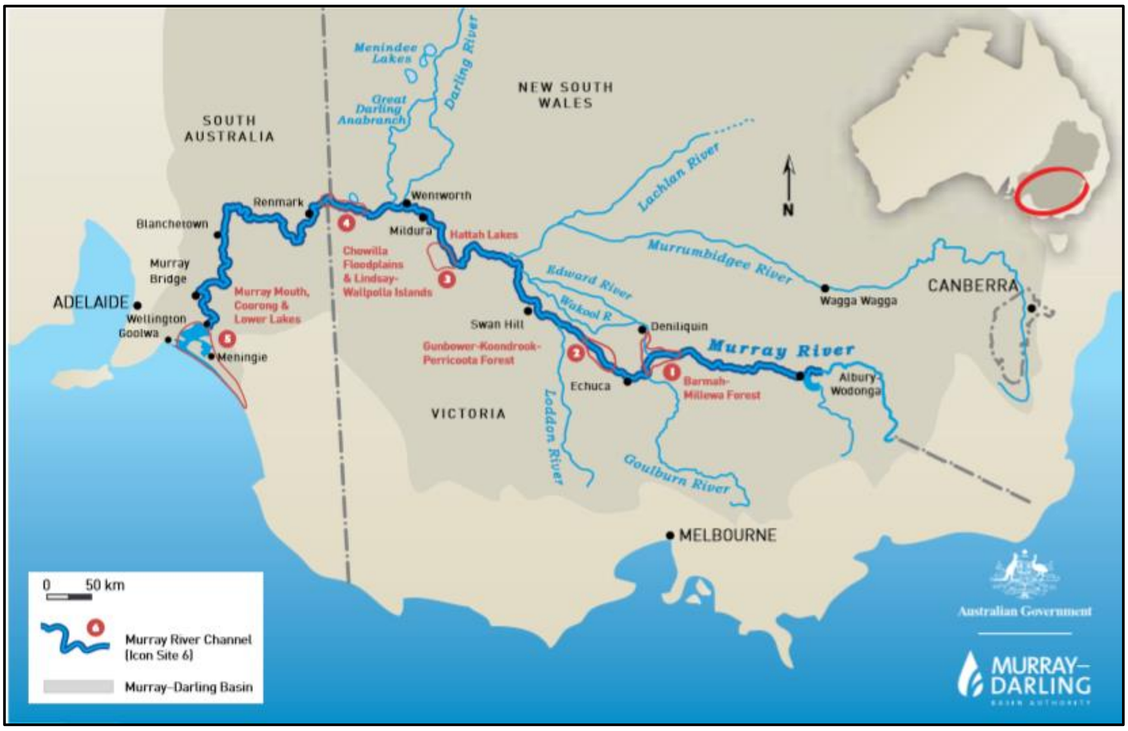


Figure 1.1. Location of The Living Murray icon sites.

The Living Murray has recovered around 489 gigalitres[1] of water for the environment and completed the largest environmental works program of its kind in Australia in 2015. These environmental works or water management structures enable water for the environment to be delivered more efficiently and effectively. The success of environmental watering is measured against icon site ecological objectives, and is monitored using fish, birds and vegetation as an overall indicator of the icon site's health.

[1] This volume is a long-term average, and the volume available in any given year depends on available allocations.

Governance and planning arrangements

The Living Murray is a joint initiative established under the following instruments and managed collaboratively by the partner governments:

- Intergovernmental Agreement (2004) on addressing water overallocation and achieving environmental objectives in the Murray-Darling Basin (IGA 2004)
- Supplementary Intergovernmental Agreement (2006) on addressing water overallocation and achieving environmental objectives in the Murray-Darling Basin (IGA 2006)
- The Living Murray Business Plan 2007 (Business Plan)
- Further agreement (2009) on addressing water over-allocation and achieving environmental objectives in the Murray-Darling Basin (IGA 2009)

Since the Basin Plan came into effect in 2012, TLM has evolved to align with the Plan. This alignment has included the establishment of the Southern Connected Basin Environmental Watering Committee (SCBEWC) by the Murray-Darling Basin Ministerial Council. SCBEWC is made up of Basin state and Australian Government environmental water holders, water managers and river operators, who coordinate the delivery of environmental water in the Southern Connected Murray-Darling Basin (MDB) consistent with the Basin Plan Environmental Watering Plan (Chapter 8 of the Basin Plan) and its objectives. In addition to the coordination function, SCBEWC also makes decisions on the use of jointly held environmental water portfolios – The Living Murray portfolio, River Murray Unregulated Flows and River Murray Increased Flows, and The Living Murray's monitoring and Indigenous Partnership programs (see Figure 1.2).

Figure 1.2. The Living Murray governance framework,

While MDBA plays a key coordination role for SCBEWC and at TLM program level, management and delivery of TLM activities at the icon sites are primarily undertaken by relevant agencies in the jurisdictions where the icon sites are located.

In Victoria, the Department of Environment, Land, Water and Planning (DELWP) oversees and coordinates the delivery of the TLM program, with Catchment Management Authorities (CMAs) acting as icon site managers.

The icon site manager for Lindsay-Mulcra-Wallpolla (LMW) Islands is the Chief Executive Officer of the Mallee Catchment Management Authority (MCMA). The MCMA coordinates delivery of the TLM program at icon site level, working in partnership with Parks Victoria (the land manager) and supported by icon site-specific committees. These committees are composed of representatives from relevant agencies and communities.

Planning context and legislation framework

The Australian Government, Victoria, New South Wales and South Australia have comprehensive legislative frameworks addressing natural resource and environmental management. For activities associated with management of TLM icon sites, including operation of works under TLM, the principal pieces of national and state legislation and planning strategies associated with LMW are listed in Table 1.1.

Table 1.1. List of legislation, agreements or conventions that may be associated with management of the LMW Icon Site.

Jurisdiction	Legislation, agreement, convention or strategy
National	Water Act 2007
	Basin Plan 2012
	Environment Protection and Biodiversity Conservation (EPBC) Act 1999
	Native Title Act 1993
	Murray-Darling Basin agreement
	China-Australia Migratory Bird Agreement (CAMBA)
	Japan-Australia Migratory Bird Agreement (JAMBA)
	Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA)
State	Aboriginal Heritage Act 2006
	Environmental Effects Act 1978
	Flora and Fauna Guarantee Act 1988
	Forests Act 1958
	Planning and Environment Act 1987
	Parks Victoria Act 2018
	Water Act 1989 and Water Amendment (Governance and other reforms) Act 2012
	Victorian Waterway Management Strategy
	NSW Fisheries Management Act 1994
	NSW Water Management Act 2000
	Water Act 2012

The Basin Plan

The management of water for the environment outcomes in the MDB is undertaken by a range of agencies under a framework that fosters coordination between local agencies, states and the Commonwealth, both in planning and real-time water delivery (MDBA, 2019a). The key elements of the Basin Plan Environmental Watering Plan framework are outlined in Figure 1.3.

The Basin-Wide Environmental Watering Strategy (MDBA 2019) outlines the expected environmental outcomes at a Basin scale. It supports water holders, managers and river operators in planning and managing environmental watering to achieve the environmental objectives of the Basin Plan, and is complemented by regional long-term water plans for each water resource area.

Asset-scale plans, such as this icon site Environmental Water Management Plan, inform Basin-state regional long-term watering plans and Water Resource Plans. In northern Victoria, the Lindsay-Mulcra-Wallpolla Islands Plan is a key reference for the Victorian Murray Long-Term Watering Plan.

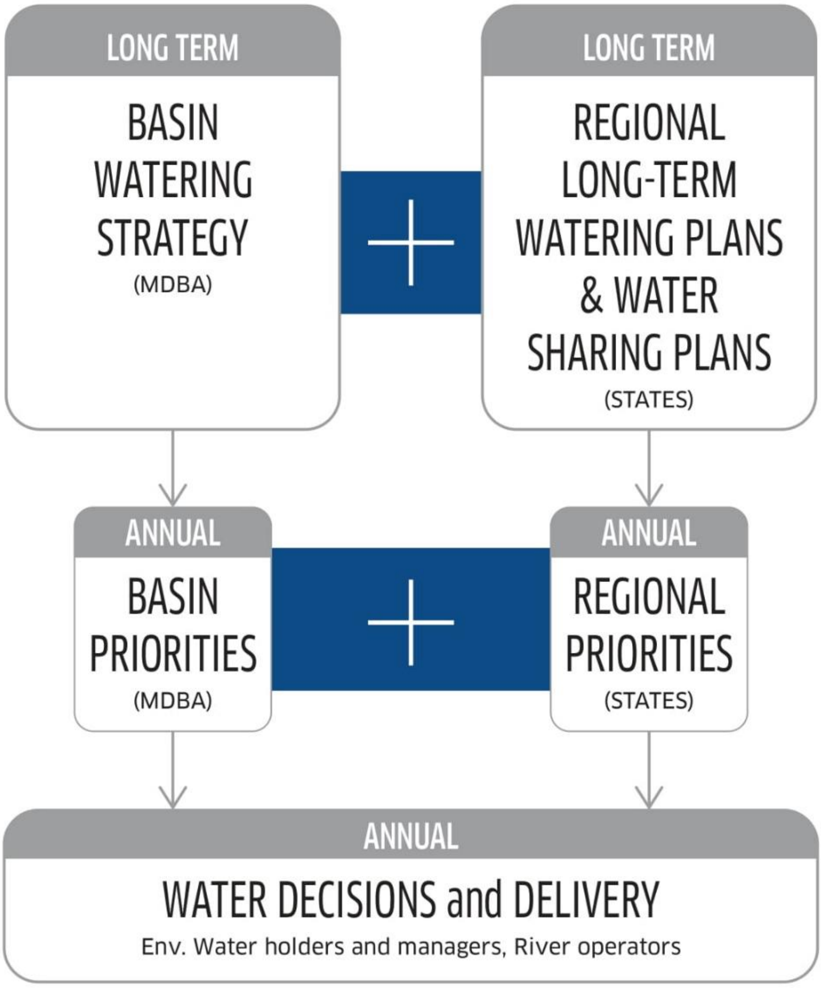


Figure 1.3. Key elements of the framework for environmental water in the Murray-Darling Basin (MDBA 2019).

The Basin annual environmental watering priorities are prepared in accordance with the requirements of the Environmental Watering Plan (Chapter 8 of the Basin Plan), First Nations' priorities and jurisdictional (state) priorities to help guide where to focus environmental watering from a whole-of-Basin perspective. In Victoria, Catchment Management Authorities prepare and submit annual seasonal watering proposals to the Victorian Environmental Water Holder (VEWH) to enable priorities to be developed at a state- and Basin-wide scale. Victoria has legal obligations to work with traditional owners in water planning. The VEWH develops a state-wide seasonal watering plan that guides environmental watering decisions in Victoria. It provides program partners, stakeholders and communities with a sense of what to expect during the financial year.

2. Consultation

Community support for activities delivered under TLM at the LMW Icon Site depends on effective engagement with a range of stakeholders. This ensures that the community is informed of the context, history, proposed processes, constraints and opportunities for environmental water management at the LMW Icon Site, and in turn, better enables environmental water managers to consider wider community values and knowledge in decision-making.

Ongoing communications and community engagement activities under TLM are being undertaken at LMW. This is particularly important for gaining support around environmental water planning and delivery. It also assists with education around water use, environmental condition and land management. Community perspectives can change over time and in response to environmental or climatic conditions, and water availability. Having an informed and educated community, along with strong relationships, is important when gaining support to undertake ongoing management actions using water.

Forms of communication cover a range of methods, which usually depend on the level of engagement required with the community and stakeholders. Information, such as interest and educational pieces, can take the form of social media posts, radio interviews, and media releases. Where a level of interaction and consultation is important (i.e. two-way exchange of information), more personal involvement is required, such as attendance at meetings, one-on-one interactions and targeted workshops. An important consideration during high levels of engagement is getting out on-site, or on Country, for First Nations communities.

First Nations engagement

First Nations people have many social, cultural, customary and economic interests in the water resources of the River Murray. Indigenous values and objectives relating to water are critically important and must be openly discussed with the community. First Nations engagement is an important part of water management planning, and the incorporation of values and objectives into planning documents provides additional benefit to proposed watering plans.

The First People of the Millewa-Mallee Aboriginal Corporation (FPMMAC; established 2019) are Latji Latji and Ngintait (Nintay) Traditional Custodians of Country, which incorporates the LMW region. Engagement with FPMMAC, as the recognised Registered Aboriginal Party (RAP), is an important aspect of managing cultural heritage, as well as environmental water planning across the LMW Islands. The FPMMAC have a close connection with this Country and take a proactive approach to assisting with the management of their land. Local water managers and the First Nations community are working to strengthen relationships and engagement on management of the LMW Icon Site.

While Indigenous values and recommendations are already informing current annual seasonal watering proposals, the development of specific Indigenous watering objectives for LMW is in the early stages. Ongoing collaboration and engagement will result in development of these objectives, through the values identified as a result of on-ground activities such as Talk Water on Country events, field walks and one-on-one discussions, informing this process. Moving forward, Indigenous objectives will be an important part of long-term water planning for the site. As this information is developed, it will be added to future updates of the EWMP.

The Indigenous Partnerships Program (IPP) under TLM aims to support First Nations' contribution to the planning and management of environmental watering activities at sites of cultural, ecological and community significance along the River Murray. The program employs an Indigenous facilitator at most of the icon sites including LMW. This facilitator ensures a strong connection between the local Indigenous group and the management of the icon site though active engagement, consultation and knowledge sharing. The program also connects people and Country through activities such as community tours, learning days and cultural mapping exercises.

3. Site overview

Site location and catchment setting

The Chowilla-Lindsay-Wallpolla Icon Site is a cross-border icon site, having components in South Australia, New South Wales and Victoria. The icon site covers 43,856 ha and has four main components – the Chowilla Floodplain (17,700 ha), which spans South Australia and New South Wales, and Lindsay, Mulcra and Wallpolla islands in northwest Victoria, which collectively cover 26,156 ha downstream of Lock 10 to the South Australian border (Figure 3.1).

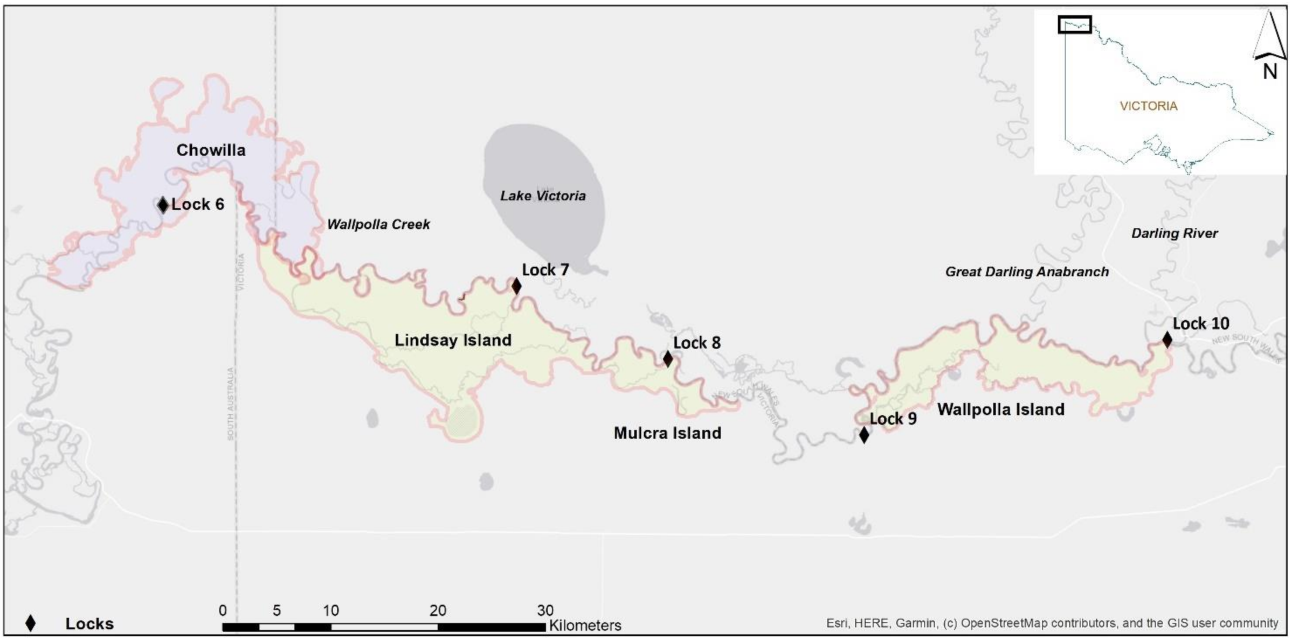


Figure 3.1. The River Murray and location of key landscape features, including the Lindsay-Mulcra-Wallpolla islands of the Chowilla-Lindsay-Wallpolla Icon Site and locks between Mildura and Renmark.

The Chowilla Floodplain and LMW Islands have specific physical differences and water delivery constraints that affect their management and the development of options for environmental watering. The sites span different states and are managed by different agencies. While having similar values and hydrology, their geographical location means that different water management infrastructures (e.g. River Murray weirs, regulators) influence the hydrology of each location. Communication and coordination between the three regions result in a sharing of technical knowledge and collaboration on monitoring and consultation activities, as well as coordinating broader landscape outcomes associated with operation of the adjacent River Murray.

The Lower Murray, downstream of the Darling River to the Murray mouth is highly developed. In the LMW region, five weirs exist over approximately 200 river kilometres (including one immediately above and below the icon site extents). In addition, a large off-channel storage, Lake Victoria, is situated adjacent to LMW in NSW. As such, ecologically significant hydrological and hydraulic changes within the Lower Murray and the LMW region have occurred. This has resulted in the near elimination of flowing water habitats in the main River Murray stem, a reduction in passing flow and permanent inundation and flow stabilisation of the river channel, wetlands, and low-lying floodplain areas adjacent to the weir pools (Walker and Thoms 1993).

Land status and management

The LMW Islands lie within the Murray-Sunset National Park and are managed by Parks Victoria. Lindsay Island was included as part of the Murray-Sunset National Park when the Park was declared in 1991, with the Mulcra Island and Wallpolla Island state forests added in 2010. Ned's Corner Station borders the southern extents of Mulcra and some of Lindsay islands. This property was formerly a sheep and cattle station, but was purchased by Trust for Nature in 2002 and is now managed for conservation. Private landholders border the southern extent of Wallpolla Island.

Climate

Historically, the climate of the Murray-Darling Basin has been variable. Climate change science indicates a likely increase in this variability, resulting in more frequent and extreme floods and droughts (MDBA 2019b).

LMW Islands are located within the semi-arid Mallee region of Victoria. The climate is the hottest and driest in Victoria, with an average annual rainfall of 270 mm (in Mildura). Average maximum temperatures are approximately 32 °C in Summer and 16 °C in Winter, with high evaporation rates throughout the year. As such, the River Murray represents an important source of water for the floodplain ecosystem.

Between 1996 and 2010, the MDB experienced drought conditions (the Millennium Drought) characterised by below-average rainfall in Autumn and Winter and few wet periods. This drought was significantly drier than the Federation Drought (mid-1890s to early 1900s) and the droughts of the World War II era (1937-1945). Beginning in Spring 2010, and continuing through the Summer of 2010-11, widespread, above average rainfall across the MDB broke the long-standing drought. Subsequent high rainfall during Spring 2016 again resulted in widespread flooding. Since then, well-below average rainfall to 2019 (worse than experienced during the Millennium Drought) resulted in a rapid shift toward drier conditions.

Under a future climate change scenario, it is expected that the region will experience warming (average 1 ºC by 2030) (DELWP 2015b). This will also result in an increase in the number of hot (> 35 ºC) days per year. Rainfall is also set to decline, with lower rainfall to be experienced through Autumn and Spring. This trend is also apparent across the broader Murray-Darling Basin, and will result in lower run-off and thus lower river flows (MDBA 2019b).

Site characteristics

Wallpolla Island is the east-most island and is bounded by Wallpolla Creek and the Lock 9 weir pool of the River Murray, covering 9,000 ha (Figure 3.2). The western end of the island is traversed by three permanently inundated anabranches, the main source of in-flow being via Dedman's Creek, connecting the River Murray and Wallpolla Creek. Further connections exist through Moorna and Milky creeks to the west. Backwater inundation from Weir 9 extends up this series of anabranches past the Wallpolla Creek-Dedman's Creek confluence. Anabranches in the east of the island require high flow in the River Murray to allow natural inundation and connection with the Weir 9 backwater in Wallpolla Creek.

Mulcra Island covers 2,000 ha between Lindsay and Wallpolla islands, and is formed by Potterwalkagee Creek and the River Murray weir pools of Lock 7 and 8 (Figure 3.3). Flows into Potterwalkagee Creek are managed via two existing regulators. At full supply level (FSL) in the Lock 8 weir pool, water enters Potterwalkagee Creek via Stoney Crossing, flowing down the lower proportion of the creek back to the Lock 7 weir pool. This connection ceases when water level upstream of Lock 8 is lowered by more than 40 cm. Increased flow, or weir pool water levels above FSL are required for water to enter upper Potterwalkagee Creek.

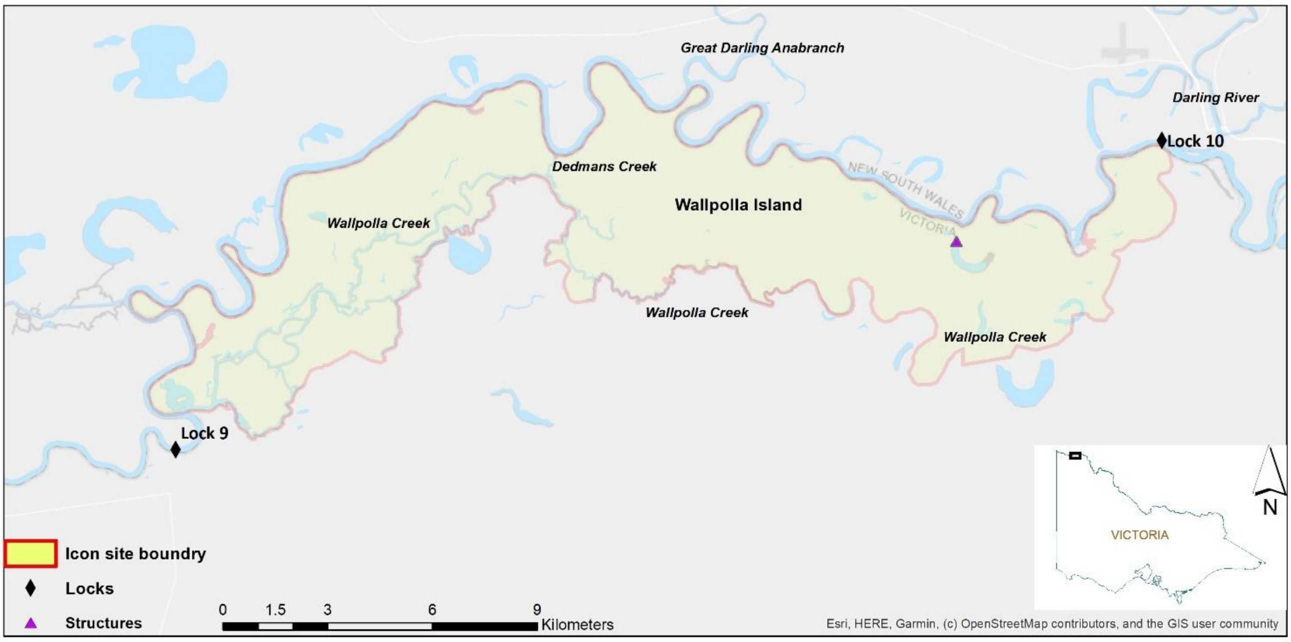


Figure 3.2. Wallpolla Island with key features identified.

Lindsay Island covers 15,000 ha and is bounded by the Lindsay River anabranch and lock's 6 and 7 weir pools (Figure 3.3). Due to the influence of ponding by Lock 7 (elevated head) the Mullaroo Creek (which flows from the River Murray to Lindsay River) exhibits permanent flow, as does the Lower Lindsay River (downstream of the Mullaroo Creek confluence) and Toupnein Creek (a River Murray anabranch). Backwater inundation from Lock 6 extends up the Lindsay River, well past the Mullaroo Creek confluence. For the Upper Lindsay River, elevated River Murray flow (or raised weir pool height at Lock 7) is required for connection between the River Murray and Lower Lindsay River. A, small, permanent connection between the River Murray and Upper Mullaroo Creek approximately 1 km upstream of the main Mullaroo Creek mouth, exists at FSL in Lock 7 weir pool.

Figure 3.3. Lindsay and Mulcra islands with key features identified.

Interactions with other sites

While LMW, and Victorian land management are the primary focus of this Plan, it is acknowledged that the LMW floodplain is inherently and ecologically linked with South Australia and New South Wales (Figure 3.1). The Chowilla Floodplain part of the icon site is located to the west of Lindsay Island and extends across New South Wales and South Australia. The waters of the River Murray are designated as New South Wales while the land south of the southern bank of the River Murray lies within Victoria. Operation of some LMW infrastructure works in conjunction with raising of the adjacent Murray weir pool.

Over the past few years, there has been a concerted effort by the states to develop a landscape-scale management approach for the lock's 6-9 reach of the River Murray and its adjoining floodplain. This recognises that the assets, which have until recently been managed as individual entities, would significantly benefit from a holistic management approach. The approach has previously been coordinated via a SCBEWC weir-pool manipulation sub-group, and more recently by the Weir Pool Manipulation Project Steering Committee (WPM PSC), which includes relevant management authorities and government organisations for the region. One of the key driving factors in the development of the WPM PSC was to identify and reconcile environmental and operational conflicts between water management objectives for the lock's 6-9 reach. The WPM PSC have taken key steps toward a coordinated management approach, which have included the development of a Watering Plan (Ecological Associates 2019), and the ongoing development of a Monitoring Plan (Wallace et al. 2021). Further work is needed to manage this reach at a landscape scale, particularly as proposed works under the Sustainable Diversion Limit Adjustment mechanism become operational (see page 49 for further information on the works). This may require reactivation of the SCBEWC weir-pool manipulation sub-group to help coordinate management and trade-offs across this region.

The River Murray channel weirs represent a key water management tool in the region. Raising and lowering of River Murray weir pools (weir pool manipulation, or WPM) has been trialled in recent years to enhance hydraulic conditions and reinstate water level variability within the main stem of the river. Weir pool manipulation creates multiple in- and off-channel benefits (Hanish et al. 2017, Wallace et al. 2021) and can be used to manage hydrology in off-channel creeks, anabranches and wetlands.

Weir pool raising results in connection of some off-channel habitat, and is used across the landscape to assist in the delivery of water to ephemeral creeks and inundate floodplains (in conjunction with other floodplain regulating structures; e.g. Mulcra Island). Raising aims to improve soil water availability, refresh low-salinity lenses, support organic carbon cycling, support water delivery to off-channel habitats, and improve lateral connectivity between off-channel habitats and the main river channel.

Weir pool lowering aims to expose and consolidate bank sediments, provide productivity benefits, promote growth of riparian vegetation, increase in-channel hydraulic diversity (e.g. flow velocity), and disconnect off-channel habitat. Disconnecting off-channel habitat creates a managed drawdown or dry phase for some creeks and anabranches which would otherwise receive water at FSL.

To meet ecological requirements and objectives at LMW, weir pool raising is a key action which facilitates delivery of environmental water to important, anabranches, creeks, wetland and floodplain assets. These actions occur predominantly during Spring, in line with natural cues and seasonal cycles.

Careful consideration is required during planning to identify ecological and operational trade-offs between weir pool raising and lowering and associated benefits and risks. It is also imperative to balance objectives and targets for LMW identified in the EWMP with ecological requirements of the River Murray channel, and New South Wales and South Australian off-channel assets, to achieve a holistic management approach.

Joint annual planning for weir pool manipulation is undertaken between NSW and Victorian government departments. Through this partnership, a joint water proposal for the region is developed and presented to SCBEWC, which guides weir pool manipulation operations. In addition, trade-offs are managed though the

WPM PSC, with projects undertaken focusing on key risks identified though planning stages. Strong cross-border relationships and coordination are critical to further improvement in the shared management of the region.

The majority of the New South Wales floodplain affected by watering of LMW through weir pool raising, is privately owned and managed for agricultural production, recreation and conservation. Significant Crown Land areas include the Taroo Group of Reserves (formerly known as Moorna, Wangumma and Lake Victoria State Forests). The ownership of some public land is currently in the process of transfer from NSW National Parks and Wildlife Service management to Indigenous owners. Although it lies in New South Wales, Lake Victoria is used as a water storage for South Australia and is owned by the South Australian government on behalf of the Murray-Darling Basin Contracting Governments (MDB Joint Venture Governments), and operated by SA Water under direction of the MDBA.

While the direct effect of watering across LMW on South Australian environmental assets is not as evident as for New South Wales, the indirect effects should be considered. Most of the South Australian floodplain upstream of Lock 6 is public land within the Chowilla Game Reserve, including the floodplain to the north of the river and the Nelwood floodplain system to the south. Some floodplain areas extend into pastoral or other leases. There are two other small floodplain systems to the south of the river, Queens Bend and Bunyip Reach, both of which are leased to private landholders. Changes made through the update of this EWMP have not altered the level of impact on South Australian assets or land.

The Chowilla portion of the Chowilla-Lindsay-Wallpolla Icon Site is managed by the South Australian government, with New South Wales government managing approximately a quarter of the floodplain that lies within their jurisdiction. TLM environmental water delivery infrastructure has also been constructed on the Chowilla Floodplain. The operation of the Chowilla Floodplain infrastructure (the Chowilla Creek environmental regulator and ancillary regulators) is undertaken in conjunction with the raising of Lock 6 to enable broad-scale inundation of the floodplain. The raising of Lock 6 has limited influence on lower Lindsay inundation due to its modest (62 cm) maximum raising limit. The scale of operation and the associated weir pool raising, is also influenced by floodplain vegetation condition and River Murray flows, with higher level operations occurring under higher flows.

A weir pool manipulation program in SA also includes the potential raising of Lock 6 independently of Chowilla operations, and increasing the scale of lowering events in the Lock 6 reach. An operation plan for Chowilla/Lock 6 that outlines the operation of this reach has been developed (Wallace and Whittle 2014), and approved by the Environmental Water Group (predecessor of SCBEWC) and the MDBA. Input was sought on all influences/impacts of operation, including across Lindsay Island, and the final document approved by all impacted parties.

Condition monitoring activities across the two parts of the icon site have some alignment, with early work undertaken at Chowilla informing the sampling methods used across LMW. Large, landscape-scale monitoring, such as that for large-bodied fish movement assessments currently (2020) being undertaken across LMW and Chowilla, allows asset efficiencies and data sharing between sites.

Water for the environment can be used at multiple sites as it moves downstream. This increases the efficiency of environmental watering by allowing the same water to be used at multiple sites. Re-using environmental water also has ecological benefits. Chemical and biological processes or life-history triggers (e.g. fish spawning) initiated by watering at upstream sites may benefit downstream sites when the water is re-used. Environmental water that returns to the River Murray upstream of Lock 10 (including the Darling River) can be used to water LMW sites. Watering within the LMW islands can be planned with respect to the timing and volume of water that these systems can return. Additionally, local watering events can also be planned to maximise water re-use within the LMW system, as well as sites further downstream into South Australia.

4. Hydrology and system operations

In the MDB, the natural diversity of rivers and floodplains, and the linkages between rivers and floodplains has evolved with highly variable natural hydrology. Since European occupation, the Murray-Darling has been transformed through the construction of major water storages, weirs and locks.

Pre-regulation hydrology

The River Murray is generally divided into three sections:

- Upper Murray – source to Yarrawonga,
- Middle Murray – Yarrawonga to the Darling confluence
- Lower Murray – Darling confluence to the mouth (Maheshwari *et al*. 1995, Walker and Thoms 1993)

Under natural conditions, the variability in flow increases as you move downstream (Maheshwari *et al*. 1995). The Lower Murray is characterised by a general channel slope of about 5.5 cm/km, which suggests the lower Murray channel has been stable for a long time (Walker and Thoms 1993). As there are no significant tributaries below the Darling River confluence, the hydrology through this section of river is strongly influenced by the hydrology of the Darling River (Walker and Thoms 1993, Maheshwari et al. 1995). Significantly, below the Murray-Darling Junction, the River Murray effectively drains the majority of the Murray-Darling Basin.

Flows in the Murray River are generally highest in September/October and lowest in February/March (Figure 4.1), coinciding with seasonal rainfall and inflow patterns. Flows within the Murray, particularly in the LMW region, can be highly variable and somewhat removed from what is occurring at the up-stream end of the system. By the time water has travelled downstream to LMW, flow can be influenced by the major tributaries (e.g. Goulburn, Murrumbidgee, Darling Rivers).

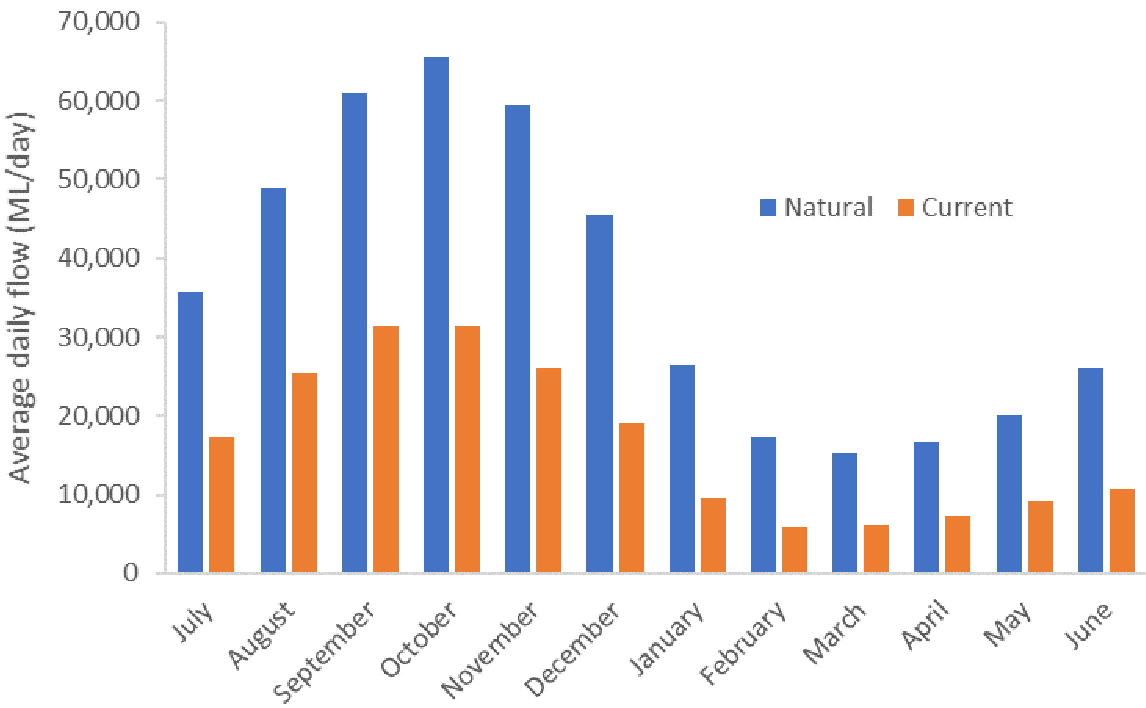


Figure 4.1. Monthly discharge at Lock 9, for average daily modelled natural flows and modelled current system flows. Based on 115 years of data (1894-2009) (Source: MDBA).

Post-regulation hydrology

Since European occupation, the construction of major water storages, weirs and locks to manage water demand has created regulated hydrology along the River Murray. Regulated hydrology has multiple effects, including reducing the magnitude, duration and frequency of overbank flows. Major storages allow the capture of water during wet periods and release it as needed during Summer or in droughts to meet consumptive and irrigation needs. This has altered the seasonality of peak flows in the system (Maheshwari *et al*. 1995) and resulted in a substantial reduction of seasonal ecological cues throughout the system.

The Lower Murray is highly developed, with 10 weirs spaced across this reach. These were originally constructed to facilitate river trade and provide permanent water sources to service irrigation areas (MDBA 2021). A series of barrages across the Lower Lakes were also constructed to prevent intrusion of saline sea water into the Lower Lakes.

Within the LMW region, five weirs directly influence local hydrology, with the operation of Lake Victoria, a large floodplain lake, used as an off-channel storage (for South Australia), also influencing hydrology in the region. A significant disparity between historic, unregulated, and current flows is evident for this region (Thoms et al. 2000). Annual flow volumes have been significantly reduced, with low flows (< 10,000 ML/day) now more frequently experienced than unregulated conditions. Flows between 30,000 and 60,000 ML/day, which inundate many low-lying wetlands, now occur at less than half the frequency of unregulated conditions, and the duration of these events has almost halved. Although the flow durations of larger floods (exceeding 70,000 ML/day) are similar to unregulated conditions, the frequency of these higher flows has markedly decreased. This has resulted in the river remaining disconnected from the floodplain for longer durations (Thoms et al. 2000, SKM 2003, 2004, SKM and Roberts 2003, MDBC 2006, Ecological Associates 2007). Seasonality of larger floods has also shifted, with peak flows occurring earlier (September) under current conditions than under unregulated conditions (October). In addition, filling of Lake Victoria generally occurs through Winter/Spring for use in Summer and Autumn. Operation of this storage can strongly influence flows passing weirs 9-7, particularly during Winter-Spring when the lake is being filled.

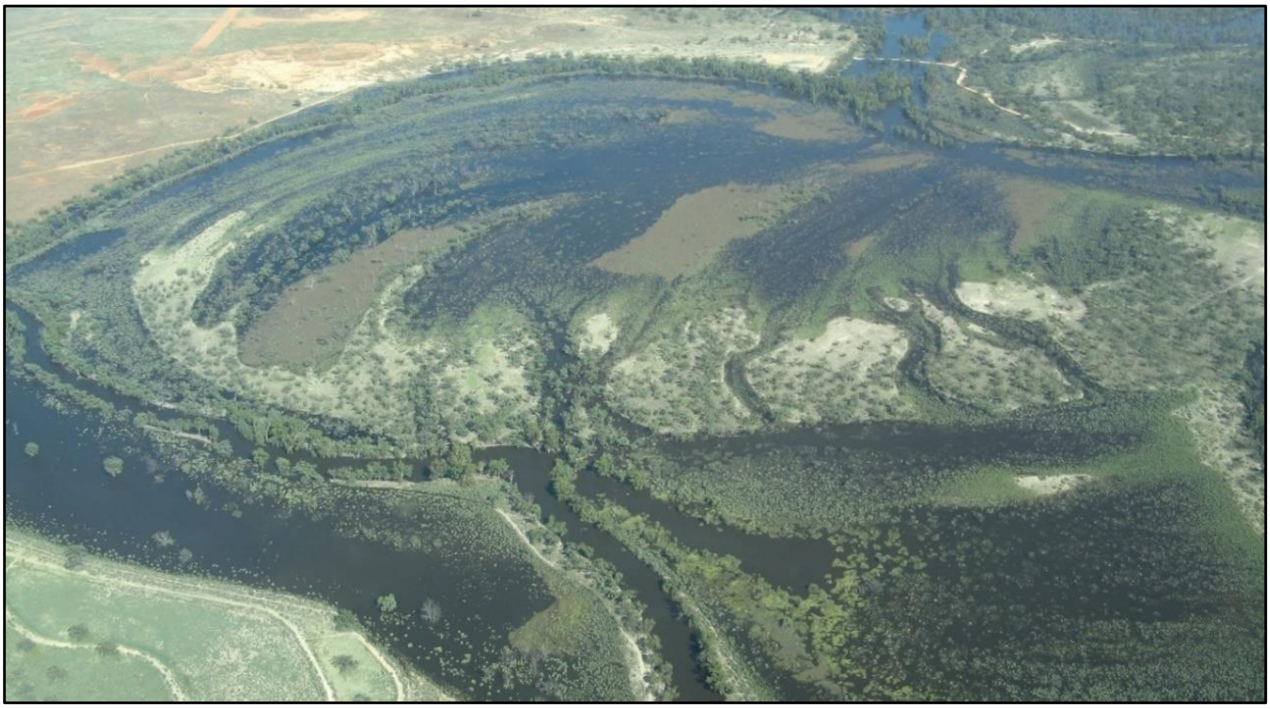
In the lower Baaka/Darling River, the natural pattern of flow has been significantly altered post regulation, with peak flows now occurring in early Summer, as opposed to peaks that would have generally occurred in September and/or March (Thoms et al. 2000). Under current conditions, flows tend to peak in early Summer, fall rapidly again during late Summer, and then remain at constant low levels until October. These flows are generally regulated releases from Menindee. Environmental flows supplementing base flows are becoming more common and look to reflect natural seasonality. These changes in seasonality, and reductions in magnitude, are significant as the Darling River historically contributed regular Summer flows to the Lower Murray downstream of Wentworth. Current annual flow volumes in the lower Darling River are significantly less than what would have occurred naturally, and in recent decades, low flows and cease-to-flow periods have increased in frequency and duration (Vertessy et. al. 2019).

Water for the environment planning

Contemporary management of the MDB is focused on the restoration of ecologically important aspects of flow regimes to achieve positive environmental outcomes (MDBA 2019a). The Living Murray Initiative, the Basin Plan and the Basin Environmental Watering Strategy seek to improve the health and resilience of the river system through the delivery of water for the environment and informed operational deliveries.

Water for the environment aims to return a more natural hydrological regime and restore the condition of floodplain and wetland communities that have degraded due to regulation of the MDB. In order to deliver water to the landscape, water delivery infrastructure has been built in some parts of the Basin. This includes a range of works and measures (including regulators and block banks), which allow delivery of environmental water to various assets across LMW. In addition, targeted water delivery using temporary pumps has been successful in maintaining the water requirements of some channels and wetlands which cannot be reached by in-channel flows or the operation of infrastructure under current flow constraints (MDBA 2013).

In recent years, rather than maintaining the historic legacy of stable weir pool levels, variable flow regimes have been trialled by manipulating weir pool levels through existing flow control structures (DEWNR 2015). Weir pool manipulation (WPM) is being used to achieve environmental benefits through the restoration of hydrological variability and wet-dry cycles in riparian habitats. This can be accomplished by surcharging and/or drawing down water levels beyond full supply level (FSL).



Floodplain inundation of West Mulcra Island during the 2010-11 floods (Source: D Wood).

Annual planning

The VEWH develops an annual Seasonal Watering Plan for all environmental watering proposed under each climatic scenario across Victoria. This is developed at the beginning of each watering season using information provided by individual CMA's Seasonal Watering Proposals, which propose watering actions under drought, dry, average and wet climatic scenarios. The watering actions are developed to reflect objectives and watering regimes outlined in individual environmental water management plans in response to water availability, opportunities and environmental priorities. A flexible decision-making framework is included in the Seasonal Watering Proposal so that water holders (primarily VEWH, Commonwealth Environmental Water Holder and SCBEWC) can assess water priorities throughout the year according to the water resource condition.

Annual water planning includes a flexible decision framework to guide prioritisation of allocation of water for the environment, as well as icon site environmental watering proposals, water availability forecasts and management objectives for water resource scenarios (see Table 4.1).

A key aspect of annual planning is undertaking system-scale planning to coordinate the delivery of water for the environment in the River Murray system and tributaries, anabranches and floodplain with all water available in the system. This coordination between multiple water holders, water managers and jurisdictions, maximises the use of available water, enabling the use and re-use of water at multiple sites along the River Murray.

Table 4.1. Objectives under different water availability scenarios for LMW.

	Extreme dry	Dry	Median	Wet
Ecological watering objectives	Avoid irretrievable loss of key environmental assets	Ensure priority river reaches and wetlands have maintained their basic functions	Ecological health of priority river reaches and wetlands have been protected or improved	Improve the health and resilience of aquatic ecosystems
Management objectives	• Avoid critical loss of species, communities and ecosystems • Maintain key refuges • Avoid irretrievable damage or catastrophic events	• Maintain river functioning with reduced reproductive capacity • Maintain key functions of high priority wetlands • Manage within dry spell tolerances • Support connectivity between sites	• Enable growth, reproduction and small-scale recruitment for a diverse range of flora and fauna • Promote low-lying floodplain-river connectivity • Support medium flow river and floodplain functional processes	• Enable growth, reproduction and large-scale recruitment for a diverse range of flora and fauna • Promote higher floodplain-river connectivity • Support high flow river and floodplain functional processes
Priority locations for LMW floodplain icon site (other sites should also be considered under dry, average and wet)	• Base flows in Mullaroo Creek to preserve Murray cod populations	• Base flows in Mullaroo Creek • Periodic flows in Potterwalkagee Creek, Lindsay River and Wallpolla Creek • Maintain condition and function of priority wetlands (Webster's Lagoon, Wallpolla Horseshoe)	• As for Dry and: • Spring pulse events in Potterwalkagee Creek and Lindsay River • Inundate Mulcra floodplain • Inundate Lake Wallawalla	• As for Median and: • Using natural flood events to inundate the broader floodplain

5. Water-dependant values

Environmental values

The LMW floodplain lies within the Murray Scroll Belt bioregion, which is typified by the River Murray floodplain, oxbow lakes, ephemeral lakes, swamps and active meanders. Here, red-brown earths, cracking clays and texture contrast soils support a range of vegetation types, including terrestrial, floodplain and aquatic (DSE 2004). This floodplain is relatively flat, and is dissected by a network of anabranches, small creeks and permanent and ephemeral wetlands.

Lindsay Island, Wallpolla Island and Lake Wallawalla are listed as nationally important wetlands (Environment Australia 2001). The LMW floodplain is an area of high ecological significance. When inundated, the waterways and wetlands of the floodplain provide refuges and resources for a range of flora and fauna. This includes threatened species and provision of important waterbird breeding habitat.

Fauna

The floodplain supports diverse aquatic, wetland-dependent and terrestrial species (Appendix 1). It provides important habitat for native fish, frogs, turtles and waterbirds, including many of conservation significance at a national and state level (GHD 2013). Forty-one fauna species listed as threatened under the *Victorian Flora and Fauna Guarantee Act 1988* have been recorded in this region. There are also a number of species listed as nationally threatened under the federal *Environment Protection and Biodiversity Conservation Act 1999,* including the regent parrot (*Polytelis anthopeplus*), growling grass frog (*Litoria raniformis*), silver perch (*Bidyanus bidyanus*) and Murray cod (*Maccullochella peelii*).

Spotted marsh frog (**Limnodynastes tasmaniensis*****), common to LMW (Source: D Wood).***

Mullaroo Creek, a permanent Lindsay Island anabranch, supports one of the most significant populations of Murray cod in the lower River Murray and Victoria. The Murray cod population there exhibits significantly better age structure and is more abundant than that in any other Victorian system (Saddlier et al. 2008, Sharpe et al. 2009, Tonkin et al. 2020). It is the robustness of the Mullaroo Creek population that makes it of particular importance to the sustainability of broader regional populations (Sharpe et al. 2009). Key habitat features contributing to the viability of the population include the sustained high velocity flows (e.g. > 0.3 m/s) and the hydraulic diversity this achieves, and high densities of submerged woody debris in the creek (Saddlier et al. 2008, Water Technology 2009, Tonkin et al. 2019).

The creeks and anabranches of LMW islands also provide essential resources for the growth and breeding of four additional fish species listed under the *Victorian Flora and Fauna Guarantee Act*; freshwater catfish (*Tandanus tandanus*), silver perch, Murray-Darling rainbowfish (*Melanotaenia fluviatilis*) and unspecked hardyhead (*Craterocephalus stercusmuscarum fulvus*) (Mallen-Cooper 2012). Other fish species, common to the Lower Murray, also inhabit LMW (Mallen-Cooper et al. 2010, Bloink et al. 2019).

During dry periods, floodplain wetlands (e.g. Lake Wallawalla) support terrestrial species such as small mammals and reptiles (Ecological Associates 2007 and 2014). When flooded, these wetlands provide important habitat for a range of wetland-dependent species, including many waterbirds (MDBC 2006, Kingsford et al. 2013, GHD 2015). When freshly inundated, these wetlands promote the growth of microbes, algae, macroinvertebrates and crustaceans, providing food and habitat for fish, frogs, bats and birds (Ecological Associates 2007, GHD 2019).

Over 200 species of water-dependant birds are known to use the LMW floodplain for breeding, feeding and roosting (Appendix 1). Of these species, 39 are considered as having conservation significance in Victoria, with 25 listed under the *Victorian Flora and Fauna Guarantee Act 1988*. At a national level, four are listed under the *Environment Protection and Biodiversity Conservation Act 1999*.

Following inundation of wetlands, as the water level drops, the muddy base becomes exposed, providing conditions for lakebed herbland to establish. This supplies ideal grazing for wading birds such as the great egret (*Ardea alba*), greenshank (*Tringa nebularia*) and the red-necked stint (*Calidris ruficollis*), all of which are listed under the Japan-Australia, Republic of Korea-Australia and the China-Australia Migratory Bird agreements (SKM 2003, MDBC 2006, Ecological Associates 2007). Lake Wallawalla on Lindsay Island is a particularly good example of this type of habitat (Henderson et al. 2012). Lake Wallawalla also supports colonial nesting waterbirds when inundated. Fish and carrion-feeding birds, such as the China-Australia Migratory Bird Agreement-listed white-bellied sea eagle (*Haliaeetus leucogaster*), are also supported by these environments (Ecological Associates 2007).

Flora

The LMW floodplains support over 250 species of plants, with many recognised as having conservation significance at a state and national level. This includes twelve species listed as having conservation status under the *Victorian Flora and Fauna Guarantee Act 1988* (Appendix 3). Plant communities on the floodplain are described by White et al. (2003) as Ecological Vegetation Classes (EVCs). Vegetation of the LMW floodplain and wetlands consists of 21 Ecological Vegetation Classes, the conservation significance of which range from ‘least concern’ to ‘endangered’ (Appendix 2) (DSE 2004).

The significant floodplain tree, river red gum (*Eucalyptus camaldulensis*), is a prominent component of the vegetation community across LMW (Table 5.1). This is the largest remaining area of natural river red gum forest in the lower Murray. It occurs mainly in riparian and floodplain zones along the River Murray channel and on the edges of waterways and wetlands. The river red gums provide a critical source of habitat and a food resource for many fauna species, including birds, reptiles and mammals. In the vicinity of waterways, river red gums may be sustained by relatively fresh, shallow groundwater (Thorburn and Walker 1993, Ecological Associates 2007); however, surface-water provided by floods is needed for these trees to survive and assist with reproduction. River red gums also provide submerged woody habitat through limb-drop or as complete trees, which supplies food and shelter for fish and aquatic macroinvertebrates (Ecological Associates 2007, Water Technology 2009). Similarly, leaf and limb-drop is a source of organic matter used to fuel primary productivity in the aquatic system (Glazebrooks and Robertson 1999).

Table 5.1. Area of Water Regime Classes found at LMW.

Water Regime Class	Area (Ha)	% cover
Alluvial Plains	4776	14.5
Black Box Woodland	9404	28.6
Deflation Basin	197	0.6
Fringing Red Gum	6615	20.1
Lignum Shrubland	9720	29.6
Low Intermittent Wetlands	980	3.0
Red Gum Forest	1058	3.2
Red Gum with Flood-tolerant Understorey	88	0.3
(Not subject to inundation)	68	0.2

Black box trees occur commonly throughout the LMW floodplain (Table 5.1), generally at higher flood elevations as their tolerance to flooding is less than that of river red gums'. They support both arid and riverine bird species, with productivity and recruitment strongly linked to flooding (Jolly and Walker 1996). As with river red gum, black box provides a significant proportion of the large structural habitat to numerous fauna of the floodplain region across LMW.

Lignum, a medium sized shrub, is of significant importance to floodplain ecosystems (Rogers and Ralph, 2011). Across LMW, it forms a considerable portion of the floodplain vegetation community (Table 5.1) and is predominantly confined to floodplain depressions where water collects and persists after floods. Regular inundation through flooding is required by this species for maintenance and improvement in condition as well as supporting reproduction (Roberts and Marston 2000). When inundated, it provides habitat for both birds and fish (Maher and Braithwaite 1992), while during dry and drying phases it facilitates the growth of floodplain understorey herbs (James et al. 2015).

Meadow of Nardoo (**Marsillea drummondii*****) on recently inundated floodplain, Wallpolla Island (Source D Wood).***

The LMW floodplain maintains a diversity of wetlands sites, with many supporting EVCs of conservation status. Typically, arid zone floodplain wetlands, such as those found on LMW are sites of high biodiversity and support both aquatic and terrestrial plant communities. Wetland vegetation is made up of species with a range of flooding tolerances, and the types of species growing at any one time is closely related to inundation status (Henderson et al. 2009). When inundated, wetlands host aquatic flora species grown from dormant seeds present in the lakebed, and seeds and propagules washed in (Ecological Associates 2007). As the lake dries, aquatic vegetation will give way to wetland herb communities (Ecological Associates 2007, Wood et al. 2018).

Anabranches dissecting the LMW floodplain provide diverse aquatic habitats, including deep and shallow sections with varied flow velocities and both steep and sloping banks. Dense stands of aquatic macrophytes are supported and significant amounts of instream woody debris are present. The diversity of habitats within anabranches supports fish, aquatic invertebrates, frogs and birds.

Ecosystem processes

Having a healthy, functioning, ecosystem relies on a series of key processes. The existence of freshwater ecosystems is driven and guided by these processes, which include biogeochemical cycles, productivity, creation of signals for flora and fauna to undertake their own cycles, and connections between the floodplain, wetlands and the river channel. Interactions between individual processes are equivocally linked to create a dynamic ecosystem (Alluvium 2010). The removal of one or more of these processes can have implications for other processes and result in an unstable system.

Connectivity is a major and important process in large-scale aquatic systems where wetting and drying cycles promote productivity. The regular connection and disconnection of creeks, wetlands and floodplain, which are prominent across LMW, allows for the transfer and exchange of aquatic communities and abiotic factors such as nutrients. Fish, invertebrates, vegetation seeds and propagules rely on aquatic connectivity to assist with migration, re-colonisation, completion of life-history stages and range expansion. Aquatic connectivity also allows them to take advantage of areas of high productivity to facilitate rapid growth. Equally, dry phases for floodplain habitats are essential in nutrient cycling and carbon partitioning (Baldwin et al. 2013). The exchange of carbon, nutrients, minerals and sediment between the floodplain and river channel are critical in ensuring a well-balanced, healthy and functioning ecosystem. The mixing and exchange of carbon and nutrients between LMW and the River Murray has significance for downstream processes, particularly during periods of high flow.

Webster's Lagoon during drawdown, Lindsay Island (Source MCMA).

Cultural values

Indigenous Australian occupation across the LMW floodplain dates back thousands of years. Populations were sustained by the rich productivity of the floodplain woodland and wetland systems, with the islands providing an abundant source of food and water. Communities maintained spiritual, cultural and emotional links with its land, waters, and traditional resources such as native species used for food and medicine. Many cultural signs still remain at the islands, including diverse archaeological site-types and complexes closely associated with floodplain features (SKM 2004). The floodplain also contains many registered sites of cultural heritage. These sites are home to multiple items of significance such as burial sites, shell middens, hearths, stone artefact scatters and culturally scarred trees (Bell 2010; Kelton 1996).

Previously, only a very small area of the icon site had been surveyed for areas of cultural significance. This is slowly changing thanks to Victorian Murray Floodplain Restoration Project's (VMFRPs) being undertaken across Lindsay and Wallpolla island's, which require surveys to inform development of Cultural Heritage Management Plans. Complementary work outside the area of proposed project influence is also being investigated to increase knowledge and learning.

Aboriginal Waterway Assessments (AWA) have previously been undertaken at Lindsay Island, in addition to on-country activities with community across LMW such as native fish re-stocking, Talk Water on Country events, one-on-one discussions and field walks. These activities are planned to continue into the future, with the inclusion of Indigenous school education projects. These will continue to build cultural knowledge from a management focus, as well as education and sharing of knowledge within the First Nations community. Engagement has been important in getting the community back on country.

Recreation and economic values

Tourism in the Mildura region generates more than $335 million annually, and is the sixth-largest industry in the region (Mildura Regional Development 2021). Sites such as the Murray-Sunset National Park are major attractions contributing to the tourism industry and local economy. At LMW specifically, visitation numbers can extend into the tens of thousands every year, with water acting as a primary driver for these numbers (B. Rogers, pers. comm., 2010). The island floodplains are popular recreation sites for the local community and visitors alike. Many families and groups, local and otherwise, have long-standing connections with the LMW landscape. Many have holidayed within the region for decades, making annual pilgrimages to enjoy the opportunities the remote landscape provides. There are ample opportunities for camping, canoeing, bird and wildlife-watching, photography, fishing and four-wheel driving across the region.

6. Ecological objectives

Management goal

Based on an understanding of the LMW icon site's characteristics and ecological requirements, First Step Decision interim ecological objectives were developed and approved by the Murray-Darling Basin Ministerial Council in 2003. Proceeding this, jurisdictional agencies have continued to review the First Step interim objectives to develop a refined vision and ecological objectives for the icon sites. These reflect learnings from the delivery of environmental water, monitoring, modelling, consultation activities and scientific research to enable a clearer, more effective, evaluation of environmental responses to environmental water delivery. The refined vision for the LMW Icon Site is to:

> *'Improve biodiversity values of Lindsay, Mulcra and Wallpolla Islands, with environmental conditions in anabranches and floodplains to be representative of those which would be expected under natural flow conditions.'*

The most recent update of this EWMP maintains the intent of TLM objectives, improves the specificity and measurability of the objectives and targets, and improves the line of sight to the Basin Plan Environmental Watering Strategy (Butcher et al. 2019). The refined objectives for the LMW Icon Site are outlined later in this section, along with targets from which to measure progress toward achieving the objectives.

Objective hierarchy and alignment to Murray-Darling Basin Plan

The objective hierarchy developed for the LMW Icon Site is presented in Figure 6.1, and shows the relationship to the three overall environmental objectives of the Basin Plan and grouping in relation to the Schedule 7 targets. This has improved line of sight to the Basin Plan Environmental Watering Plan framework and will support future updates of the Victorian Murray Long-Term Watering Plan.

Waterbirds on Lake Wallawalla, Lindsay Island (Source MCMA).

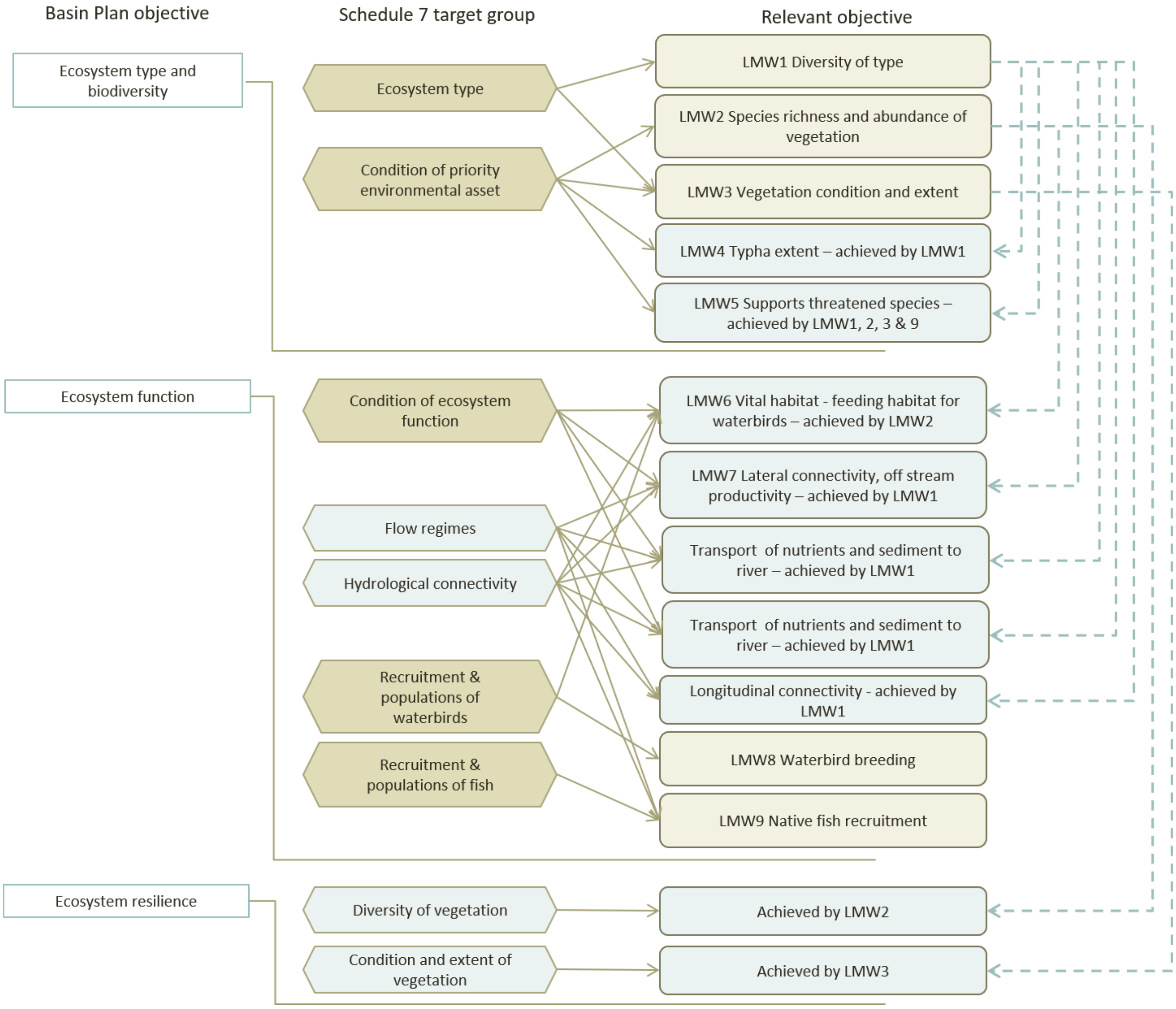


Figure 6.1. Basin Plan objectives, Schedule 7 target groups and relationship to ecological objectives for the Lindsay-Mulcra- Wallpolla Icon Site. LMW1-9 equate to the objectives presented below.

In some cases, the watering regime established for one objective (e.g. diversity of ecosystem type) will achieve the water requirements of several other objectives/targets; these are highlighted in Figure 6.1. Nine ecological objectives and associated targets have been developed. The majority of these are based on the original objectives, but have been made SMART and/or adapted to align with the Basin Plan Environmental Watering Plan objectives.

As well as alignment with Basin Plan overall environmental objectives, the objectives have alignment with Basin-Wide Environmental Watering Strategy objectives and State-level Long-term Watering Plan objectives. Table 6.1 maps the current EWMP objectives against these objectives and shows the line of sight.

Table 6.1. Mapping LMW EWMP objectives to Basin Plan Environmental Watering Plan (EWP) objectives, Basin Plan Schedule 7 targets, Basin-Wide Environmental Watering strategy (BWS) Quantified Environmental Expected Outcomes (QEEO) (MDBA 2019a), and Long-term Watering Plan (LTWP) Victorian Murray objectives (DELWP 2015a).

EWMP objectives	Basin Plan EWP objective	Relevant Schedule 7 target	Relevant BWS QEEO^	LTWP objective*
LMW1: Diversity of ecosystem type	8.05,3(b) 8.06,6(a)	-Ecosystem type		
LMW2: Species richness and abundance of aquatic vegetation	8.05,3(b) 8.06,6(a)	-Ecosystem type -Diversity of water-dependent native vegetation -Extent and contiguousness of water-dependent native vegetation -Condition of priority assets – supports significant biodiversity	BWS11	LTWPVM2 LTWPVM3
LMW3: Condition and extent of floodplain vegetation	8.05,3(b) 8.06,6(a)	-Ecosystem type -Recruitment and populations of native water-dependent vegetation -Condition of priority assets – supports significant biodiversity -Community structure of ecosystems	BWS10 BWS11 BWS12 BWS13	LTWPVM5 LTWPVM6 LTWPVM7 LTWPVM8
LMW4: Limit *Typha* (Cumbungi)	8.07,5	-Extent and contiguousness of water-dependent vegetation -Diversity of water-dependent vegetation		
LMW5: Support threatened species	8.05,3(a)	-Condition of priority asset – supports listed species and communities	BWS26	LTWPVM18 LTWPVM19
LMW6: Create vital habitat-feeding habitat for waterbirds	8.06,6(a)	-Recruitment and populations of native water-dependent birds -Condition of priority ecosystem functions – vital habitat (breeding and feeding) -Condition of priority assets – significant biodiversity	BWS15 BWS18 BWS19	LTWPVM10 LTWPVM11 LTWPVM12
LMW7: Lateral connectivity to support off-stream productivity	8.06,3(b)(ii)	-Condition of priority ecosystem functions – lateral connections for off-stream primary production	BWS6 BWS7	LTWPVM1
LMW8: Waterbird breeding	8.06,6(a) 8.06,6(b)	-Recruitment and populations of native water-dependent birds -Condition of priority ecosystem functions – vital habitat (breeding)	BWS18 BWS19	LTWPVM10 LTWPVM11 LTWPVM12
LMW9: Native fish recruitment	8.06,6(a)	-Recruitment and populations of native fish -Condition of priority assets – significant biodiversity	BWS21 BWS22 BWS24	LTWPVM14 LTWPVM15 LTWPVM18

^BWS QEEO details and codes shown in Appendix 4.

*LTWP objective details and codes shown in Appendix 5

Specific objectives

The watering requirements and associated water regimes necessary to meet the objectives and targets are summarised in the sections below. The watering regime of the LMW Icon Site relates to topographical and geomorphologic features of the icon site, with some water regimes able to meet the requirements for multiple objectives. For example, river red gum forest requires longer and more frequent inundation than river red gum woodland. Black box on the other hand, being located higher on the floodplain requires shorter and less frequent inundation than either of the river red gum associations.

Ecosystem type and biodiversity

Ecosystem type

Objective LMW1: Diversity of ecosystem type

By 2030, maintain diversity of freshwater ecosystem types at the Lindsay-Mulcra-Wallpolla Icon Site, including palustrine, riverine and floodplain ecosystems with temporary and permanent water regimes.

Targets for Objective LMW1

Maintain a variable hydrograph which supports a range of hydraulic conditions including:

- A minimum of 60 per cent of the Mullaroo Creek will exhibit fast flowing habitat within a flow envelope of 0.2-0.5 m/s (mean cross-sectional velocity) for 100 per cent of the time. A flow of 600 ML/day in the Mullaroo Creek is recommended to achieve this target.
- A minimum of 75 per cent of the Mullaroo Creek will exhibit fast flowing habitat within a flow envelope of 0.2-0.5 m/s (mean cross-sectional velocity) during Spring annually (September-November). A flow of 1200 ML/day in the Mullaroo Creek is recommended to achieve this target.
- The Upper Lindsay River (defined as the proportion of Lindsay River upstream from the Mullaroo Creek confluence; specifically, Lindsay River North) will have Low flow of 10-45 ML/d for a minimum of three months* (September-November) 8 in 10 years. Every 4 in 10 years (as a subset of Low flow) a High-Low flow of 45-92 ML/d for 3 to 6 months (September-November/June-November) will occur. Additionally, Lindsay River South will experience Low flow (5-50 ML/d) for 3-6 months (September-November /June-November) 4 in 10 years.
- Lower Potterwalkagee Creek (downstream of Stoney Crossing) will have Low flow (35 ML/d) for three months* (September-November) 9 in 10 years. Every 5 in 10 years (as a subset of Low flow) a High-Low flow of 115-280 ML/d for 3 to 6 months (September-November/July-December) will occur. Every 3 in 10 years (as a subset of High-Low flow), overbank flows of 475 ML/d for four months (August-November) should occur.
- Upper Potterwalkagee Creek (upstream of Stoney Crossing) will have Low flow (15-145 ML/d) for 3-6 months (September-November/July-December) 5 in 10 years. Every 3 in 10 years (as a subset of Low flow), overbank flows of 370 ML/d for 4 months (August-November) should occur.
- Inundation of floodplain to an area of similar size to the area that would be inundated by a natural flow event of ~40,000 ML/day (QW9) 5 in 10 years (on average) for a duration of > 30 days (river red gum) in areas which can be managed.
- Inundation of floodplain to an area of similar size to the area that would be inundated by a natural flow event of ~60,000 ML/day (QW9) 3 in 10 years (on average) for a duration of > 30 days (river red gum-black box-lignum) in areas which can be managed.
- Inundation of floodplain to an area of similar size to the area that would be inundated by a natural flow event of > 80,000 ML/day (QW9) 2 in 10 years (on average) for a duration of > 30 days (black box-lignum) in areas which can be managed.

- Provide water to ephemeral creeks and wetlands consistent with the watering regimes outlined in Table 6.2 to provide a diversity of creek and wetland habitats across the icon site.

*Year-round flow is possible and may occur in response to operational requirements or high river/flooding.

Table 6.2. Watering regime for ecological objective LMW1 specifically for major creeks of the Lindsay-Mulcra-Wallpolla Icon Site. These sites are typically managed via weir pool manipulations and/or regulating structures (*year-round flow is possible and may occur in response to operational requirements or high river/flooding).

Reach	Control structure	Flow component	Expression of flow component		
			Target flow (ML/day)	Duration (period)	Frequency (years)
Mullaroo Creek	Mullaroo Regulator	Low flow	600	Year-round	10 in 10
		High-Low flow	1,200	3 months (Sept-Nov)	10 in 10
Lindsay River North	Lindsay River North Regulator	Low flow	10-45	Minimum 3 months* (Sept-Nov)	8 in 10
		High-Low flow	45-95	3-6 months (Sept-Nov/Jun-Nov)	4 in 10 (as subset of Low flow)
Lindsay River South	Lindsay River South Regulator	Low flow	5-50	3-6 months (Sept-Nov/Jun-Nov)	4 in 10
Potterwalkagee Creek (Lower)	Stoney Crossing Regulator	Low flow	35	Minimum 3 months* (Sept-Nov)	9 in 10
		High-Low flow	115-280	3-6 months (Sept-Nov/Jul-Dec)	5 in 10 (as subset of Low flow)
		Overbank (in conjunction with Lower Potterwalkagee Regulator)	475	4 months (Aug-Nov)	3 in 10 (as a subset of High-Low flow)
Potterwalkagee Creek (Upper)	Upper Potterwalkagee Regulator	Low flow	15-145	3-6 months (Sept-Nov/Jul-Dec)	5 in 10
		Overbank (in conjunction with Lower Potterwalkagee Regulator)	370	4 months (Aug-Nov)	3 in 10 (as a subset of Low flow)

Table 6.3. Watering regime for ecological objective LMW1 specifically for wetlands and channels of the Lindsay-Mulcra-Wallpolla Icon Site. These sites are typically managed via temporary pumping and/or regulating structures.

Waterbody description	Waterbody names	Frequency (years)
Semi-permanent wetland	Webster's Lagoon, Mulcra Horseshoe, Wallpolla Horseshoe	9 in 10
Ephemeral wetland	Scotties Billabong, Crankhandle, Stockyards (aka. Upper Mullaroo Wetland Complex), Wetland 33, Lilyponds Billgoes Billabong, Snake Lagoon Extension Lake Wallawalla*	7 in 10 4 in 10 2-3 in 10
Ephemeral channel	Woodcutters, Lindsay-Mullaroo Connector, Sandy Creek, Finnigans Creek Wallpolla Creek East	8 in 10 4 in 10
Floodplain inundation^	~40,000 ML/d ~60,000 ML/d > 80,000 ML/d	5 in 10 3 in 10 2 in 10

*A High-Low flow in Lindsay River North and Low flow in Lindsay River South is required to fill (pump) Lake Wallawalla. An extended duration (> 6 months) is required to allow partial or complete filling.

^As at 2020, floodplain inundation through managed inundation is currently only feasible on Mulcra Island.

Rationale for watering regime

The objective is focused on providing a range of hydraulic conditions within creek channels as well as inundating/drying floodplain and wetland habitats. Target hydrological requirements should meet the surrounding environmental requirements of the waterway; however, landscape-scale interactions should be taken into important consideration and consultation, and alignment of outcomes with adjacent water managers should be attempted when undertaking seasonal and long-term water planning. With future potential to relax flow constraints in the southern MDB, larger managed flows (~40,000 ML/d) to mimic more natural hydrology may assist in achieving these, as well as broader landscape objectives and targets.

More detailed information relating to site-specific hydrology and water regime rationale is provided in the Watering Guide for LMW. Achieving the specified watering regime for each waterway is expected to progress achievement of the targets set. Targets may be met through managed (environmental water) and/or natural (flooding) outcomes.

Mullaroo regulator, Lindsay Island (Source: MCMA).

Condition of priority environmental asset

Objective LMW2: Species richness and abundance of aquatic vegetation

Improve the species richness and abundance of native wetland and floodplain aquatic vegetation functional groups by 2030.

Targets for Objective LMW2

By 2030, maintain or improve:

- A reference target for wetland vegetation communities at Lindsay-Mulcra-Wallpolla Icon Site for water responsive species richness 80th percentile ≥ 4.85 in wetlands 8 in 10 years.
- A reference target for wetland vegetation communities at Lindsay-Mulcra-Wallpolla Icon Site for water responsive species abundance 80th percentile ≥ 32.47 in wetlands in 8 in 10 years.

Reference target for floodplain water responsive vegetation species richness maintained or improved at three flood return frequencies for Lindsay-Mulcra-Wallpolla Icon Site by 2030 (lower, mid and upper floodplain – see Brown et al. 2016):

- Lower floodplain water responsive species richness 80th percentile is ≥ 5.45
- Mid floodplain water responsive species richness 80th percentile is ≥ 3.25
- High floodplain water responsive species richness 80th percentile is ≥ 1.5

Reference target for floodplain water responsive species abundance maintained or improved at three flood return frequencies (lower, mid and upper floodplain – see Brown et al. 2016):

- Lower floodplain water responsive species abundance 80th percentile is ≥ 25.3
- Mid floodplain water responsive species abundance 80th percentile is ≥ 11.45
- High floodplain water responsive species abundance 80th percentile is ≥ 3.7

Relevant functional groups include those identified in Huntley et al. (2016): amphibious plants, amphibious floating plants, amphibious herbs, amphibious woody plants, floating plants and terrestrial and drought tolerant functional groups.

Rationale for watering regime

The LMW floodplains and wetlands provide habitat for a diverse and extensive range of vegetation species and communities. A number of vegetation classes (EVCs) found across LMW have recognised conservation status in Victoria, with many requiring flooding to maintain their ecological character. Additionally, individual species of state and national conservation status are also recorded, with many of these having a requirement for inundation to support life-cycle requirements.

Wetland plant communities respond to a gradient of hydrological conditions determined by a water regime that can vary from maximum inundation to dry. Water depth, duration, frequency, rate of filling and drying, timing and predictability of flood and dry phases can all interact to determine the patterns and zonation of wetland plant communities. Adopting a watering regime which inundates a range of aquatic ecosystem types within the icon site will provide conditions suitable for the range of plant functional groups.

Assessing species richness of the different functional groups includes a temporal element, as the inundation stage sampled will affect the proportion of the different functional groups present. This needs to be taken into consideration for the analysis of data. Targets have been established following previous refinement of the TLM condition monitoring program (Robinson 2014) and have been further developed by Brown et al. (2015 and 2016). This process was undertaken using TLM LMW condition monitoring floodplain and wetland understory vegetation data.

The water requirements for supporting native wetland and floodplain aquatic vegetation are assumed to be achieved by meeting the watering regime for LMW1.

Objective LMW3: Condition and extent of floodplain vegetation

*Improve condition and maintain extent (ha) from baseline (2006) levels of river red gum (*Eucalyptus camaldulensis*), black box (*E. largiflorens*) and lignum (*Duma florulenta*) to sustain communities and processes typical of such communities at Lindsay-Mulcra-Wallpolla Icon Site by 2030.*

Targets for Objective LMW3

For the Lindsay-Mulcra-Wallpolla Icon Site, by 2030:

- In standardised transects that span the floodplain elevation gradient and existing spatial distribution, ≥ 70 per cent of river red gum trees with Tree Condition Index ≥ 10 (Wallace et al. 2020), with annual mortality < 1 per cent.
- In standardised transects that span the floodplain elevation gradient and spatial distribution, ≥ 70 per cent of black box trees with Tree Condition Index ≥ 10 (Wallace et al. 2020), with annual mortality < 1 per cent.
- River red gum follow the appropriate J-curve defined by Smith et al. (1997) in George et al. (2005) for tree population structure with an Index value of ≥ 0.79.
- Black box follow the appropriate J-curve defined by Smith et al. (1997) in George et al. (2005) for tree population structure with an Index value of ≥ 0.8.
- Condition in standardised transects that span the floodplain elevation gradient and existing spatial distribution, ≥ 70 per cent of lignum plants in good condition with a Lignum Condition Score (LCI) ≥ 4.
- By 2030, maintain 1249 ha of river red gum, 2125 ha of black box and 2818 ha of lignum across the Lindsay-Mulcra-Wallpolla Icon Site (based on 2006 data).

Rationale for watering regime

Riparian forests, and floodplain woodlands are reliant on flooding to maintain their growth, and to recharge and refresh soil water and groundwater (Roberts and Marston 2020). Each major structural form has different flooding requirements which reflects their position on the floodplain. River red gum and black box form dominant components of the LMW floodplain. Both species are of critical importance across the region, providing structural habitat and offering a food source in the icon site while supporting essential ecological processes.

River red gums lining Potterwalkagee Creek, Mulcra Island (Source: MCMA).

Objectives relating to river red gum and black box have been associated with the icon site since inception (MDBMC 2003, MDBC 2007). Various revisions have refined the objective to increase its usefulness, and added targets (based on historic condition monitoring data) to allow a component of measurement based on condition monitoring (Henderson et al. 2013, Robinson 2014, Brown et al. 2015). Tree condition targets have recently (2020) been reviewed. The previous targets and method of analysis were not providing the sensitivity required for determining change in tree condition across the icon site. Based on a recent review of how tree condition data is analysed (Wallace et al. 2020), the target has been updated to reflect the latest science and industry best practice. This provides a much clearer representation of shifts in overall tree condition, with trigger values based on known recovery pathways of these species. Population structure targets for LMW have previously been developed (Brown et al, 2015) based on an extensive body of work undertaken by George et al. (2005) on a nearby floodplain.

Lignum shrublands are a common feature of the River Murray floodplain, and make up a significant component of the LMW landscape. They have been identified as an ecologically significant floodplain shrub and play an important role in floodplain processes (Roberts and Marston 2020). Inundation is the main driver of growth, with flooding frequency influencing size and vigour of individual shrubs (Roberts and Marston 2020). Lignum has separate male and female plants which can differ in response to environmental factors (Roberts and Marston 2020). Targets relating to lignum were initially developed using historic TLM condition monitoring data as part of an earlier refinement process (Robinson 2014).

The watering regime and associated water requirements to meet the objective are specified in Table 6.4.

Table 6.4. Watering regime and requirements for ecological objective LMW3.

Water regime	**Watering requirements**					
	Flow (ML/day)	**Depth**	**Duration**	**Timing**	**Frequency**	**Maximum interflood period**
Deliver water to inundate river red gum forest and woodland	Forest: > 40,000 (or managed equivalence) Woodland: 40,000-60,000 (or managed equivalence)	Up to 2 m	2-4 months (maintenance)	Any (most frequent Spring)	Forest: 7 in 10 years Woodland: 6 in 10 years Consecutive years for seed/ germination	Forest: 4 years Woodland: 7 years
Deliver water to inundate black box	> 80,000 (or managed equivalence)	Up to 1 m	2-6 months (maintenance)	Any (most frequent Spring)	1-3 in 10 years	3-7 years
Deliver water to inundate lignum	> 80,000 or managed equivalence	Up to 1 m EVC 808 up to 50 cm	3-6 months (maintenance) Maximum of 6 months for EVC 808 Maximum of 4 months for EVC 823	Any (most frequent Spring)	1-3 in 10 years (vigorous growth) 3-5 in 10 years (maintain health) 5-7 in 10 years (maintain vigour)	7-10 years
			Seed establishment 4-6 weeks	Before or during Summer	Once per 12-18 months during the first 3 years	

Objective LMW4: Limit *Typha* (Cumbungi)

By 2030, limit the spread of Typha *and other invasive flora species.*

Targets for Objective LMW4

Within anabranches and the River Murray channel of Lindsay Island, Mulcra Island and Wallpolla Island units:

- By 2030, maintain or reduce *Typha* extent in flowing creeks of Lindsay, Mulcra and Wallpolla islands so all creeks in which *Typha* occurs retain < 10 per cent bank cover, with < 1 per cent of stands spanning the channel.

Within temporary wetlands:

- By 2030, a maximum of 1 per cent of quadrats will contain declared weeds, in any given survey.
- By 2030, a maximum of 20 per cent of quadrats will contain exotic taxa in temporary wetlands, in any given survey.

In shedding floodplain zones:

- By 2030, a maximum of 1 per cent of quadrats will contain declared weeds, in any given survey.
- By 2030, a maximum of 5 per cent of quadrats will contain exotic taxa in any given survey.

Rationale for watering regime

Invasive flora species present a significant threat to the natural ecosystem and the prominence of native species. By limiting the influence of invasive species, there should be a positive outcome for native species as competition for resources and space is reduced. Incorrect management of water regimes can sometimes be more beneficial to invasive species, and as such invasive species need to be considered and monitored to determine if water regimes should be altered.

Although *Typha* is a native species, its growth patterns can sometimes represent that of invasive species. *Typha's* rapid growth in favourable conditions enables it to quickly out-compete other native species, resulting in monospecific stands. In many cases, stands can completely choke waterways, significantly altering hydrology and passage for aquatic species. Variable water levels do not provide ideal growing conditions for *Typha*. Therefore, maximising hydraulic diversity and varying water levels in-channel should limit *Typha* expansion. The objective relating to *Typha* has been in operation at LMW since the previous version of this document. The target was recently developed (in 2020) to provide a suitable measure against this objective.

It is assumed that by restoring a more natural water regime (i.e. variable water levels and/or flooding) in wetlands and floodplains, the number and cover of invasive species would be limited (Greet et. al. 2015). This may be influenced by the antecedent conditions of the aquatic ecosystem (i.e. period of dry phase, ecological condition, water quality). Targets relating to invasive species within wetlands and floodplain zones are new (2020) and will allow the objective to be adequately addressed.

The targets for this objective are expected to be met by the watering regime specified for LMW1 and 3.

Objective LMW5: Support threatened species

Improve or maintain the populations of threatened flora and fauna that are flow-dependent at the Lindsay-Mulcra-Wallpolla Icon Site by 2030.

Targets for Objective LMW5

- By 2030, improve the abundance (CPUE) by > 10 per cent from baseline levels during annual condition monitoring sampling of the large-bodied species, Murray cod (*Maccullochella peelii*) (target = 47 individuals annually)*, freshwater catfish (*Tandanus tandanus*) (target = presence every year)*, and silver perch (*Bidyanus bidyanus*) (target = 10 individuals annually)*; and the small-bodied species, Murray-Darling rainbowfish (*Melanotaenia fluviatilis*) (target = 140)[#] and unspecked hardyhead (*Craterocephalus stercusmuscarum fulvus*) (target = 4530) [#].
- By 2030, increase number of Murray cod recruits by 20 per cent from baseline (2006-2009) measured as number of fish < 400 mm total length (target = 21).
- By 2030, maintain abundance of growling grass frog (*Litoria raniformis*) as measured by being recorded at 60 per cent of waterbodies sampled during any given year.
- By 2030, maintain presence of listed plant species including *Isolepis australiensis*, *I. congrua*, *Cyperus pygmaeus*, *Ammania multiflora*, and *Lipocarpha microcephala* in 70 per cent of surveys undertaken.
- By 2030, maintain presence of broad shelled turtle (*Chelodina expansa*) in 50 per cent of waterbodies sampled during any given year.

* targets determined from average of electrofishing data; 2006-2009

[#] targets determined from average of small fyke netting data; 2008-09

Rationale for watering regime

The hydrological diversity provided by the LMW icon site supports a wide range of significant flora and fauna populations. As with most species which inhabit floodplain and wetland landscapes, they have a high reliance on the provision of water in the form of variable flows within channel and frequent inundation of wetlands and the floodplain. While the objective relating to flow-dependant species is not new in this version of the EWMP, specific targets relating to key species for the LMW icon site have recently (2020) been developed to provide a measure against the objective.

Five fish with state or national conservation status reside across LMW (Table 6.5), with the various creeks and anabranches providing important habitat for these species. Abundance targets for these species have been developed using ‘baseline’ levels suitable to the most appropriate sampling method for that species type from TLM LMW condition monitoring fish data. Specific flow requirements for each species are relatively well known and can readily be found in available literature.

Table 6.5. Fish species conservation status identified for targets under objective LMW5. Conservation status as per Victorian Rare or Threatened Species (VRoTS) list; en=endangered, vu=vulnerable. EPBC; CE=Critically endangered, VU=Vulnerable (DSE, 2013). ***Flora and Fauna Guarantee Act 1988*** **(FFG); L=Listed (DELWP 2019b).**

Scientific name	Common name	EPBC	VRoTS	FFG
Bidyanus bidyanus	Silver perch	CE	vu	L
Craterocephalus stercusmuscarum fulvus	Un-specked hardyhead			L
Maccullochella peelii	Murray cod	VU	vu	L
Melanotaenia fluviatilis	Murray-Darling rainbowfish		vu	L
Tandanus tandanus	Freshwater catfish		en	L

Growling grass frogs (EPBC; Vulnerable, VRoTS; Endangered, Listed under FFG) have been recorded at sites across LMW previously. The depth of a waterbody can influence its appropriateness as suitable habitat for this

species. Some studies have recommended maintaining wetlands with areas that are at least 1.5 m deep to restrict the dominance of emergent vegetation, and facilitate growth of submerged and floating species. For growling grass frogs, breeding occurs once a year between Spring and Autumn. Tadpole development time can vary from 12 months in cooler regions to 2.5 months in warmer water (Wassens 2011).

Key understorey vegetation species of conservation significance from LMW have been identified (Table 6.6). These species are reliant on variable water regimes for development and persistence. The presence of these species provides an indicator of water regimes, which will support other species that have similar water requirements.

Table 6.6. Flora species conservations status identified for targets under objective LMW5. Conservation status in Victoria (VRoTS); vu=vulnerable, k=Poorly known (DEPI 2014). FFG; L=Listed (DELWP 2019b).

Scientific name	Common name	VRoTS	FFG
Ammania multiflora	Jerry-jerry	vu	
Cyperus pygmaeus		vu	
Isolepis australiensis	Inland club-sedge	k	
Isolepis congrua		vu	L
Lipocarpha microcephala	Button rush	vu	

Broad shelled turtles (VRoTS; Endangered, Listed under FFG) has been recorded at LMW, although there is no data on their population size or distribution. Nesting occurs predominantly through Autumn and Winter and occasionally in Spring. This species' eggs are able to enter diapause cued by low temperatures, and can overwinter in the nest. Consequently, the eggs can have incubation times that can vary considerably from 192 to 522 days. In terms of watering requirements, frequency of inundation is less important than access to permanent water bodies as these are their preferred habitats. Abundance is only weakly correlated with water depth and distance from the river (Cottingham et al. 2016). Complementary land management practices (e.g. pest control programs) will likely also be important in the management of Broad shelled turtles.

The watering requirements for threatened species are met by the watering regimes for LMW1 & 9 (fish, turtles), LMW 1 & 3 (plants, frogs).

Ecosystem function

Condition of priority ecosystem functions

Objective LMW6: Create vital habitat – feeding habitat for waterbirds

By 2030, protect and restore vital feeding habitat that supports sustainable communities of colonial nesting waterbirds, waterfowl, waders and piscivores to maintain the current species diversity at the Lindsay-Mulcra-Wallpolla Icon Site.

Targets for Objective LMW6

- By 2030, support feeding habitat for waterfowl, and herbivore and piscivore waterbirds, 8 years in 10, with the following common species recorded annually: Australian wood duck (*Chenonetta jubata*), Australian darter (*Anhinga novaehollandiae*), Australasian grebe (*Tachybaptus novaehollandiae*), little pied cormorant (*Microcarbo melanoleucos*), Pacific black duck (*Anas superciliosa*), pied cormorant (*Phalacrocorax varius*), white-faced heron (*Egretta novaehollandiae*), and yellow-billed spoonbill (*Platalea flavipes*).
- Feeding habitat defined as a mixture of deep feeding areas (water > 1 m) and shallow feeding areas (< 0.5 m depth and or drying mud) with intermittent inundation of densely vegetated shrublands (flooding of lignum habitat for 5-6 months every 2 years on average).

Rationale for watering regime

The hydrological diversity across the LMW Icon Site offers suitable habitat and feeding opportunities for waterbirds. Jaensch (2002) describes five guilds of feeding habitat for waterbirds at Menindee Lakes, which are applicable to the species commonly found at the LMW Icon Site:

- Feeds mainly in dense inundated vegetation
- Feeds in shallows (0.5 m) and or mud
- Feeds in deep water (> 1 m)
- Feeds away from wetland habitats
- Feeds in non-tidal saline water

The most relevant feeding guilds at the site are shallow and deep water, and areas away from wetland habitats. Deep water habitats are provided by the main channel of the River Murray including the weir pools. These habitats support a large proportion of the fish-eating species and diving specialists including members of the ducks, grebes, cormorants, terns and pelicans. Those that feed in the shallow water habitats and or in mud are reliant on seasonal and intermittent wetlands and inundated floodplain areas for foraging. This guild is often comprised of the largest number of species (Jaensch 2002), and takes advantage of both the wet and drying phase in temporary wetlands.

While feeding habitat is being characterised by water level in this instance, it needs to be noted that this is not an indication of food availability or quality. These factors should be investigated independently where further information and clarification is required.

As part of new (2020) target development, 'Common' species for the LMW Icon Site have been determined from condition monitoring waterbird data. The habitat requirements have been determined from suitable literature and known requirements for the 'common' species.

The watering requirements to support waterbird feeding habitats will be achieved by meeting the water regime requirements for LMW1 and 3.

Objective LMW7: Lateral connectivity to support off-stream productivity

By 2030, improve ecosystem functions of water-dependent ecosystems by maintaining or improving productivity linkages between the river and floodplain habitats (on and off) at the Lindsay-Mulcra-Wallpolla Icon Site by achieving variable extents of lateral connectivity.

Targets for Objective LMW7

- Reinstate small-to-medium (40,000-60,000 ML/d) sized floodplain inundation events on Lindsay, Mulcra and Wallpolla island's at a frequency of 2 to 3 years in 10.
- Reinstate inundation and connectivity of semi-permanent creeks (e.g. Potterwalkagee Creek and the Upper Lindsay River) to the River Murray 5-9 years in 10 and ephemeral creek lines (e.g. Finnigan's and Sandy Creek, Mullaroo-Lindsay connector) to the weir pool (downstream) 8 years in 10.

Rationale for watering regime

The Basin Plan defines connectivity as the connections between natural habitats, such as the river channel, adjacent wetland areas and along the length of rivers. Hydrological connectivity is often taken to refer to the passage of water from one part of the landscape to another, and is expected to generate some catchment run-off response (Bracken and Croke 2007). Three basic elements of connectivity are required for sustaining and preserving ecologically functioning floodplains: lateral hydrological connectivity between the river and floodplain, a variable flow regime which incorporates a range of flow levels, and adequate geographical extent of inundation to allow key processes to occur (Opperman et al. 2010). Connectivity is a central concept in functional aquatic ecosystems, and is a driver of floodplain diversity and productivity, with the periodic inundation of floodplains closely linked to floodplain productivity (e.g. Junk et al. 1989; Kingsford et al. 1999; Covino 2017).

Lateral connectivity can mean connection with the riparian zone and/or the floodplain. Lateral hydrological connectivity is significant in a number of ecological processes and functions (Covino 2017) as it:

- attenuates downstream fluxes and increases watershed nutrient retention;
- can substantially alter or set reach to watershed-scale nutrient flux dynamics;
- influences groundwater recharge and helps maintain base flow; and
- stream incision and loss of connections between the stream/river and riparian/floodplain areas can lead to strong decreases in water and nutrient retention.

Connectivity is bidirectional and depends on hydrologic flow conditions, watershed wetness, and channel-floodplain geomorphology. Connection can be from river out to floodplain during high flow periods and reversed during lower flow conditions. There are three general phases. The first phase occurs when the main channel and floodplain are disconnected, and the dominant biogeochemical pathways are facilitated by biota. In the second phase, there is connection and wetting of the floodplain, which promotes the productivity phase. A significant influx of nutrients arrives with the river water, which when combined with higher residence times, promotes high algal and macrophyte productivity. The third phase represents the peak of connectivity in which the physical transport processes dominate, with particulates and soluble organic matter being mobilised and flushed back into the riverine system (Covino 2017).

Whilst not a direct objective, nutrient and sediment transport associated with longitudinal connectivity is also a priority ecosystem function for the site. Compared to lateral connectivity, longitudinal connectivity is unidirectional (downstream) for water and nutrients (although some upstream connectivity may occur through migration of fish), and bi-directional for organisms (Covino 2017).

The key driver of connectivity in the lower River Murray is the inundation via flooding. Currently, constraints around water delivery down the River Murray channel impact the maximum flow that can be achieved outside of natural flooding. While floodplain infrastructure allows small-to-moderate floodplain inundation to occur in the absence of the equivalent flows in the River Murray, relaxation around delivery and supply constraints in the wider southern MDB may provide future opportunities for watering outside areas managed through infrastructure. This will result in larger, River Murray flow events (supported by environmental water), intending to mimic more natural hydrology, inundation and connectivity.

Previously, this objective has not been measurable, but the new (2020) targets represent knowledge of the process required to support connectivity across the floodplain. Targets also reflect modified ‘natural’ inundation scenarios for known channels. These are described in greater detail in LMW1.

Recruitment and populations of waterbirds

Objective LMW8: Waterbird breeding

By 2030, protect and restore breeding habitat for colonial nesting waterbirds at Lake Wallawalla and non-colonial waterbird breeding at Mulcra Horseshoe and Wallpolla Horseshoe.

Targets for Objective LMW8

- By 2030, increased frequency in successful breeding (recruitment into adult population – i.e. fledging) of one or more of the following colonial nesting cormorant species 3 years in 10, when conditions are favourable at Lake Wallawalla: great cormorant (*Phalacrocorax carbo*), little black cormorant (*Phalacrocorax sulcirostris*), little pied cormorant (*Microcarbo melanoleucos*), and pied cormorant (*Phalacrocorax varius*).

- By 2030, increased frequency in successful breeding (recruitment into adult population – i.e. fledging) of five or more species of non-colonial nesting waterbird species 3 years in 10, when conditions are favourable across the Lindsay-Mulcra-Wallpolla Icon Site. Breeding species to be from different functional groups including ducks and allies, grebes, cranes, crakes, rails, water hens and coots.

Rationale for watering regime

Breeding of colonial waterbird species is somewhat limited within the Mallee region outside flooding. Lake Wallawalla, Mulcra and Wallpolla Horseshoes are, however, known to provide breeding habitat for colonial nesting species when hydrological conditions are favourable and sufficient resources (i.e. food) are available. For the purpose of this objective, breeding habitat is defined as including a watering regime that allows successful recruitment of young into the adult population.

The water regime for colonial nesting species is based on meeting the watering requirements for breeding in great cormorants, as breeding records exist for this icon site. Also, the great cormorant represents an extreme in terms of flooding requirements, so it is assumed that targeting the water requirements of this species will satisfy the breeding and flooding requirements of all other species within the functional group.

Breeding is triggered by both flooding and season, but great cormorants may breed at any time of the year when food is plentiful. To maintain breeding populations, great cormorants require (from Cottingham et al. 2016):

- A large flood (to fill the wetland) with a frequency of 1 flood in every 5 years; and
- Small top up (to maintain suitable habitat) floods every 1-2 years.
- Due to a preference for large deep permanent waters, great cormorants are likely to breed at semi-permanent and ephemeral wetlands opportunistically (Rogers 2011).

Water should be deep enough (e.g. minimum depth of 0.3-0.5 m) to permit diving for prey, and water should be maintained around the nest for the duration of breeding or a minimum of 7 months. For great cormorants, a flood in late-Winter or Spring, through to Autumn accounts for this minimum requirement, but longer durations are preferable. According to Cottingham et al. (2016), the:

- Minimum lag time to commence breeding is 3 months;
- Ideal lag time to commence breeding is 9 months;
- Breeding duration is 4 months;
- Minimum duration of flooding to enable successful breeding is 7 months; and
- Ideal flood duration to enable successful breeding is 13 months.

Non-colonial breeding species – including the ducks, water hens, crakes, dotterels and stilts – are more prevalent across LMW. These species generally breed as dispersed pairs across a range of wetlands and water courses where favorable hydrological regimes and feeding and nesting habitats exist. Habitat for most species is dependent on vegetation, either dead or live trees or shrubs, tree hollows, sedges and reeds, floating vegetation, or nests made from vegetation on the ground. There is evidence to suggest that waterbird breeding occurs when food resources are at a maximum (Kingsford and Norman 2002). This depends on the season and diet of the species and can lag behind the commencement of inundation for periods of four weeks to seven months.

Once breeding has commenced, many Australian waterbirds require surface water to remain in and around nesting sites until offspring are independent feeders (Jaensch 2002). Drying prior to this can lead to abandonment of nests and young by parents, or insufficient food resources for successful fledging. It is suggested that inundation for a minimum of four months would be required to allow for courting/mating, nest site selection and building, incubation and raising of young to independence (Jaensch 2002). Consequently, the watering requirements for great cormorants, as well as those for river red gum and black box outcomes (LMW3), will meet the water requirements of the non-colonial nesting species (Table 6.7).

New (2020) targets developed under LMW8 reflect known water requirements for key or representative species. Incorporated into this are wetland hydrological requirement information and past waterbird data collected though TLM condition monitoring.

Table 6.7. Water regime and requirements for ecological objective LMW8. See also water regime and requirements for river red gum forests and woodlands under Objective LMW3.

Water regime	Water requirements					
	Flow (ML/day)	Depth	Duration	Timing	Frequency	Maximum interflood period
Water regime for great cormorant breeding – opportunistic Spring top-up at Lake Wallawalla	> 40,000	Minimum 0.3-0.5 m	Ideally 13 months, minimum of 7 months under the nesting tree	September to April	Large flood (to fill) 2 in 10 years Top-up flood 1-2 years following a large flooding event.	Three years between maintenance floods
Water regime to support floodplain vegetation (river red gum) and black box as specified in LMW3 will support non-colonial breeding species water requirements.						

Recruitment and populations of native fish

Objective LMW9: Native fish recruitment

By 2030, improve native fish populations (large- and small-bodied fish) across the Lindsay-Mulcra-Wallpolla Icon Site and their relative abundance and diversity; assessment to include comparison with 2006-2012 levels for short-lived species and the spread of age-classes for long-lived fish.

Targets for Objective LMW9

- By 2030, average (mean ± 95 per cent CI) number of large-bodied native species recorded per site for riverine, anabranch and channel habitats is ≥ 6.7 (see Huntley et al. 2016) at enough sites for the P expected score to be ≥ 0.9 in 80 per cent of years. Species include: Murray cod (*Maccullochella peelii*), silver perch (*Bidyanus bidyanus*), golden perch (*Macquaria ambigua*), and freshwater catfish (*Tandanus tandanus*).
- By 2030, evidence of recruitment of small-bodied native fish species on an annual basis, including: Australian smelt (*Retropinna semoni*), carp gudgeon (*Hypseleotris* spp.), flyspecked hardyhead (*Craterocephalus stercusmuscarum fulvus*), and Murray-Darling rainbowfish (*Melanotaenia fluviatilus*):
  - Mean proportion of recruits using P-recruits index is ≥ 0.5 in 80 per cent of sampling events (see Brown et al. 2016).
  - Mean proportion of natives using P-native index is ≥ 0.7 in 80 per cent of sampling events (see Brown et al. 2016).

Rationale for water regime

LMW supports a diverse fish community with a range of hydrological conditions providing a mosaic of habitats for these species. The fish community can be separated into three main groups, each with general watering requirements required by species from within each group.

Long-lived apex predators, such as Murray cod, do not require an increase in flow to facilitate spawning. Higher flows do, however, increase habitat availability for nesting and provide opportunity for juveniles to connect with off-channel nursery habitat. Subsequent connecting flows are important in maintaining links with these habitats as they allow recolonisation of main channel habitats to promote dispersal (Cottingham et al. 2016).

Flow-dependant specialists, such as golden perch and silver perch, require increasing Spring water temperatures to induce the development of ova. They also generally require a flood pulse to initiate spawning in river and (potentially) wetland ecosystems. Adults of this guild often undergo large upstream migrations prior to spawning, with larval fish being carried downstream to aid dispersal (Cottingham et al. 2016).

Foraging generalists, such as carp gudgeon, are less dependent upon large flooding events for recruitment and may benefit from lower flows. These species may benefit from numerous small-scale watering events during the spawning period to assist in habitat availability. For off-stream habitats, a watering regime designed to maximise habitat availability and facilitate connectivity between wetlands across LMW and the main channel is likely to achieve targets for small-bodied native fish. Small-bodied generalist species are also likely to recruit in both main channel and wetland habitats.

Improvement in local habitat and resources, through improved local water management, will potentially support larger populations. Additionally, and importantly, the life-history requirements of key fish species mean that this objective should also consider the broader fish populations at the landscape and even basin-wide scale (and associated landscape scale water management). This is particularly true for flow-dependant specialists, which have large-scale migration patterns and particular spawning requirements. Local conditions during any given year may not meet breeding and recruitment requirements, with a reliance on these conditions elsewhere in the basin, and dispersal, to maintain local populations (Stuart and Sharpe 2020).

Targets have been established following previous refinement of the TLM condition monitoring program (Robinson 2014) and further refined (Brown et al. 2016) following application and testing of the initial targets. This process was undertaken using TLM condition monitoring data. The targets for this objective are expected to be met by the water regime specified for LMW1.

Carp gudgeon (**Hypseleotris spp.*****); a common small-bodied fish to the Lindsay-Mulcra-Wallpolla region (Source D Wood)***

7. Water delivery infrastructure

A range of water management infrastructure for LMW islands have been built across the icon site since 2006 under the Living Murray initiative. These structures assist with water management and when there are high flow events in the River Murray. They allow the regulation of releases in creeks and inundation of wetlands and floodplain, and can be manipulated to extend the duration of flows across some regions. While these structures go some way to assisting with water for the environment delivery, inundation of LMW wetlands and floodplain is limited to an area of approximately 1500 hectares. Much of the current management, outside the use of infrastructure, focuses on the inundation of single wetlands or creek lines using temporary pumps. This can be a costly process, but offers the only means of delivering water for the environment to most sites.

More detailed descriptions of water delivery infrastructure and operational scenarios can be found in the Lindsay-Mulcra-Wallpolla Icon Site Operating Plan (MCMA 2020).

Infrastructure details

Lindsay Island

Water management structures at Lindsay Island consist of six regulators managing water flow into Mullaroo Creek, the Lindsay River, Lake Wallawalla and Webster's Lagoon (Table 7.1).

Table 7.1 Infrastructure and function for water management at Lindsay Island.

Structure	Function
Mullaroo Creek regulator and fishway	Controls flows entering Mullaroo Creek and allows fish passage between the Mullaroo Creek and the River Murray
Lindsay North Regulator	Opened to allow water to enter the Upper Lindsay River North branch during elevated weir pool levels or increase flow in the River Murray.
Lindsay South Regulator	Opened to allow water to enter the Upper Lindsay River South branch during elevated weir pool levels or increase flow in the River Murray.
Lake Wallawalla East Regulator	Opened to allow high river flows to enter Lake Wallawalla. Closed to retain water and allow filling via pumping (permeant pump outlet designed into structure).
Lake Wallawalla West Regulator	Opened to allow high river flows to enter Lake Wallawalla. Closed to retain water and allow filling via pumping.
Webster's Lagoon Regulator	Manages water levels in Webster's Lagoon (allows natural wetting and drying).

Mulcra Island

Seven structures are able to be operated to achieve varying water regimes in the Mulcra Island section of the icon site. These are summarised in Table 7.2.

Wallpolla Island

The only structure currently on Wallpolla Island is a regulator at the western end of Wallpolla Horseshoe, which connects to Finnigan's Creek. The regulator enables control over the extent of inundation, including closing to allow pumped inundation.

Table 7.2. Infrastructure and function for water management at Mulcra Island.

Structure	Function
Upper Potterwalkagee Regulator	Opened to allow water to enter Upper Potterwalkagee Creek during elevated weir pool levels or increase flow in the River Murray.
Stoney Crossing Regulator	Allows periodic drying of Potterwalkagee Creek, controls flow into the lower section of the Potterwalkagee Creek and improves fish passage through Potterwalkagee Creek.
Lower Potterwalkagee Regulator	Allows increased floodplain inundation in conjunction with raising Lock 8 weir pool when closed.
L1 Regulator	Manages water levels in the Mulcra Horseshoe.
L5 Regulator	Manages water levels in the Mulcra Horseshoe.
Mulcra Horseshoe channel	Allows water to flow towards Mulcra Horseshoe from behind the Lower Potterwalkagee Regulator.
'The Cutting' block bank	Prevents flow back into the River Murray under elevated water levels on the floodplain.

River Murray weirs

Three weirs are located directly adjacent the LMW Icon Site (with a further weir located immediately upstream and one downstream). These weirs can be used to manipulate and manage water by raising or lowering the water level. This is defined as weir pool manipulation. The level of variability at each weir is determined by engineering constraints and is different for each of the weirs. Raising and lowering the weir pool influences the hydrological regime at LMW island's (as well as in the River Murray, and the NSW floodplain). These weirs are critical in assisting with delivering environmental flows to anabranch creeks, off-channel wetlands and floodplain (e.g. Mulcra Island), as well as achieving in-channel environmental benefits.

Operational constraints

It is not currently feasible to achieve managed inundation of floodplain across Lindsay and Wallpolla island's, as there is no infrastructure to support water delivery to large areas of the floodplain, or meaningful capacity to boost high/unregulated flows due to constraints in the Murray and tributary systems. Inundation of individual wetlands and ephemeral channels can be undertaken using temporary features (e.g. pumps and levees); however, the majority of assets cannot be watered due to their distance from a water source and the associated pumping cost. The exception is Mulcra Island, which has suitable infrastructure to undertake large-scale floodplain inundation and filling of wetlands and channels within the area that can be watered using the infrastructure.

Inundation on LMW, whether through localised pumping or operation of infrastructure is generally contained to Parks Victoria land and does not reach private land on the Victorian side of the River Murray. Complementing the operation of infrastructure on LMW with that of weir pools (e.g. raising), does result in low-level inundation of some private land in New South Wales.

As operation of the weir pools influences both Victorian and New South Wales waterways and floodplains, joint planning of their operation is essential. This helps to coordinate, where possible, environmental and management objectives across the region. As well as focusing on individual assets, a larger landscape scale view helps with coordinating the delivery of water for the environment, to maximise environmental benefits across the region. Weir pool manipulation planning is currently undertaken in partnership between Victoria and New South Wales, and in consultation with South Australia. The Weir Pool Manipulation Project Steering Committee has also been established for the region to support the coordination of monitoring and planning at the regional scale.

In instances where water for the environment has been delivered to LMW, it may return to the River Murray (or tributaries) where it can be re-used. The return water can be made available for environmental purposes downstream. One of the main concerns around return water is the quality. Return water of poor quality may have detrimental impacts on downstream users, and in order to manage this risk, it is monitored before, during and after any water delivery.

Proposed works

To provide flexibility, the Murray-Darling Basin Plan (Basin Plan) includes a mechanism to adjust Sustainable Diversion Limits in the Southern Basin. The mechanism requires a suite of projects to be implemented so that Basin Plan environmental outcomes can be achieved with less water. Part of this program is the mechanism through which water savings can be made from the building or improvement of river or water management structures.

Through the Sustainable Diversion Limit Adjustment Mechanism, environmental works projects have been identified for Lindsay Island – Lindsay Island (Stage 2) Floodplain Management Project, and Wallpolla Island – Wallpolla Island Floodplain Management Project. These form part of a program of nine environmental works projects called the Victorian Murray Floodplain Restoration Project.

As of 2021, the projects are in Stage 1 (pre-construction), with detailed designs complete. The next step is obtaining regulatory and cultural approvals by undertaking extensive consultation with Traditional Owner's and the broader community over a period of approximately 18 months. Both projects require environmental impact assessment (Environmental Effects Statement) under the Environment Effects Act 1978 (Vic), and have been determined a controlled action under the *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth). The regulatory approvals are required to finalise detailed designs and be ready for construction gateway assessment by the Australian Government. Both projects are scheduled for completion by mid-2024. Expected changes to hydrology and ecology at LMW or within neighbouring floodplain systems (NSW and SA) resulting from proposed works will be considered in detail in the planning process and addressed in future EWMP's, operating plans and via collaborative adaptive management with partner agencies.

As of 2021, New South Wales are in the early stages of investigating a package of works; Lower Murray Sustainable Diversion Limits project: Locks 8 and 9. This program aims at undertaking works that allow changes to operational level through weir pool manipulations at Locks 8 and 9. The program of works also aims to improve connectivity between the River Murray, Carr's, Cappitt's and Bunberoo Creeks and Lake Victoria. It is being undertaken adjacent to, and will interact with, operations on the Victorian floodplain and across LMW.

To find further detail and up-to-date information, please contact the appropriate project teams (Victorian projects; https://www.vmfrp.com.au/ and NSW projects; https://www.industry.nsw.gov.au/water/plans-programs/sdlam).

Lindsay Island

The proposed works will inundate 5,152 hectares and connect many parts of the floodplain (Figure 7.1). This will be achieved through tiered watering events to areas ranging from unique fast-flowing aquatic habitat, through to floodplain sections of black box, lignum and higher alluvial terraces. The proposed works will operate in tandem with the Living Murray works at this site (Stage 1) and Lock 7 to mimic flows ranging from 40,000 ML/day to 120,000 ML/day. They include six major regulators, 13 smaller control structures and 7.5 km of levees.

Wallpolla Island

The works will complement existing works at Wallpolla Islands and proposed works associated with the Locks 8 and 9 Weir Pool Manipulation project. This project will increase the frequency and duration of floodplain inundation across 2,650 hectares (Figure 7.2), providing significant benefit to nationally important species, threatened vegetation communities, ecological values, carbon cycling and downstream water quality. The proposed works include four major regulators, 20 smaller containment regulators and 3.4 kilometres of levees (raised tracks).

Once operational, the new infrastructure and existing TLM infrastructure will be managed concurrently to improve environmental watering capacity across LMW. Specific operation of the new infrastructure in water delivery planning will be incorporated into the next update of this EWMP (and associated schedules), with a revision undertaken once works are completed.

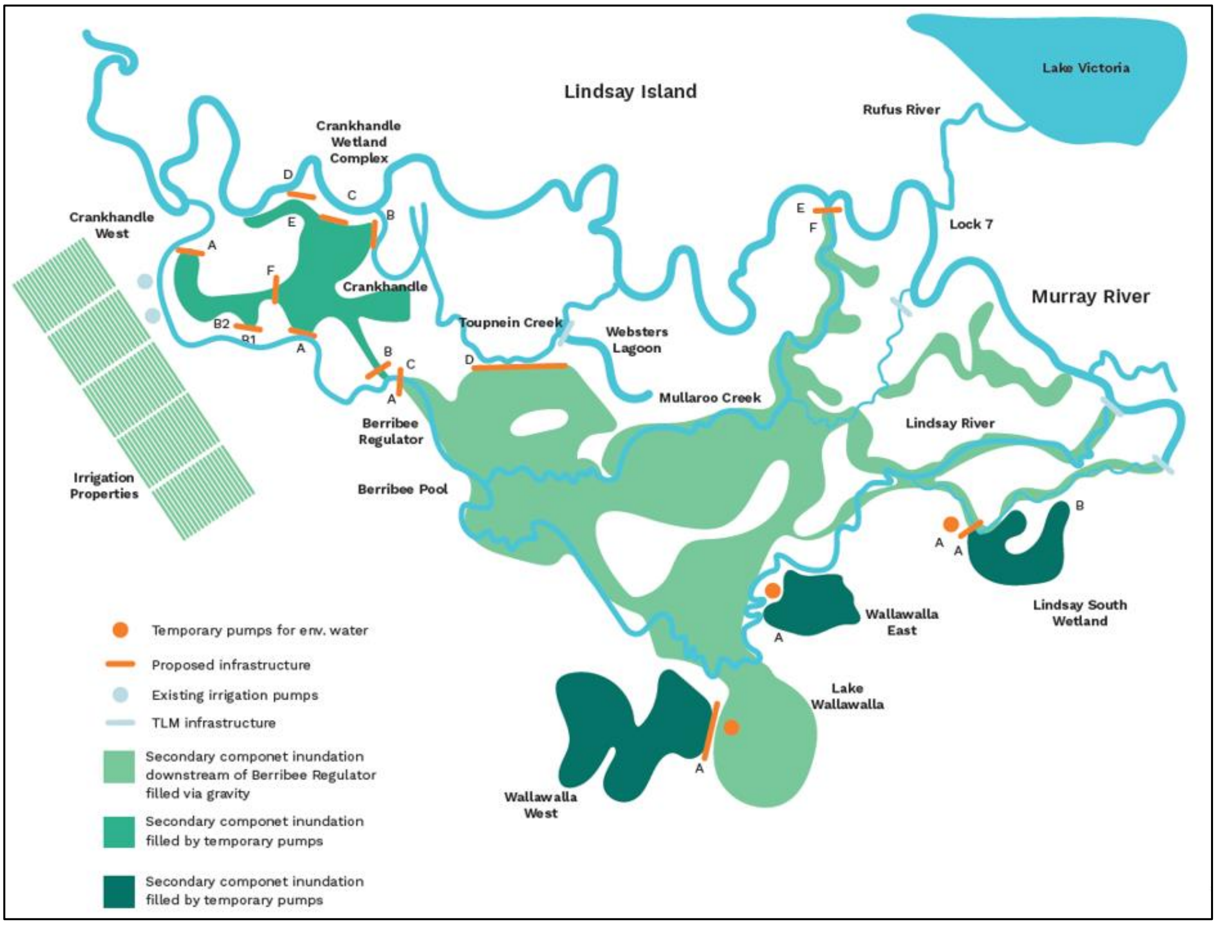


Figure 7.1. Proposed works at Lindsay Island, including areas of inundation.

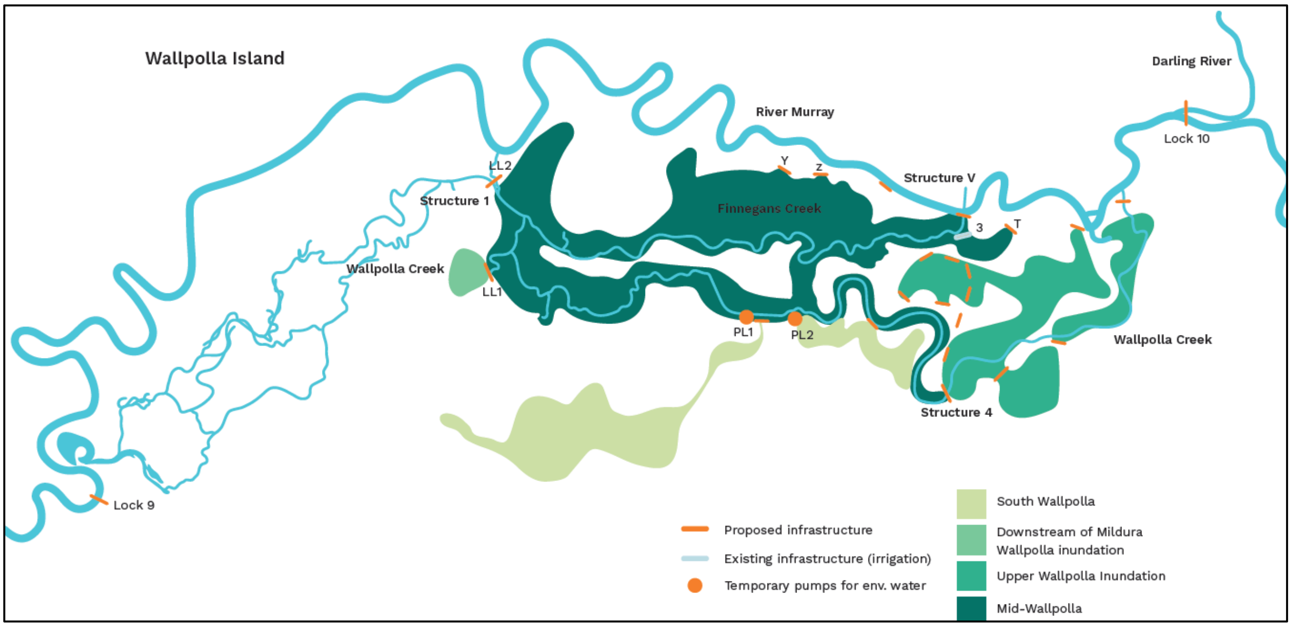


Figure 7.2. Proposed works at Wallpolla Island, including areas of inundation.

8. Managing risks to achieving objectives

While there are clear benefits in restoring a more natural water regime, there are potential threats that must be considered in the planning and delivery of water for the environment. A risk assessment has been undertaken with regards to the adverse effects on the environment which could occur during environmental watering delivery at LMW icon site (Table 8.1). The risks within this table focus on environmental risks only. As part of annual water planning, undertaken in conjunction with VEWH and delivery partners, an extensive risk framework is reviewed and updated. This process identifies potential threats associated with that year's environmental watering program from both an operational and environmental perspective. Where individual threats have been determined as a significant risk, monitoring and mitigation will be carried out, the results of which will be taken into consideration when implementing adaptive management principles.

Table 8.1. Potential environmental risks associated with watering at Lindsay-Mulcra-Wallpolla Islands. (*risk determined from Likelihood × Consequence as per risk matrix in Appendix 6 – Risk description and matrix)

Threat	Likelihood	Consequence	Risk*	Management Measure
Change in ground and surface water salinity impacting survival of flora and fauna	Unlikely	Major	H	Salinity investigations and assessments guiding operations. Targeted investigation Ongoing monitoring
Reduction in hydrodynamic diversity	Unlikely	Moderate	M	Targeted investigation Ongoing monitoring
Managed inundation regimes do not match ecological flow requirements of key species	Possible	Moderate	M	Clear objectives guiding inundation Specific risk assessment identifying species affected under each inundation Keep up-to-date with relevant science Monitoring and targeted investigation
Ecosystem does not respond to environmental watering or condition of values continues to decrease.	Possible	Moderate	M	Review environmental water intervention. Review possible causes for no visible response, considering long-term response or lag phase in response to watering events.
Mis-matching fish/waterbird breeding cues/recruitment and general ecological requirement	Possible	Moderate	M	Clear objectives guiding inundation (targeting birds or fish or individual species) Monitoring and targeted investigation
Mis-match between vegetation (i.e. different species) water requirements	Possible	Moderate	M	Clear objectives guiding inundation (targeting birds or fish or individual species) Monitoring and targeted investigation
Insufficient water regime to meet water dependant community requirements resulting in a community shift	Unlikely	Moderate	M	Maintain long-term inundation scenarios to inundate WRCs at the appropriate time interval Monitoring and targeted investigation
Water depth and/or inundation period insufficient to benefit, or negatively impacts certain vegetation species	Possible	Moderate	M	Flood depth managed to avoid overly deep inundation on the floodplain Manage inundation length according to specific requirements of the WRCs Manage inundation length according to specific requirements of the WRCs Monitoring and targeted investigation

Threat	Likelihood	Consequence	Risk*	Management Measure
Stranding/isolation of native fish on floodplain/in wetlands flowing inundation or drawdown	Almost certain	Moderate	H	Clear objectives guiding inundation (identify that fish will be stranded and water the inundation will benefit) Identify options and practicality of returning fish to river (e.g. weir pool manipulation)
Barriers to fish (and aquatic fauna) movement	Unlikely	Moderate	M	Appropriate design and operation of fish passages (i.e., fishways) Monitoring and targeted investigation
Enhancing carp and other pest fish recruitment conditions	Likely	Major	M	Clear objectives guiding inundation (is to benefit native species) Shift timing (outside carp breeding period) or use preventative measures (carp screen) to prevent recruitment and colonisation Monitoring and targeted investigation
Flow regime favouring high risk invasive plant species	Likely	Moderate	H	Clear objectives guiding inundation (is to benefit native species) Shift timing to prevent recruitment (outside germination period) Monitoring and targeted investigation
Poor water quality (including blue-green algae proliferation) on floodplain or in wetlands	Unlikely	Minor	L	Use models to identify potential issues early and manage accordingly Adjust timing and flexibility in application of water Monitoring and targeted investigation
Poor water quality downstream following inundation and return of water to main channel	Unlikely	Moderate	M	Use models to identify potential issues early and manage accordingly Adjust timing and flexibility in application of water Monitoring and targeted investigation
Blackwater events result from watering	Unlikely	Minor	L	Use models to identify potential issues early and manage accordingly Monitoring and targeted investigation
Increase in native and non-native pest mammals (pigs, rabbits, kangaroos)	Almost certain	Moderate	H	Clear objectives guiding inundation (is to benefit certain species/communities) Shift timing to prevent recruitment (outside breeding period) Implement appropriate control measures (i.e., culling/eradication) Monitoring and targeted investigation

9. Demonstrating outcomes

Environmental monitoring

A range of monitoring programs and activities are used to assess progress towards meeting the LMW Icon Site ecological objectives. These include Basin-wide tree condition assessments and aerial waterbird surveys, and TLM icon site condition and intervention monitoring.

The Living Murray Outcomes Evaluation Framework (MDBC 2007) outlines the rationale for the TLM monitoring methods, which are summarised below.

Icon site condition monitoring

Icon site condition monitoring focuses on assessing progress against site-specific objectives and targets through a regular monitoring cycle. Since the start of the TLM monitoring program in 2007, the site objectives and supporting condition monitoring plans have been refined to reflect learnings from over ten years of data collection. The evolution of the condition monitoring program has seen the establishment of site-specific objectives and a refinement program to develop indices and reference targets that assist with addressing the objectives. The recent review by the Mallee CMA, as outlined in Section 6, has revised the ecological objectives to improve alignment with the Basin Plan and develop SMART targets for the LMW Icon Site.

Annual icon condition monitoring at LMW focuses on fish, waterbirds and vegetation, and these are linked to icon site-specific ecological objectives. Icon site annual condition monitoring uses locally appropriate. This monitoring responds to unique icon site characteristics and, at LMW, includes:

- tree condition;
- tree population structure;
- understorey plant assemblages, including wetland and floodplain species, and targeted surveys to assess lignum (*Duma florulenta*) condition and cumbungi (*Typha* sp.) extent;
- fish community surveys; and
- waterbirds.

These assessments are used to determine shifts in species composition, trends and condition, and are compared with a point of reference, or target value. The point of reference provides a means of tracking progress towards, or away from the ecological objectives relevant to the icon site for each component.

Tree condition

Since 2008, tree condition assessments of river red gum and black box trees have been conducted annually at locations within the Lindsay-Mulcra-Wallpolla Icon Site. Sites are stratified across the icon site to include the main forest-woodland vegetation types. Assessment of condition using the Tree Condition Method (MDBA 2009) is undertaken at both river red gum and black box sites of 30 trees each, in Summer annually.

Tree population structure

Since 2008, transect surveys to establish the population structure (size class) of river red gum and black box have been undertaken. Sites are geographically stratified across the icon site to include the main forest-woodland vegetation types. Transects are of varying lengths (100-200 m) and 20 m wide. Within each transect, all river red gum or black box are counted and their Diameter at Breast Height (DBH) measurements are taken. As population structure is likely to vary little from year to year, surveys are conducted on a three-year rolling basis (i.e. a full survey period therefore takes three years to complete). Every three years, the structure of river red gum and black box populations can be compared to the Population Status Index, to determine if the populations are moving toward, or away from a sustainable level.

Lignum condition

At the LMW Icon Site, lignum communities are represented by three EVCs: lignum shrubland, lignum swamp and lignum woodlands. Lignum monitoring sites are geographically distributed across the icon site to represent the lignum community. Annual assessments of lignum monitoring sites (20 × 20 m quadrat) determine the proportion of above ground biomass using the Lignum Condition Index (LCI). The LCI provides a means of determining the condition of lignum across the icon site.

Wetland understorey

Since 2007, understorey wetland vegetation monitoring sites across semi-permanent wetlands and ephemeral wetlands have been assessed annually at the icon site. Assessments at each wetland are undertaken using transects located between the base of the wetlands and top of their banks. At pre-determined elevations (quadrats) along each transect, presence of species is recorded through a series of 1 m × 1 m cells. This information allows calculation of species richness and species abundance of understorey vegetation species.

Floodplain understorey

Understorey floodplain vegetation monitoring sites that determine species richness and abundance at various elevations on the floodplain were established in 2007-08. These were categorised as often flooded, sometimes flooded and rarely flooded. Annual surveys assess for the presence of species from replicate cells across transects within each flooding category. A point of reference index was developed for species richness and species abundance for each flooding category. This reference provides a means of assessing the spatio-temporal patterns across floodplain understorey species, and is ultimately used to determine whether there is progress towards, or away from the ecological objectives.

Cumbungi

The distribution and potential expansion of cumbungi (*Typha* sp.) is monitored at the LMW Icon Site. Creek and River Murray reaches are assessed for the presence and distribution of cumbungi. Total length of individual stands is compiled to determine the total combined length (and percent bank cover) of cumbungi stands along the banks of target reaches.

Fish community

At the LMW Icon Site, over thirty fixed monitoring sites have been established across various anabranches and the River Murray. Surveys are conducted annually in Autumn using a combination of methods and sampling equipment, including boat electrofishing, backpack electrofishing, and fyke and seine nets. The condition of the sampled fish population is assessed using three indices: Recruitment Index, Nativeness Index and Expectedness Index. The reference indices provide a means of assessing the spatio-temporal patterns in fish populations.

Waterbirds

Trends in waterbird populations have been investigated across the LMW Icon Site since the mid 2000's. Permanent monitoring sites have been established at seven wetlands, and a standardised count used to identify species and numbers of waterbirds at each location. Surveys are undertaken biannually, in Spring and Autumn to determine the waterbird community.

Vegetation off-set monitoring

Monitoring undertaken as part of the condition monitoring is also used for reporting on off-set monitoring, which is required as part of the legislative approval for the TLM water management infrastructure at the icon site.

Conditions are applied under Victoria's Native Vegetation Framework, which aim to achieve a net gain in the extent and condition of native vegetation across the state. This asserts that any native vegetation clearing associated with TLM infrastructure can be offset using the measured improvement in condition of the areas watered by the works. As a result of unavoidable removal of native vegetation associated with TLM infrastructure, an offset management plan was developed for vegetation at Mulcra Island. Offset survey monitoring was undertaken in year two (2014-15) and year five (2018-19), and will be completed in year 10 (2024) following vegetation removal. This policy recognises that significant biodiversity gains will occur through large-scale environmental watering, and require implementation of a monitoring program across proposed offset sites to demonstrate the maintenance or improvement of vegetation condition.

Intervention monitoring

To improve icon site management and enhance ecological outcomes, intervention monitoring investigates the links between environmental watering, infrastructure and ecological outcomes. Intervention monitoring targets environmental watering events that will inform key knowledge gaps and ecological questions. These results can be applied to other icon sites with similar ecological communities, hydrology and processes. Intervention monitoring provides the ultimate adaptive management approach, allowing targeted management questions to be answered.

Intervention monitoring can focus on various components of an environmental watering event, including abiotic factors such as water quality, ground water and salinity, and biotic factors such as fish, birds, or vegetation. Understanding interactions between environmental water, and abiotic and biotic factors is essential to developing an understanding of the impact and outcomes at a landscape scale, and be used to direct future management at an asset.

A wide range of intervention monitoring projects have been undertaken across the LMW Icon Site since 2004. The following section takes a brief look at the types of projects that have previously been undertaken. A summary of all historic report references can be found in the Watering Guide for this icon site.

Vegetation

In 2016-17, a project was established investigating the effect of flooding history on black box tree condition and regeneration at Lindsay and Mulcra islands. Specifically, the project examined the population status, regeneration and condition of black box trees under two flooding treatments: (1) 'recently flooded' and (2) 'historically flooded'.

In 2018, surveys of aquatic vegetation condition were undertaken at Lake Wallawalla to provide baseline information on productivity, food sources and habitat availability for fauna that use the littoral zone of the lakebed.

Undertaking environmental monitoring (Source D Wood).

Fish

From 2007, various projects have been implemented to assess the response of local fish assemblages to environmental watering events at Lindsay and Mulcra island's.

Between 2007 and 2008, the impact of low flows and drought on the spatio-temporal distribution of fish assemblages in the Mullaroo Creek-Lindsay River complex was investigated.

Since 2013, the movement of fish in response to flow has been assessed across Lindsay and Mulcra island's. Monitoring has been undertaken using various methods to assess the movement of individual fish across the landscape, their broad-scale use of floodplain and anabranch channels, and influence of structures on breeding success. Outcomes from this program provide an improved understanding of migration cues and habitat use by native and exotic fish species under a range of managed and natural flow events.

In 2018-19, the quality and availability of structural woody habitat and River Murray channel bed characteristics for weir pool's 8, 7 and 6 were mapped using side scan sonar, boat-based LiDAR and drone photogrammetry. Detailed outputs will be used to ensure there is sufficient habitat complexity for native large-bodied species during managed weir pool operations.

Birds

Between 2013 and 2015, the abundance and breeding activity of waterbirds in response to specific environmental watering events was investigated at Mulcra Island.

Since 2015, surveys of floodplain woodland bird communities were conducted on Mulcra Island in response to environmental watering to assess the bird communities across varied vegetation types. In 2018, surveys of Lindsay Island were added and the project was ongoing into 2020.

Frogs

Between 2009 and 2014, infrequent monitoring of frog and tadpole populations in response to environmental watering events occurred at the LMW Icon Site.

Ecosystem processes

From 2004, various projects have been undertaken to develop hydrologic and hydraulic models for Lindsay, Mulcra and Wallpolla islands, to assist in the assessment of water management options and to facilitate the development of flow enhancement strategies.

Concerns around returning poor quality water back to the River Murray following the operation of the Lower Potterwalkagee Regulator and flows in the Lindsay River prompted the monitoring of water quality between 2013 and 2015.

In 2018-19, the response of the aquatic ecosystem and vegetation communities to variable water levels in Lake Wallawalla was investigated. The study assessed conditions in the littoral zone to provide information on productivity, and the food reserve and habitat available for birds and fish that currently or potentially use the lake.

In 2018, a project was established to estimate the organic litter loads on the Lindsay-Wallpolla Icon Site floodplains, and to quantify the potential concentrations of dissolved organic carbon (DOC) leached from litter on the floodplains during managed flooding. This program was completed in 2021 with the development of a blackwater model for Lindsay and Mulcra. This will be an important tool for future planning of environmental watering events.

In addition to monitoring ecological outcomes and risks, groundwater and salinity monitoring is undertaken across the icon site.

Adaptive management

An adaptive approach is critical in managing water-dependent ecosystems, as it enables waterway managers, land managers and policy-makers to update strategies based on the outcomes of research and watering actions. This is known as 'learning by doing', and involves designing, implementing, monitoring, reporting and evaluating our work.

Environmental water management plans are constantly refined though adaptive management, by incorporating outcomes from environmental delivery, ecological monitoring, works, modelling and community consultation.

A close relationship is required between water management and monitoring to ensure that the system is operated to optimise ecological outcomes and minimise environmental risks. Management of water for the environment occurs adaptively in line with the following process (see Figure 9.1 and Table 9.1).

Table 9.1. A description of each stage of the management cycle.

Stage	Description
Assessment	The ecological issues, objectives, water requirements, priority areas and actions, and associated risks for restoring the floodplain are assessed. This assessment includes information gathered as part of earlier stages of the adaptive management process. This stage also requires community and expert input.
Design	Knowledge of the floodplain condition and its ecology are used to develop hypotheses, in terms of expected responses, and set objectives and targets. Interventions are designed, including a proposed package of works and operating rules. Agreed changes from earlier stages of the cycle are converted into changes to structural, operational or procedural plans.
Implementation	The recommended interventions are implemented.
Monitoring	The monitoring program is coordinated by the local Catchment Management Authority in conjunction with land managers. The different types of monitoring are discussed later in this section.
Evaluation	The monitoring results are evaluated in light of the expected outcomes (i.e. ecological response). Triggers are identified to inform if/how management needs to adjust (e.g. the size of flood event adopted, depending on water availability). Both short- and long-term triggers are used. Short-term triggers include water movement into or out of structures, and whether specific biota (flora and fauna) begin to appear. Long-term triggers include more detailed targets for ecological response over time.
Adjustment	The Icon Site Managers consider the monitoring outcomes (and any new knowledge on the issues) to determine whether changes are required to the operating strategy and to redefine the expected outcomes from the operation (i.e. the objectives).

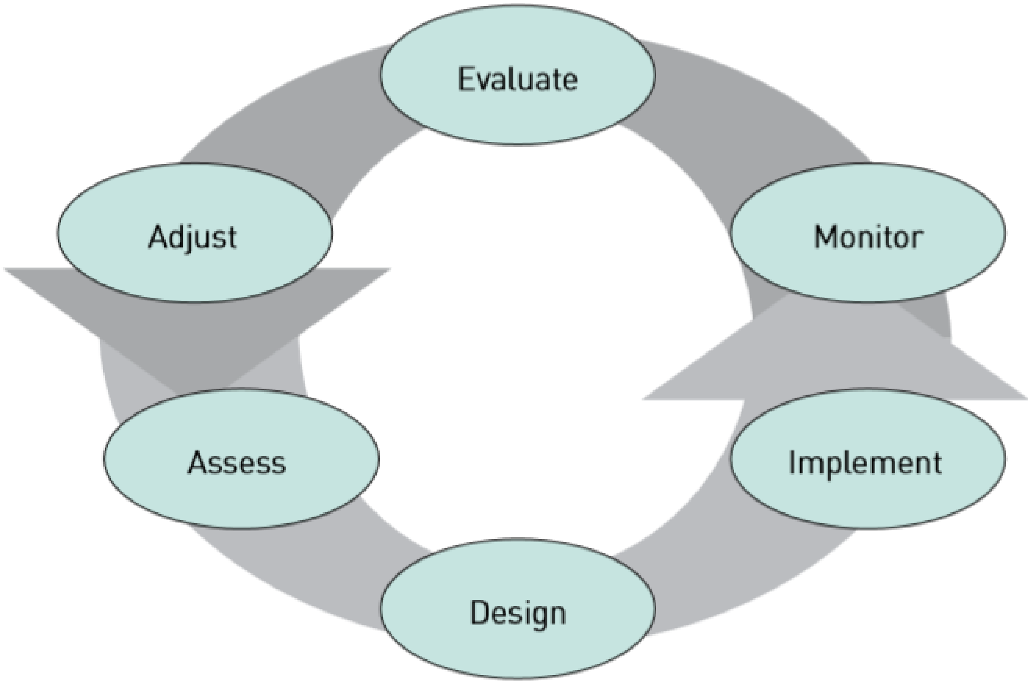


Figure 9.1. The adaptive management cycle.

Reporting

TLM monitoring is used to report on and evaluate outcomes of watering events, and to improve the delivery of water for the environment in subsequent years. Reporting of outcomes is undertaken by the Victorian government, Victorian Catchment Management Authorities, MDBA, VEWH and the Commonwealth Environmental Water Holder. For example, each year icon site asset report cards, which report on the health of each of the icon sites, are published on the MDBA website (https://www.mdba.gov.au/issues-murray-darling-basin/water-for-environment/water-over-time). These report cards use condition monitoring results to assess site health and track progress against site ecological objectives.

An annual report on the work of SCBEWC is provided to the Murray-Darling Basin Ministerial Council and published on the MDBA website (https://www.mdba.gov.au/publications/mdba-reports/southern-connected-basin-environmental-water-committee-annual-reports). The report provides information on watering actions, environmental outcomes, lessons learnt, communication and community involvement. It also provides an overview on the use of jointly managed TLM water and other TLM activities.

Outcome reporting is also provided by Victoria through Basin Plan annual reporting, 5-year reporting and the VEWH's annual Reflections report, which provides stories of how water for the environment is improving the health of our waterways for Victorian communities.

Abbreviations and acronyms

Abbreviation	Description
AHD	Australian Height Datum
BWS	Basin-Wide Environmental Watering Strategy
CAMBA	China-Australia Migratory Bird Agreement
DELWP	Department of Environment, Land, Water and Planning
EPBC	*Environment Protection and Biodiversity Conservation Act 1999*
EVC	Ecological Vegetation Class
FFG	*Flora and Fauna Guarantee Act 1988*
FPMMAC	First Peoples of the Millewa-Mallee Aboriginal Corporation
FSL	Full Supply Level
JAMBA	Japan-Australia Migratory Bird Agreement
LMW	Lindsay-Mulcra-Wallpolla
LTWP	Long-term Watering Plan
MCMA	Mallee Catchment Management Authority
MDB	Murray-Darling Basin
MDBA	Murray-Darling Basin Authority
MDBC	Murray-Darling Basin Commission
ML/d	Megalitres a day
NSW	New South Wales
PEA	Priority Ecosystem Assets
PEF	Priority Ecosystem Functions
POE	Probability of Exceedance
RAP	Registered Aboriginal Party
RoKAMBA	Republic of Korea-Australia Migratory Bird Agreement
SCBEWC	Southern Connected Basin Environmental Water Committee
TLM	The Living Murray
VEWH	Victorian Environmental Water Holder
Q	Flow
QEEO	Quantified Environmental Expected Outcomes
WRC	Water Regime Class

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Appendix 1 – Fauna species list

List of fauna species recorded from Lindsay-Mulcra-Wallpolla; including conservation status. Environment Protection and Biodiversity Conservation (EPBC) Act 1999; CE=Critically Endangered, EN=Endangered, VU=Vulnerable. Conservation status in Victoria (VRoTS); cr=critically endangered, en=endangered, vu=vulnerable, nt=near threatened, dd=data deficient (DSE 2013). FFG; L=Listed (DELWP 2019b). Non-native species*.

REPTILES				
Common name	**Scientific name**	**EPBC**	**VRoTS**	**FFG**
Common death adder	*Acanthophis antarcticus*		dd	L
Broad-shell turtle	*Chelodina expansa*		en	L
Common long-neck turtle	*Chelodina longicollis*		dd	
Marbled gecko	*Christinus marmoratus*			
Carnaby's wall skink	*Cryptoblepharus carnabyi*			
Painted dragon	*Ctenophorus pictus*			
Saltbush striped skink	*Ctenotus olympicus*		cr	
Eastern striped skink	*Ctenotus orientalis*			
Regal striped skink	*Ctenotus regius*			
De Vis' banded snake	*Denisonia devisi*		cr	
Bearded gecko	*Diplodactylus damaeus*			
Southern spiny-tailed gecko	*Diplodactylus intermedius*			
Tessellated gecko	*Diplodactylus tessellatus*			
Tree skink	*Egernia striolata*			
Murray River turtle	*Emydura macquarii*		vu	L
Eastern water skink	*Eulamprus quotii*		nt	
Red-naped snake	*Furina diadema*		vu	L
Tree dtella	*Gehyra variegata*			
Bynoe's gecko	*Heteronotia binoei*			
Bougainville's skink	*Lerista bougainvillii*			
Spotted burrowing skink	*Lerista punctatovittata*			
Bearded gecko	*Lucasium damaeum*			
Grey's skink	*Menetia greyii*			
Murray-Darling carpet python	*Morelia spilota metcalfei*		en	L
Boulenger's skink	*Morethia boulengeri*			
Thick-tailed gecko	*Nephrurus milii*			
Central bearded dragon	*Pogona vitticeps*			
Western brown snake	*Pseudonaja nuchalis*		dd	
Red-bellied black snake	*Pseudechis porphyriacus*			
Eastern brown snake	*Pseudonaja textilis*			
West Australian blind snake	*Ramphotyphlops australis*			
Dark-spined blind snake	*Ramphotyphlops bicolor*			
Peter's blind snake	*Ramphotyphlops bituberculatus*			
Mallee-black-backed snake	*Rhinoplocephalus nigriceps*			

REPTILES				
Common name	**Scientific name**	**EPBC**	**VRoTS**	**FFG**
Beaked gecko	*Rhynchoedura ornata*		cr	L
Mitchell's short-tailed snake	*Suta nigriceps*			
Curl snake	*Suta suta*		vu	
Stump-tailed lizard	*Tiliqua rugosa*			
Thick-tailed gecko	*Underwoodisaurus milii*			
Sand goanna	*Varanus gouldii*			
Lace monitor	*Varanus varius*		en	

MAMMALS				
Common name	**Scientific name**	**EPBC**	**VRoTS**	**FFG**
Feathertail glider	*Acrobates pygmaeus*			
Feral cattle	*Bos taurus**			
Goat	*Capra hircus**			
Gould's wattled bat	*Chalinolobus gouldii*			
Chocolate wattled bat	*Chalinolobus morio*			
Little pied bat	*Chalinolobus picatus*			
Water-rat	*Hydromys chrysogaster*			
Cat	*Felis catus**			
European hare	*Lepus europeaus*			
Western grey kangaroo	*Macropus fuliginosus*			
Eastern grey kangaroo	*Macropus giganteus*			
Red kangaroo	*Macropus rufus*			
Southern freetail bat (LP)	*Mormopterus ozimops plaiceps*			
Freetail bat	*Mormopterus ozimops petersi*			
Freetail bat	*Mormopterus ozimops ridei*			
House mouse	*Mus musculus**			
Large-footed myotis	*Myotis macropus*			
Corben's long-eared bat	*Nyctophilus corbeni*	VU	en	L
Lesser long-eared bat	*Nyctophilus geoffroyi*			
Gould's long-eared bat	*Nyctophilus gouldi*			
European rabbit	*Oryctolagus cuniculus**			
Giles' planigale	*Planigale gilesi*		nt	L
Grey-headed flying-fox	*Pteropus poliocephalus*	VU	vu	L
Little red flying-fox	*Pteropus scapulatus*			
Yellow-bellied sheath-tailed Bat	*Saccolaimus flaviventris*		dd	L
Inland broad-nosed bat	*Scotorepens balstoni*			
Little broad-nosed bat	*Scotorepens greyii*			
Fat tailed dunnart	*Sminthopsis crassicaudata*		nt	
Feral pig	*Sus scrofa**			
Short beaked echidna	*Tachyglossus aculeatus*			
Common brush-tailed possum	*Trichosurus vulpecula*			

MAMMALS				
Common name	**Scientific name**	**EPBC**	**VRoTS**	**FFG**
White-striped freetail bat	*Tadarida australis*			
Inland forest bat	*Vespadelus baverstocki*			
Large forest bat	*Vespadelus darlingtoni*			
Southern forest bat	*Vespadelus regulus*			
Little forest bat	*Vespadelus vulturnus*			
Red fox	*Vulpes vulpes**			
Black wallaby	*Wallabia bicolor*			

FISH				
Common name	**Scientific name**	**EPBC**	**VRoTS**	**FFG**
Silver perch	*Bidyanus bidyanus*	CE	vu	L
Goldfish	*Carassius auratus**			
Un-specked hardyhead	*Craterocephalus stercusmuscarum fulvus*			L
Common carp	*Cyprinus carpio carpio**			
Eastern mosquitofish	*Gambusia holbrooki**			
Carp gudgeon	*Hypseleotris* spp.			
Spangled perch	*Leiopotherapon unicolor*			
Murray cod	*Maccullochella peelii*	VU	vu	L
Golden perch	*Macquaria ambigua*		nt	
Murray-Darling rainbowfish	*Melanotaenia fluviatilis*		vu	L
Oriental weatherloach	*Misgurnus anguillicaudatus**			
Bony herring	*Nematalosa erebi*			
European perch	*Perca fluviatilis**			
Flathead gudgeon	*Philypnodon grandiceps*			
Dwarf flathead gudgeon	*Philypnodon macrostomus*			
Australian smelt	*Retropinna semoni*			
Freshwater catfish	*Tandanus tandanus*		en	L

FROGS				
Common name	**Scientific name**	**EPBC**	**VRoTS**	**FFG**
Plains froglet	*Crinia parinsignifera*			
Eastern banjo frog	*Limnodynastes dumerilii*			
Barking marsh frog	*Limnodynastes fletcheri*			
Spotted marsh frog	*Limnodynastes tasmaniensis*			
Peron's tree frog	*Litoria peroni*			
Growling grass frog	*Litoria raniformis*	VU	en	L
Common spadefoot toad	*Neobatrachus sudelii*			

BIRDS				
Common name	**Scientific name**	**EPBC**	**VRoTS**	**FFG**
Spiny-cheeked honeyeater	*Acanthagenys rufogularis*			
Inland thornbill	*Acanthiza apicalis*			
Yellow-rumped thornbill	*Acanthiza chrysorrhoa*			
Striated thornbill	*Acanthiza lineata*			
Yellow thornbill	*Acanthiza nana*			
Buff-rumped thornbill	*Acanthiza reguloides*			
Chestnut-rumped thornbill	*Acanthiza uropygialis*			
Eastern spinebill	*Acanthorhynchus tenuirostris*			
Collared sparrowhawk	*Accipiter cirrhocephalus*			
Brown goshawk	*Accipiter fasciatus*			
Australian reed-warbler	*Acrocephalus australis*			
Clamorous reed warbler	*Acrocephalus stentoreus*			
Australian owlet-nightjar	*Aegotheles cristatus*			
Skylark	*Alauda arvensis*			
Striated grass-wren	*Amytornis striatus*		nt	
Chestnut teal	*Anas castanea*			
Grey teal	*Anas gracilis*			
Australasian shoveler	*Anas rhynchotis*		vu	
Pacific black duck	*Anas superciliosa*			
Australasian darter	*Anhinga novaehollandiae*			
Red wattlebird	*Anthochaera carunculata*			
Australian pipit	*Anthus novaeseelandiae*			
Southern whiteface	*Aphelocephala leucopsis*			
Wedge-tailed eagle	*Aquila audax*			
Great egret	*Ardea alba*			L
Intermediate egret	*Ardea intermedia*		en	L
Eastern great egret	*Ardea modesta*		vu	
White-necked heron	*Ardea pacifica*			
Black-faced wood-swallow	*Artamus cinereus*			
Dusky wood-swallow	*Artamus cyanopterus*			
White-breasted wood-swallow	*Artamus leucorynchus*			
Masked wood-swallow	*Artamus personatus*			
White-browed wood-swallow	*Artamus superciliosus*			
Hardhead	*Aythya australis*		vu	
Australian ringneck	*Barnardius zonarius*			
Mallee ring neck parrot	*Barnardius zonarius* subsp. *barnardi*			
Musk duck	*Biziura lobata*		vu	
Cattle egret	*Bubulcus ibis*			
Bush stone-curlew	*Burhinus grallarius*		en	L
Sulphur-crested cockatoo	*Cacatua galerita*			

BIRDS				
Common name	**Scientific name**	**EPBC**	**VRoTS**	**FFG**
Major Mitchell's cockatoo	*Cacatua leadbeateri*		vu	L
Little corella	*Cacatua sanguinea*			
Fantail cuckoo	*Cacomantis flabelliformis*			
Sharp-tailed sandpiper	*Calidris acuminata*			
Red-necked stint	*Calidris ruficollis*			
European goldfinch	*Carduelis carduelis**			
Black honeyeater	*Certhionyx niger*			
Pied honeyeater	*Certhionyx varegatus*			
Inland dotterel	*Charadrius australis*		vu	
Red-capped plover	*Charadrius ruficapillus*			
Australian wood duck	*Chenonetta jubata*			
White-backed swallow	*Cheramoeca leucosternus*			
Spotted bowerbird	*Chlamydera maculata*		cr	L
Whiskered tern	*Chlidonias hybrida*		nt	
Silver gull	*Chroicocephalus novaehollandiae*			
Horsfield's bronze cuckoo	*Chrysococcyx basalis*			
Black-eared cuckoo	*Chrysococcyx osculans*		nt	
Brown songlark	*Cincloramphus cruralis*			
Rufous songlark	*Cincloramphus mathewsi*			
Chestnut quail-thrush	*Cinclosoma castanotus*		nt	
Swamp harrier	*Circus approximans*			
Spotted harrier	*Circus assimilis*			
Banded stilt	*Cladorhynchus leucocephalus*			
White-browed treecreeper	*Climacteris affinis*		vu	L
Brown tree-creeper	*Climacteris picumnus*			
Grey shrike-thrush	*Colluricincla harmonica*			
Feral pigeon	*Columba livia*			
Ground cuckoo-shrike	*Coracina maxima*		vu	L
Black-faced cuckoo-shrike	*Coracina novaehollandiae*			
White-bellied cuckoo-shrike	*Coracina papuensis*			
White-winged chough	*Corcorax melanorhamphos*			
White-throated treecreeper	*Cormobates leucophaeus*			
Little crow	*Corvus bennetti*			
Australian raven	*Corvus coronoides*			
Little raven	*Corvus mellori*			
Stubble quail	*Coturnix pectoralis*			
Brown quail	*Coturnix ypsilophora*			
Pied butcherbird	*Cracticus nigrogularis*			
Grey butcher bird	*Cracticus torquatus*			
Pallid cuckoo	*Cuculus pallidus*			

BIRDS				
Common name	**Scientific name**	**EPBC**	**VRoTS**	**FFG**
Black swan	*Cygnus atratus*			
Laughing kookaburra	*Dacelo novaeguineae*			
Varied sittella	*Daphoenositta chrysoptera*			
Mistletoebird	*Dicaeum hirundinaceum*			
Emu	*Dromaius novaehollandiae*		nt	
Southern scrub-robin	*Drymodes brunneopygia*			
Little egret	*Egretta garzetta*		en	L
White-faced heron	*Egretta novaehollandiae*			
Black-fronted dotterel	*Elseyornis melanops*			
Blue-faced honeyeater	*Entomyzon cyanotis*			
White-fronted chat	*Epthianura albifrons*			
Galah	*Eolophus roseicapilla*			
Orange chat	*Epthianura aurifrons*			
Crimson chat	*Epthianura tricolor*			
Red-kneed dotterel	*Erythrogonys cinctus*			
Spotted nightjar	*Eurostopodus argus*			
Brown falcon	*Falco berigora*			
Nankeen kestrel	*Falco cenchroides*			
Australian hobby	*Falco longipennis*			
Peregrine falcon	*Falco peregrinus*			
Crested (Eastern) shrike-tit	*Falcunculus frontatus*			
Eurasian coot	*Fulica atra*			
Dusky moorhen	*Gallinula tenebrosa*			
Black-tailed native-hen	*Gallinula ventralis*			
Buff-banded rail	*Galliraillus philippensis*			
Gull-billed tern	*Gelochelidon nilotica*		en	L
Dimond dove	*Geopelia cuneata*		nt	L
Peaceful dove	*Geopelia placida*			
Western gerygone	*Gerygone fusca*			
Purple-crowned lorikeet	*Glossopsitta porphyrocepala*			
Little lorikeet	*Glossopsitta pusilla*			
Magpie lark	*Grallina cyanoleuca*			
Australian magpie	*Gymnorhina tibicen*			
White-bellied sea-eagle	*Haliaeetus leucogaster*		vu	L
Whistling kite	*Haliastur sphenurus*			
Black-breasted buzzard	*Hamirostra melanosternon*			
Little eagle	*Hieraaetus morphnoides*			
Black-winged stilt	*Himantopus himantopus*			
Welcome swallow	*Hirundo neoxena*			
Caspian tern	*Hydroprogne caspia*		vu	L

BIRDS				
Common name	**Scientific name**	**EPBC**	**VRoTS**	**FFG**
Shy heath-wren	*Hylacola cauta*			
White-winged triller	*Lalage tricolor*			
Malleefowl	*Leipoa ocellata*	VU	en	L
White-eared honeyeater	*Lichenostomus leucotis*			
Yellow-plumed honeyeater	*Lichenostomus ornatus*			
White-plumed honeyeater	*Lichenostomus penicillatus*			
Singing honeyeater	*Lichenostomus virescens*			
Pink-eared duck	*Malacorhynchus membranaceus*			
Superb fairy-wren	*Malurus cyaneus*			
Variegated fairy-wren	*Malurus lamberti*			
White-winged fairy-wren	*Malurus leucopterus*			
Splendid fairy-wren	*Malurus splendens*			
Yellow-throated miner	*Manorina flavigula*			
Noisy miner	*Manorina melanocephala*			
Little grassbird	*Megalurus gramineus*			
Hooded robin	*Melanodryas cucullata*			L
Brown-headed honeyeater	*Melithreptus brevirostris*			
White-naped honeyeater	*Melithreptus lunatus*			
Budgerigar	*Melopsittacus undulatus*			
Rainbow bee-eater	*Merops ornatus*			
Little pied cormorant	*Microcarbo melanoleucos*			
Jacky Winter	*Microeca fascinans*			
Black kite	*Milvus migrans*			
Singing bushlark	*Mirafra javanica*			
Restless flycatcher	*Myiagra inquieta*			
Red-browed finch	*Neochmia temporalis*			
Blue-winged parrot	*Neophema chrysostoma*			
Elegant parrot	*Neophema elegans*		vu	
Scarlet-chested parrot	*Neophema splendida*		vu	L
Southern boobook	*Ninox novaeseelandiae*			
Blue bonnet parrot	*Northiella haematogaster*			
Nankeen night heron	*Nycticorax caledonicus*		nt	
Cockatiel	*Nymohicus hallandicus*			
Crested pigeon	*Ocyphaps lophotes*			
Crested bellbird	*Oreoica gutturalis*		nt	L
Blue-billed duck	*Oxyura australis*		en	L
Gilbert’s whistler	*Pachycephala inornata*			
Golden whistler	*Pachycephala pectoralis*			
Rufous whistler	*Pachycephala rufiventris*			
Spotted pardalote	*Pardalotus punctatus*			

BIRDS				
Common name	**Scientific name**	**EPBC**	**VRoTS**	**FFG**
Striated pardalote	*Pardalotus striatus*			
House sparrow	*Passer domesticus**			
Australian pelican	*Pelecanus conspicillatus*			
Fairy martin	*Petrochelidon ariel*			
Tree martin	*Petrochelidon nigricans*			
Red-capped robin	*Petroica goodenovii*			
Scarlet robin	*Petroica multicolor*			
Great cormorant	*Phalacrocorax carbo*			
Little-black cormorant	*Phalacrocorax sulcirostris*			
Pied cormorant	*Phalacrocorax varius*		nt	
Common bronzewing	*Phaps chalcoptera*			
Little friarbird	*Philemon citreogularis*			
Noisy friarbird	*Philemon corniculatus*			
White-fronted honeyeater	*Phylidonyris albifrons*			
Tawny-crowned honeyeater	*Phylidonyris melanops*			
New Holland honeyeater	*Phylidonyris novaehollandiae*			
Yellow-billed spoonbill	*Platalea flavipes*			
Royal spoonbill	*Platalea regia*		nt	
Yellow rosella	*Platycercus elegans flaveolus*			
Eastern rosella	*Platycercus eximius*			
Striped honeyeater	*Plectorhyncha lanceolata*			
Glossy ibis	*Plegadis falcinellus*		vu	
Tawny frogmouth	*Podargus strigoides*			
Great crested grebe	*Podiceps cristatus*			
Hoary-headed grebe	*Poliocephalus*			
Regent parrot	*Polytelis anthopeplus*	VU	vu	L
Chestnut-crowned babbler	*Pomatostomus ruficeps*			
White-browed babbler	*Pomatostomus superciliosus*			
Purple swamphen	*Porphyrio porphyrio*			
Australian spotted crake	*Porzana fluminea*			
Baillon's crake	*Porzana pusilla*		vu	L
Red-rumped parrot	*Psephotus haematonotus*			
Mulga parrot	*Psephotus varius*			
Redthroat	*Pyrrholaemus brunneus*		en	L
Red-necked avocet	*Recurvirostra novaehollandiae*			
Grey fantail	*Rhipidura fuliginosa*			
Willie wagtail	*Rhipidura leucophrys*			
Australian painted snipe	*Rostratula australis*	EN	cr	L
White-browed scrub-wren	*Sericornis frontalis*			
Weebill	*Smicrornis brevirostris*			

BIRDS				
Common name	**Scientific name**	**EPBC**	**VRoTS**	**FFG**
Freckled duck	*Stictonetta naevosa*		en	L
Grey currawong	*Strepera versicolor*			
Mallee emu-wren	*Stripiturus mallee*	EN	en	L
Apostlebird	*Struthidea cinerea*			L
Common starling	*Sturnus vulgaris**			
Australian grebe	*Tachybaptus novaehollandiae*			
Australian shelduck	*Tadorna tadornoides*			
Zebra finch	*Taeniopygia guttata*			
Australian white ibis	*Threskiornis moluccus*			
Straw-necked ibis	*Threskiornis spinicollis*			
Red-backed kingfisher	*Todiramphus pyrrhopygia*		nt	
Sacred kingfisher	*Todiramphus sanctus*			
Rainbow lorikeet	*Trichoglossus moluccanus*			
Common greenshank	*Tringa nebularia*		vu	
Red-chested button quail	*Turnix pyrrhothorax*		vu	L
Little button-quail	*Turnix velox*		nt	
Barn owl	*Tyto alba*			
Masked lapwing	*Vanellus miles*			
Banded lapwing	*Vanellus tricolor*			
Silvereye	*Zosterops lateralis*			

Appendix 2 – Ecological Vegetation Classes

Ecological Vegetation Classes (EVCs) found across Lindsay-Mulcra-Wallpolla island's and their conservation status (DSE 2004).

EVC number	EVC name	Conservation status
86	Woorinen sands Mallee	Depleted
97	Semi-arid woodland	Vulnerable
98	Semi-arid chenopod woodland	Depleted
102	Low chenopod shrubland	Depleted
103	Riverine chenopod woodland	Depleted
104	Lignum swamp	Vulnerable
106	Grassy riverine forest	Depleted
107	Lakebed herbland	Vulnerable
158	Chenopod Mallee	Vulnerable
200	Shallow freshwater marsh	Vulnerable
806	Alluvial plains semi-arid grassland	Vulnerable
807	Disused floodway shrubby herbland	Endangered
808	Lignum shrubland	Least Concern
809	Floodplain grassy wetland	Endangered
810	Floodway pond herbland	Depleted
811	Grassy riverine forest/floodway pond herbland complex	Depleted
813	Intermittent swampy woodland	Depleted
818	Shrubby riverine woodland	Least Concern
819	Spike-sedge wetland	Vulnerable
820	Sub-saline depression shrubland	Vulnerable
823	Lignum swampy woodland	Depleted

Appendix 3 – Flora species list

List of flora species recorded from Lindsay-Mulcra-Wallpolla; including conservation status (weed species*). Conservation status in Victoria (VRoTS); en=endangered, vu=vulnerable, r=rare, k=poorly known (DEPI 2014). FFG; L=Listed (DELWP 2019b). Non-native species*.

Common name (Vic)	Scientific name	VRoTS	FFG
Chingma lantern	*Abutilon theophrasti**		
Nealie	*Acacia loderi*	vu	L
Umbrella wattle	*Acacia oswaldii*	vu	L
Eumong	*Acacia stenophylla*		
Lesser joyweed	*Alternanthera denticulata*		
Common joyweed	*Alternanthera nodiflora*	k	
	Alternanthera sp. 1 (VIC)	k	
Dwarf amaranth	*Amaranthus macrocarpus* var. *macrocarpus*	vu	
Jerry-jerry	*Ammannia multiflora*	vu	
Box mistletoe	*Amyema miquelii*		
Pimpernel	*Anagallis arvensis*		
Twin-leaf bedstraw	*Asperula gemella*	r	
Small saltbush	*Atriplex eardleyae*		
Slender-fruit saltbush	*Atriplex leptocarpa*		
Saltbush	*Atriplex leptocarpa* × *semibaccata*		
Spreading saltbush	*Atriplex limbata*	vu	L
Flat-top saltbush	*Atriplex lindleyi*		
Baldoo	*Atriplex lindleyi* subsp. *conduplicata*	r	
Corky saltbush	*Atriplex lindleyi* subsp. *inflata*		
Flat-top saltbush	*Atriplex lindleyi* subsp. *lindleyi*	k	
	Atriplex lindleyi/semibaccata		
Old-man saltbush	*Atriplex nummularia*		
Old-man saltbush	*Atriplex nummularia* subsp. *nummularia*		
Berry saltbush	*Atriplex semibaccata*		
Kidney saltbush	*Atriplex stipitata*		
Sprawling saltbush	*Atriplex suberecta*		
Silver saltbush	*Atriplex rhagodioides*	vu	L
Bladder saltbush	*Atriplex vesicaria*		
Bladder saltbush	*Atriplex vesicaria* subsp. *macrocystidia*	k	
Bladder saltbush	*Atriplex vesicaria* subsp. *variabilis*		
Mallee cucumber	*Austrobryonia micrantha*	r	
Rough spear-grass	*Austrostipa scabra*		
Rough spear-grass	*Austrostipa scabra* subsp. *falcata*		
Rough spear-grass	*Austrostipa scabra subsp. falcata*		
Pacific azolla	*Azolla filiculoides*		
Ferny azolla	*Azolla pinnata*		

Small water-fire	*Bergia trimera*	vu	
Tah-vine	*Boerhavia dominii*		
Variable daisy	*Brachyscome ciliaris*		
Variable daisy	*Brachyscome ciliaris* var. *ciliaris*		
Variable daisy	*Brachyscome ciliaris* var. *lanuginosa*		
	Brachyscome melanocarpa		
Woodland swamp-daisy	*Brachyscome paludicola*		
Woodland swamp-daisy	*Brachystome basaltica*		
Mediterranean turnip	*Brassica tournefortii**		
Matted water-starwort	*Callitriche sonderi*		
Pale beauty-heads	*Calocephalus sonderi*		
Garland lily	*Calostemma purpureum*	r	
Blue burr-daisy	*Calotis cuneifolia*	r	
Hairy burr-daisy	*Calotis hispidula*		
Tufted burr-daisy	*Calotis scapigera*		
Ward's weed	*Carrichtera annua**		
	*Centaurium tenuiflorum**		
Common sneezeweed	*Centipeda cunninghamii*		
Spreading sneezeweed	*Centipeda minima* subsp. *minima*		
Spreading sneezeweed	*Centipeda minima subsp. minima*		
Desert sneezeweed	*Centipeda thespidioides*		
Flat spurge	*Chamaesyce drummondii*		
Crested goosefoot	*Chenopodium cristatum*		
	Chenopodium melanocarpum		
Nitre goosefoot	*Chenopodium nitrariaceum*		
Clammy goosefoot	*Chenopodium pumilio*		
Spear thistle	*Cirsium vulgare**		
Common cotula	*Cotula australis*		
Rosinweed	*Cressa australis*		
Paddy melon	*Cucumis myriocarpus* subsp. *leptodermis**		
Field dodder	*Cuscuta campestris**		
Hoary scruff pea	*Cullen cinereum*	en	L
Darling lily	*Crinum flaccidum*	vu	L
Couch	*Cynodon dactylon*		
Native couch	*Cynodon dactylon* var. *pulchellus*	k	
Variable flat-sedge	*Cyperus difformis*		
Lax flat-sedge	*Cyperus flaccidus*		
Spiny flat-sedge	*Cyperus gymnocaulos*		
	Cyperus pygmaeus	vu	
Star fruit	*Damasonium minus*		
Australian carrot	*Daucus glochidiatus*		
Rounded noon-flower	*Disphyma crassifolium*		
Rounded noon-flower	*Disphyma crassifolium* subsp. *clavellatum*		

Stinkwort	*Dittrichia graveolens**		
Slender hop-bush	*Dodonaea viscosa* subsp. *angustissima*		
Tangled lignum	*Duma florulenta*		
	Dysphania glomulifera		
Globular pigweed	*Dysphania glomulifera* subsp. *glomulifera*		
Clammy goosefoot	*Dysphania pumilio*		
Yellow twin-heads	*Eclipta platyglossa*		
Nodding saltbush	*Einadia nutans*		
Nodding saltbush	*Einadia nutans* subsp. *nutans*		
Waterwort	*Elatine gratioloides*		
Common spike-sedge	*Eleocharis acuta*		
Pale spike-sedge	*Eleocharis pallens*	k	
Small spike-sedge	*Eleocharis pusilla*		
Ruby saltbush	*Enchylaena tomentosa*		
Ruby saltbush	*Enchylaena tomentosa* var. *tomentosa*		
Spreading nut-heads	*Epaltes australis*		
Cane grass	*Eragrostis australasica*	vu	
Mallee love-grass	*Eragrostis dielsii*		
Purple love-grass	*Eragrostis lacunaria*	vu	
Bristly love-grass	*Eragrostis setifolia*	vu	
Bignonia emu-bush	*Eremophila bignoniiflora*	vu	L
Spreading emu-bush	*Eremophila divaricata*	r	
Spreading emu-bush	*Eremophila divaricata* subsp. *divaricata*	r	
Berrigan	*Eremophila longifolia*		
Twiggy emu-bush	*Eremophila polyclada*	vu	
Flaxleaf fleabane	*Erigeron bonariensis**		
Tall fleabane	*Erigeron sumatrensis**		
	Erigeron sumatrensis var. *sumatrensis**		
	Eriochloa crebra	k	
River red gum	*Eucalyptus camaldulensis*		
Black box	*Eucalyptus largiflorens*		
	Euchiton sphaericus		
Flat spurge	*Euphorbia dallachyana*		
Plains spurge	*Euphorbia planiticola*	en	L
Earth cress	*Geococcus pusillus*		
Hairy carpet-weed	*Glinus lotoides*		
Slender carpet-weed	*Glinus oppositifolius*		
Desert mud-mat	*Glossostigma drummondii*		
Small mud-mat	*Glossostigma elatinoides*		
Southern liquorice	*Glycyrrhiza acanthocarpa*		
Indian cudweed	*Gnaphalium polysaulon*		
Silky goodenia	*Goodenia fascicularis*		
Pale goodenia	*Goodenia glauca*		

Spreading goodenia	*Goodenia heteromera*		
	Gratiola pubescens		
Dwarf brooklime	*Gratiola pumilo*	r	
Rough raspwort	*Haloragis aspera*		
Bluish raspwort	*Haloragis glauca*	k	
Blueish raspwort	*Haloragis glauca* f. *Glauca*	k	
Smooth heliotrope	*Heliotropium curassavicum*		
Common heliotrope	*Heliotropium europaeum**		
Creeping heliotrope	*Heliotropium supinum**		
Smooth cat's-ear	*Hypochaeris glabra**		
Grass cushion	*Isoetopsis graminifolia*		
Inland club-sedge	*Isolepis australiensis*	k	
	Isolepis congrua	vu	
Grassy club-sedge	*Isolepis hookeriana*		
Tussock rush	*Juncus aridicola*		
Toad rush	*Juncus bufonius*		
Billabong rush	*Juncus usitatus*		
Twining toadflax	*Kickxia elatine* subsp. *crinita**		
Common blown-grass	*Lachnagrostis filiformis*		
Prickly lettuce	*Lactuca serriola**		
Wires-and-wool	*Lemooria burkittii*	en	
Thin duckweed	*Landoltia punctata*		
Jersey cudweed	*Laphangium luteoalbum*		
	*Lepidium africanum**		
Native peppercress	*Lepidium pseudohyssopifolium*	k	L
Austral mudwort	*Limosella australis*		
Large mudwort	*Limosella curdieana*		
Bottom rush	*Lipocarpha microcephala*	vu	
Clove-strip	*Ludwigia peploides* subsp. *montevidensis*		
	Lysiana exocarpi		
Pimpernal	*Lysimachia arvensis* s.l.*		
Small loosestrife	*Lythrum hyssopifolia*		
	Maireana aphylla	r	
Grey bluebush	*Maireana appressa*		
Short-leaf bluebush	*Maireana brevifolia*		
Black cotton-bush	*Maireana decalvans*		
Hairy bluebush	*Maireana pentagona*		
Sago bush	*Maireana pyramidata*		
Three-wing bluebush	*Maireana triptera*	r	
Goat head	*Malacocera tricornis*	r	
Small-flower mallow	*Malva parviflora**		
Short-leaf bluebush	*Mariana breviflora*		
Narrow-leaf nardoo	*Marsilea costulifera*		

Common nardoo	*Marsilea drummondii*		
Short-fruit nardoo	*Marsilea hirsuta*		
Little medic	*Medicago minima**		
Burr medic	*Medicago polymorpha**		
Sweet melilot	*Melilotus indicus**		
River mint	*Mentha australis*		
Common ice-plant	*Mesembryanthemum crystallinum**		
Small ice-plant	*Mesembryanthemum nodiflorum**		
Small monkey-flower	*Mimulus prostratus*	r	
Creeping monkey-flower	*Mimulus repens*		
Woolly minuria	*Minuria denticulata*	r	
Mousetail	*Muosurus australis*		
Creeping myoporum	*Myoporum parvifolium*		
Parrot's feather	*Myriophyllum aquaticum**		
Robust water-milfoil	*Myriophyllum papillosum*		
Red water-milfoil	*Myriophyllum verrucosum*		
Soda bush	*Neobassia proceriflora*	en	
Velvet tobacco	*Nicotiana velutina*		
Wavy marshwort	*Nymphoides crenata*		L
Babbagia	*Osteocarpum acropterum* var. *deminutum*		
Bonefruit	*Osteocarpum salsuginosum*		
Swamp lily	*Ottelia ovalifolia*		
Swamp lily	*Ottelia ovalifolia* subsp. *ovalifolia*		
Grassland wood-sorrel	*Oxalis perennans*		
Warrego Summer-grass	*Paspalidium jubiflora*		
Water couch	*Paspalum distichum**		
Pale knotweed	*Persicaria lapathifolia*		
Creeping knotweed	*Persicaria prostrata*		
Fog-fruit	*Phyla canescens**		
Lagoon spurge	*Phyllanthus lacunarius*	vu	
Squat picrus	*Picris squarrosa*	r	
Weeping pittosporum	*Pittosporum angustifolium*		
Prostrate knotweed	*Polygonum aviculare**		
Small knotweed	*Polygonum plebeium*		
Small knotweed	*Polygonum plebium*		
Common purslane	*Portulaca oleracea*		
Furrowed pondweed	*Potamogeton sulcatus*		
Blunt pondweed	*Potomageton ochreatus*		
Furrowed pondweed	*Potomageton sulcatus*		
Spiny mud-grass	*Pseudoraphis spinescens*		
Yellow tails	*Ptiloyus nobilis* var. *nobilis*	en	
False sow-thistle	*Reichardia tingitana**		
Hedge saltbush	*Rhagodia spinescens*		

Paper sunray	*Rhodanthe corymbiflora*		
Dwarf bitter-cress	*Rorippa eustylis*	r	
Marsh yellow-cress	*Rorippa palustris**		
Mud dock	*Rumex bidens*		
Slender dock	*Rumex brownii*		
Glistening dock	*Rumex crystallinus*	vu	
Narrow-leaf dock	*Rumex tenax*		
Common wallaby-grass	*Rytidosperma caespitosum*		
Prickly saltwort	*Salsola tragus*		
Prickly saltwort	*Salsola tragus* subsp. *tragus*		
Sarcozona	*Sarcozona praecox*	r	
Slender spurge	*Sauropus trachyspermus*	vu	
Spiked centaury	*Schenkia australis*		
Spiked centaury	*Schenkia australis*		
Cushion knawel	*Scleranthus minusculus*		
Short-wing saltbush	*Sclerochlamys brachyptera*		
Short-wing saltbush	*Sclerochlamys brachyptera*		
	Sclerolaena bicornis var. *horrida*		
	Sclerolaena brachyptera		
Red burr	*Sclerolaena calcarata*	en	
	Sclerolaena cuneata		
Green copperburr	*Sclerolaena decurrens*	vu	
Grey copperburr	*Sclerolaena diacantha*		
Tangled copperburr	*Sclerolaena divaricata*	k	
Poverty bush	*Sclerolaena intricata*	vu	
Black roly-poly	*Sclerolaena muricata*		
Dark roly-poly	*Sclerolaena muricata* var. *semiglabra*	k	
Grey roly-poly	*Sclerolaena muricata* var. *villosa*		
Black roly-poly	*Sclerolaena muricata var. muricata*	k	
Limestone Copperburr	*Sclerolaena obliquicuspis*		
Mallee Copperburr	*Sclerolaena parviflora*		
Star bluebush	*Sclerolaena stelligera*		
Streaked Copperburr	*Sclerolaena tricuspis*		
Two-spined Copperburr	*Sclerolaena uniflora*	r	
Salt Copperburr	*Sclerolaena ventricosa*	en	L
Branching groundsel	*Senecio cunninghamii* var. *cunninghamii*	r	
Cotton fireweed	*Senecio quadridentatus*		
Tall fireweed	*Senecio runcinifolius*		
Mallee groundsel	*Senecio spanomerus*		
Twiggy sida	*Sida intricata*	vu	
Smooth mustard	*Sisymbrium erysimoides**		
Quena	*Solanum esuriale*		
Lagoon nightshade	*Solanum lacunarium*	vu	

Black nightshade	*Solanum nigrum**		
Dwarf jo-jo	*Soliva anthemifolia**		
Rough sow-thistle	*Sonchus asper**		
Common sow-thistle	*Sonchus oleraceus**		
Salt sea-spurrey	*Spergularia brevifolia*		
Lesser sand-spurrey	*Spergularia diandra**		
Red sand-spurrey	*Spergularia rubra**		
Spreading nut-heads	*Sphaeromorphaea littoralis*		
Rat-tail couch	*Sporobolus mitchellii*		
Lesser chickweed	*Stellaria pallida*		
Blue rod	*Stemodia florulenta*		
Hairy darling-pea	*Swainsonia greyana*	en	L
Aster-weed	*Symphyotrichum subulatum**		
Round templetonia	*Templetonia egena*	vu	
	Tetragonia eremaea		
	Tetragonia moorei	k	
New Zealand spinach	*Tetragonia tetragonioides*		
Grey germander	*Teucrium racemosum*		
Narrow-leaf cumbungi	*Typha domigenisis*		
Broad-leaf cumbungi	*Typha orientalis*		
Eel grass	*Valliseneria Americana* var. *Americana*		
Common verbena	*Verbena officinalis**		
Trailing verbena	*Verbena supina**		
Annual New Holland daisy	*Vittadinia cervicularis* var. *cervicularis*		
Dissected New Holland daisy	*Vittadinia dissecta*		
Dissected New Holland daisy	*Vittadinia dissecta* var. *hirta*		
Woolly New Holland daisy	*Vittadinia gracilis*		
Winged New Holland daisy	*Vittadinia pterochaeta*	vu	
River bluebell	*Wahlenbergia fluminalis*		
Noogoora burr	*Xanthium occidentale**		
	*Xanthium orientale**		
Golden everlasting	*Xerochrysum bracteatum*		
Pointed twin-leaf	*Zygophyllum apiculatum*		
Pale twin-leaf	*Zygophyllum glaucum*		

Appendix 4 – Basin-Wide Environmental Watering Strategy and Quantified Environmental Expected Outcomes

Objective details specified in the Basin-Wide Environmental Watering Strategy (BWS) and their associated BWS codes and Quantified Environmental Expected Outcomes (QEEO).

Quantified Environmental Expected Outcomes (QEEO)	BWS theme	BWS code
Maintained base flows: at about 60 per cent of natural levels in the main catchment rivers	River flows and connectivity	BWS1
Improved overall flow: 10 per cent more into the Barwon-Darling	River flows and connectivity	BWS2
Improved overall flow: 30 per cent more into the River Murray	River flows and connectivity	BWS3
Improved overall flow: 30-40 per cent more to the Murray mouth (and it open to the sea 90 per cent of the time)	River flows and connectivity	BWS4
Maintained connectivity in areas where it is relatively unaffected: between rivers and floodplains in the Paroo, Moonie, Nebine, Warrego and Ovens	River flows and connectivity	BWS5
Improved connectivity with bank-full and low floodplain flows	River flows and connectivity	BWS6
Improved connectivity with bank-full and low floodplain flows: by 30-60 per cent in the Murray, Murrumbidgee, Goulburn and Condamine-Balonne	River flows and connectivity	BWS7
Improved connectivity with bank-full and low floodplain flows: by 10-20 per cent in remaining catchments	River flows and connectivity	BWS8
Maintain the Lower Lakes above sea level at all times	River flows and connectivity	BWS9
Maintain the current extent of: about 350,000 hectares of river red gum; 402,000 ha of black box; 310,000 ha of coolibah forest and woodlands; and existing large communities of lignum	Vegetation	BWS10
Maintain the current extent of: non-woody communities near or in wetlands, streams and on low-lying floodplains	Vegetation	BWS11
Improved condition of lowland floodplain forests and woodlands of: river red gum	Vegetation	BWS12
Improved condition of lowland floodplain forests and woodlands of: black box	Vegetation	BWS13
Improved condition of lowland floodplain forests and woodlands of: coolibah	Vegetation	BWS14
Maintained current species diversity of: all current Basin waterbirds	Waterbirds	BWS15
Maintained current species diversity of: current migratory shorebirds at the Coorong	Waterbirds	BWS16
Increased abundance: 20-25 per cent increase in waterbirds by 2024	Waterbirds	BWS17
Improved breeding: up to 50 per cent more breeding events for colonial nesting waterbird species	Waterbirds	BWS18
Improved breeding: a 30-40 per cent increase in nests and broods for other waterbirds	Waterbirds	BWS19
Improved distribution: of key short and long-lived fish species across the Basin	Fish	BWS20
Improved breeding success for: short-lived species (every 1-2 years)	Fish	BWS21

Quantified Environmental Expected Outcomes (QEEO)	BWS theme	BWS code
Improved breeding success for: long-lived species in at least 8/10 years at 80 per cent of key sites	Fish	BWS22
Improved breeding success for: mulloway in at least 5/10 years	Fish	BWS23
Improved populations of: short-lived species (numbers at pre-2007 levels)	Fish	BWS24
Improved populations of: long-lived species (with a spread of age classes represented)	Fish	BWS25
Improved populations of: Murray cod and golden perch (10-15 per cent more mature fish at key sites)	Fish	BWS26
Improved movement: more native fish using fish passages	Fish	BWS27

Appendix 5 – Objectives and targets from Long-Term Watering Plan

Objective details specified in the Victorian Murray LTWP (Table 5 and 6, DEWLP 2015) and associated codes.

LTWP objective	Code
Improve connectivity between floodplains, anabranches and wetlands	LTWPVM1
Improve the species richness of aquatic vegetation in wetlands	LTWPVM2
Improve the species richness of in-channel aquatic vegetation	LTWPVM3
Improve the extent of aquatic vegetation	LTWPVM4
Improve the condition of river red gum-dominated EVCs	LTWPVM5
Improve the condition of black box-dominated EVCs	LTWPVM6
Maintain the extent of black box-dominated EVCs	LTWPVM7
Improve the condition of shrub and lignum-dominated EVCs	LTWPVM8
Successful growth and flowering of Moira grass plants	LTWPVM9
Improve breeding opportunities for colonial-nesting waterbirds	LTWPVM10
Improve breeding opportunities for waterbirds	LTWPVM11
Improve habitat for waterbirds	LTWPVM12
Improve feeding areas for waterbirds	LTWPVM13
Improve abundance of large-bodied native fish	LTWPVM14
Maintain abundance of small-bodied native fish in wetlands	LTWPVM15
Maintain distribution of threatened small-bodied native fish in wetlands	LTWPVM16
Improve habitat for native fish	LTWPVM17
Maintain species richness of native fish	LTWPVM18
Improve habitat for frog communities	LTWPVM19
Maintain species richness of frog communities	LTWPVM20

Appendix 6 – Risk description and matrix

Risk likelihood description.

Rating	Description
Rare	The event may occur only in exceptional circumstances
Unlikely	The event could occur at some time
Possible	The event might occur
Likely	The event will probably occur in most circumstances
Almost certain	The event is expected to occur in most circumstances

Risk consequence description.

Rating	Description
Negligible	No material effect on the environment, contained locally within a single site/ area. Environment affected for days.
Minor	Limited effect on the environment, restricted to a single township or locality. Environment affected for weeks.
Moderate	Moderate effect on the environment, impacting on a municipality or multiple localities. Environment affected for months.
Major	Major effect on the environment, impacting on a region or multiple municipalities. Environment affected for 1-3 years.
Extreme	Very serious effect on the environment, impacting on the state or multiple regions. Environment affected for > 3 years.

Risk rating matrix.

Likelihood	Consequence				
	Negligible	**Minor**	**Moderate**	**Major**	**Extreme**
Almost certain	Low	Medium	High	Extreme	Extreme
Likely	Low	Medium	High	Extreme	Extreme
Possible	Low	Medium	Medium	High	Extreme
Unlikely	Low	Low	Medium	High	Extreme
Rare	Low	Low	Low	Medium	High