Hattah Lakes

Environmental Water Management Plan

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Cover Image: Lake Bitterang channel (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

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About this plan

The Hattah Lakes 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 regimes and water delivery options for the site.

This revision builds on previous iterations of the Hattah Lakes 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 Hattah Lakes (MDBA 2012) has been used as the guiding document during the initial stages of water delivery using TLM infrastructure at the Hattah Lakes 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 Hattah Lakes 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:

- **Hattah Lakes 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.
- **Hattah Lakes Icon Site Watering Guide** – contains key ecological and hydrological information to inform environmental water management.
- **Hattah Lakes 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.

Executive summary

The Hattah Lakes Environmental Water Management Plan establishes priorities for the use of water for the environment within the Hattah Lakes 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 state governments and is coordinated by the Murray-Darling Basin Authority (MDBA). The Hattah Lakes Icon Site is one of six icon sites under TLM initiative recognised for their ecological, cultural, recreational, heritage and economic significance.

The Hattah Lakes in northwest Victoria, and surrounding floodplain, were selected as an icon site because of their extent, condition, diversity and habitat value, as well as their social and cultural importance. The Hattah Lakes Icon Site consists of an extensive complex of lakes and floodplain within the Hattah–Kulkyne National Park. The system includes more than 20 perennial and intermittent freshwater lakes, ranging in size from less than 10 ha to about 200 ha. Twelve of these lakes are listed as internationally important wetlands under the Ramsar Convention on Wetlands of International Importance (the Ramsar Convention), primarily for their value as waterbird habitat and importance in maintaining regional biodiversity.

The flora and fauna have attracted people to the area for thousands of years, and continue to do so today. The Hattah Lakes provided resources for Indigenous communities who continue to maintain a strong connection to Country. Over 1,000 archaeological sites have been documented, with many more sites known to local land managers. These sites provide evidence of the use of the lakes for resources, and include middens, scar trees, hearths and burial sites. Eleven sites of post-European settlement heritage significance have been identified within the Hattah Lakes Icon Site (Heritage Victoria 2010).

Today, the icon site provides a social and economic value to the community who benefit financially from increased numbers of people visiting for recreation activities including camping, bushwalking, bird watching and, when the lakes hold water, swimming, kayaking and canoeing. Maintenance of heritage sites and the provision of recreational and economic services are reliant upon the management of water and health of the Hattah Lakes Icon Site.

The floodplain of the Hattah Lakes has become severely degraded due to regulation of the River Murray and the extraction of water for agriculture, industry and urban use, as well as the confounding impacts of changing climatic conditions. The resulting reduction in the frequency, magnitude and duration of high flows has affected the flow regime of the wetland system. The impacts associated with the change in hydrological regime include reductions in the condition of river red gum and black box communities (and even tree deaths), a transition to a more terrestrial understorey, and a change in the abundance and composition of floodplain and wetland flora (Kattel et al. 2009). Through The Living Murray initiative, a range of water management infrastructures that assist with the delivery of water for environment to the Hattah Lakes floodplain were completed in 2012. Operation of these infrastructures has helped to maintain the site's ecological, cultural, social and economic values, by returning the floodplain to a more natural hydrological state. Efforts to relax delivery and supply constraints in the wider southern Murray-Darling Basin 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 hydrological conditions and inundations.

Ecological objectives, which guide the delivery of water for the environment at the site, were first established for Hattah Lakes in 2003 as part of The Living Murray's First Step Decision. Building on progress achieved, and to complement adaptive management, there has been ongoing refinement of the vision and objectives, with the most recent vision, to:

> *'Improve biodiversity values of Hattah Lakes, maintaining wetland and floodplain communities 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 Plans. 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 Hattah Lakes, which are summarised in the table below. Details of targets can be found in Section 6.

Objectives for the Hattah Lakes Icon Site	
HL1 Diversity of ecosystem type	Maintain a diversity of freshwater ecosystem types within the Hattah Lakes Icon Site, including semi-permanent lakes, persistent temporary wetlands, floodplain woodlands, shrublands, and episodic wetlands (Lake Kramen) by 2030.
HL2 Maintain ecological character of the Ramsar site	Maintain the ecological character of the Hattah-Kulkyne Lakes Ramsar site by 2030
HL3 Species richness and abundance of aquatic vegetation	Improve species richness and abundance of native water-dependent floodplain and wetland aquatic vegetation at the Hattah Lakes Icon Site by 2030.
HL4 Condition and extent of floodplain vegetation	Improve condition and maintain extent 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 Hattah Lakes Icon Site by 2030.
HL5 Support threatened species	By 2030, improve biodiversity at Hattah Lakes by supporting the life-cycle of the EPBC-listed regent parrot (*Polytelis anthopeplus monarchoides*).
HL6 Create refugia for waterbirds in dry periods	Provide refugia to support the long-term survival and resilience of water-dependent populations of waterbirds, including during drought, to allow for subsequent re-colonisation beyond Hattah Lakes by 2030.
HL7 Create vital habitat – feeding habitat for waterbirds	By 2030, maintain or improve biodiversity at Hattah Lakes by ensuring that feeding habitat for the dominant guilds of waterbirds, most notably waterfowl, herbivores and piscivores, are supported.
HL8 Colonial waterbird breeding	Protect and restore ecosystem functions of water-dependent ecosystems that support successful colonial nesting waterbird species at Hattah Lakes by providing conditions for breeding and fledging at least three times every 10 years.
HL9 Native fish recruitment	Maintain recruitment of populations of small-bodied native fish and presence of large-bodied native fish at Hattah Lakes by 2030.

To assess progress toward objectives set out for Hattah Lakes, an extensive monitoring program has been in place for more than 15 years, which includes Basin-scale-, condition- 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 Hattah Lakes since 2005 using standard methodologies to investigate 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. Potential 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 Hattah Lakes 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, during the development of watering proposals and monitoring activities being proposed under TLM program. Many of these can be appropriately managed though monitoring, consultation and adaptive management to reduce the actual or perceived risk.

This plan supersedes the Hattah Environmental Management Plan 2012 and, following the Basin Plan coming into effect in 2012, reflects the 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 of high-level planning documents, such as the Basin-Wide Environmental Watering Strategy.

Lake Lockie during filling with environmental water (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

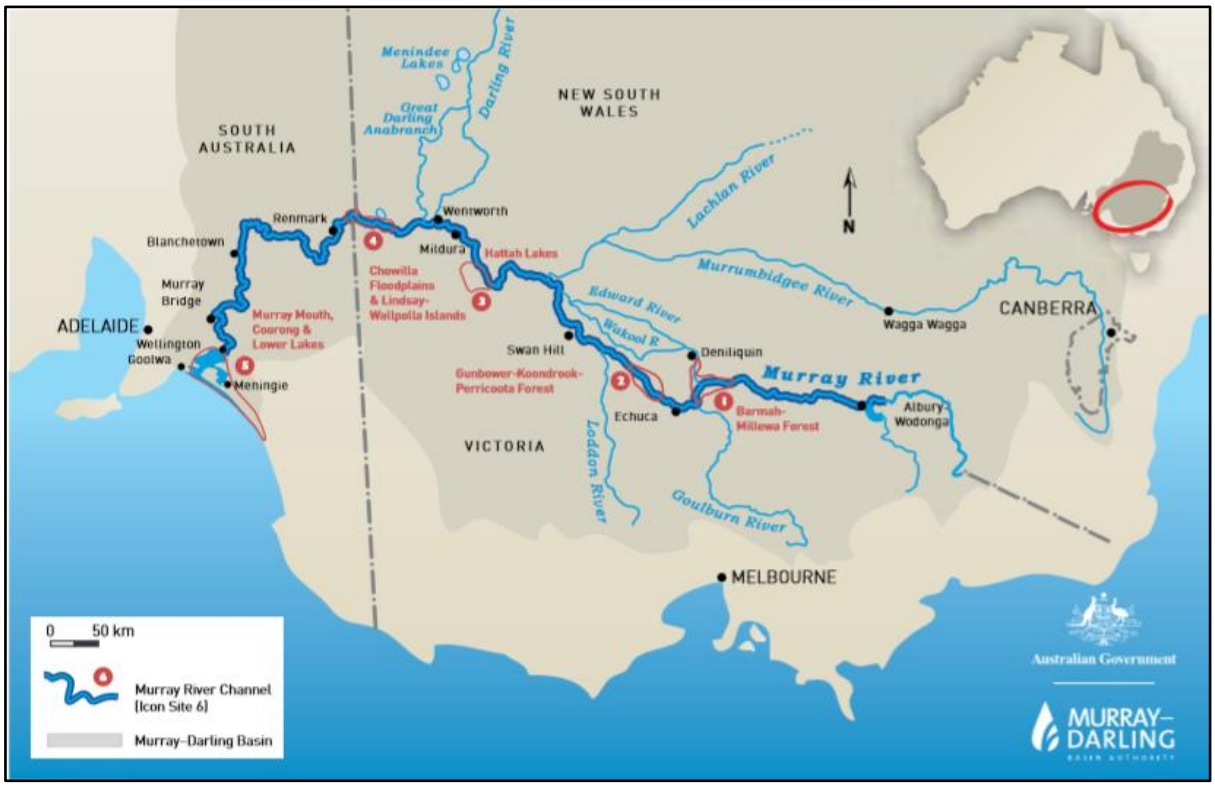

Figure 1.1. Location of The Living Murray icon sites.

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 all 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 the 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 the Hattah Lakes Icon Site 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 the management of TLM icon sites, including operation of works under TLM, the principal pieces of legislation and planning strategies associated with Hattah are listed in Table 1.1.

Table 1.1. List of legislation, agreement or conventions that may be associated with the management of the Hattah Lakes 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)
	Convention on Wetlands of International Importance (Ramsar Convention)
State	Aboriginal Heritage Act 2006
	Aboriginal Heritage Amendment Act 2016
	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

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 planning 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 Hattah Lakes Plan is a key reference for the Victorian Murray Long-Term Watering Plan.

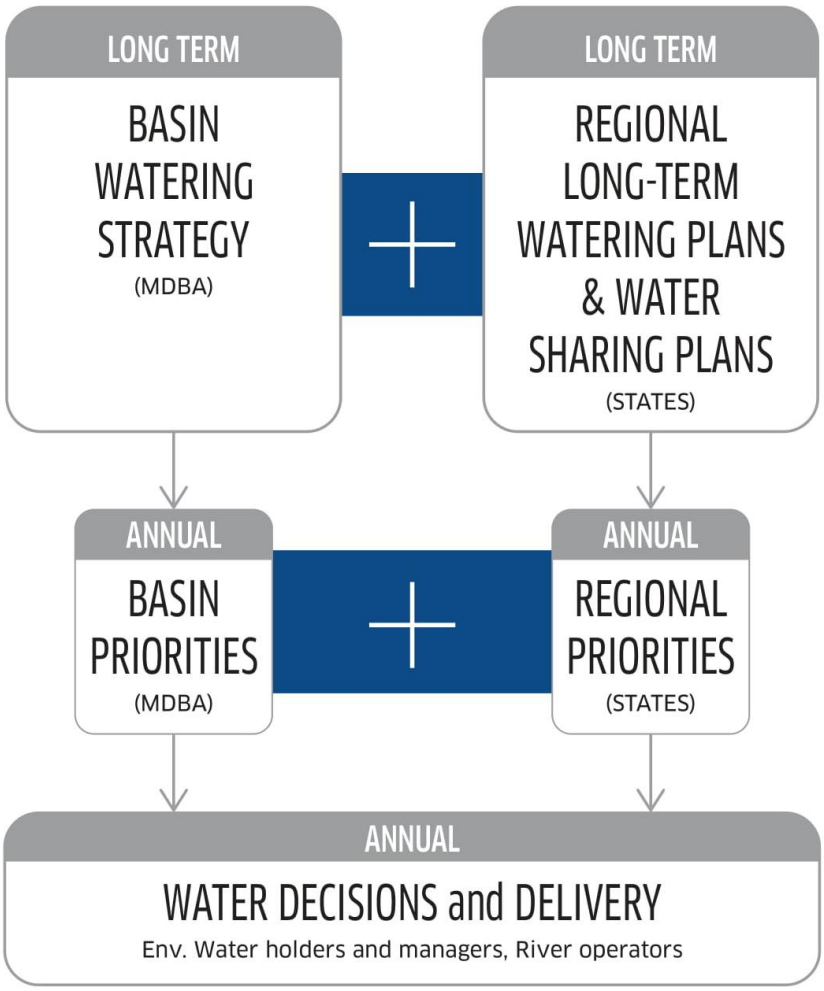

Figure 1.3. Key elements of the framework for environmental water in the Murray-Darling Basin (MDBA 2019).

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 Hattah Lakes Icon Site depends on effective engagement with a range of stakeholders. This ensures that the community is informed of the context, history, proposed processes, opportunities and constraints for environmental water management, 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 Hattah Lakes. 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 variable 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, school excursions and media releases. Where a level of interaction and consultation is required (i.e. two-way exchange of information), more personal involvement is required, such as attendance at group meetings, one-on-one interactions and targeted workshops. An important aspect to consider during high levels of engagement is getting out on-site, particularly when communicating with the Indigenous community.

First Nations engagement

First Nation's 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 Indigenous 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.

While there are two documented language groups, the Latji and the Jari, recognised for the Hattah Lakes area (SKM 2007), there are no officially recognised Aboriginal parties associated with Hattah Lakes. There are, however, a number of community members with connection to Country in the region. Local water managers and the Indigenous community are working to strengthen relationships and engagement on water management. Talk Water on Country events have been held to discuss Indigenous values of the Hattah Lakes site, and the incorporation of comments and recommendations into seasonal watering proposals. Moving forward, integration of local Indigenous values and objectives into annual and long-term water planning for the site is expected to become commonplace.

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 Hattah Lakes. This facilitator ensures a strong connection between the local Indigenous groups 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.

The Ramsar Convention encourages the integration of the socio-economic and cultural-spiritual values of wetlands, as well as traditional knowledge. This is used in the management of wetlands, making First Nations engagement equally important for the wetland's management as a Ramsar site.

3. Site overview

Site location and catchment setting

The Hattah Lakes are an extensive complex of approximately 13,000 ha of lakes and floodplain set within the 48,000 ha Hattah-Kulkyne National Park and the Murray-Kulkyne Park. The site is in north-west Victoria on the bank of the River Murray between Robinvale and Mildura.

The Hattah Lakes Icon Site comprises a complex of lakes, wetlands, flood-runners and adjoining terrestrial floodplain within a Mallee landscape. The extent of the floodplain is defined by the largest flood on record (which occurred in 1956) (see Figure 3.1). The Hattah Lakes system consists of 20 perennial and intermittent freshwater lakes, and is fed from the River Murray at times of elevated river flow. Chalka Creek links the start of the lake system to the River Murray approximately 18 km away. From the southern lakes, Chalka Creek flows a further 25 km north to return back to the River Murray. The River Murray adjacent to Hattah Lakes is free-flowing and not influenced by weir pools. The nearest upstream weir is Lock 15 (Euston, ~60 river kilometres) while Mildura Lock 10 is 120 km downstream.

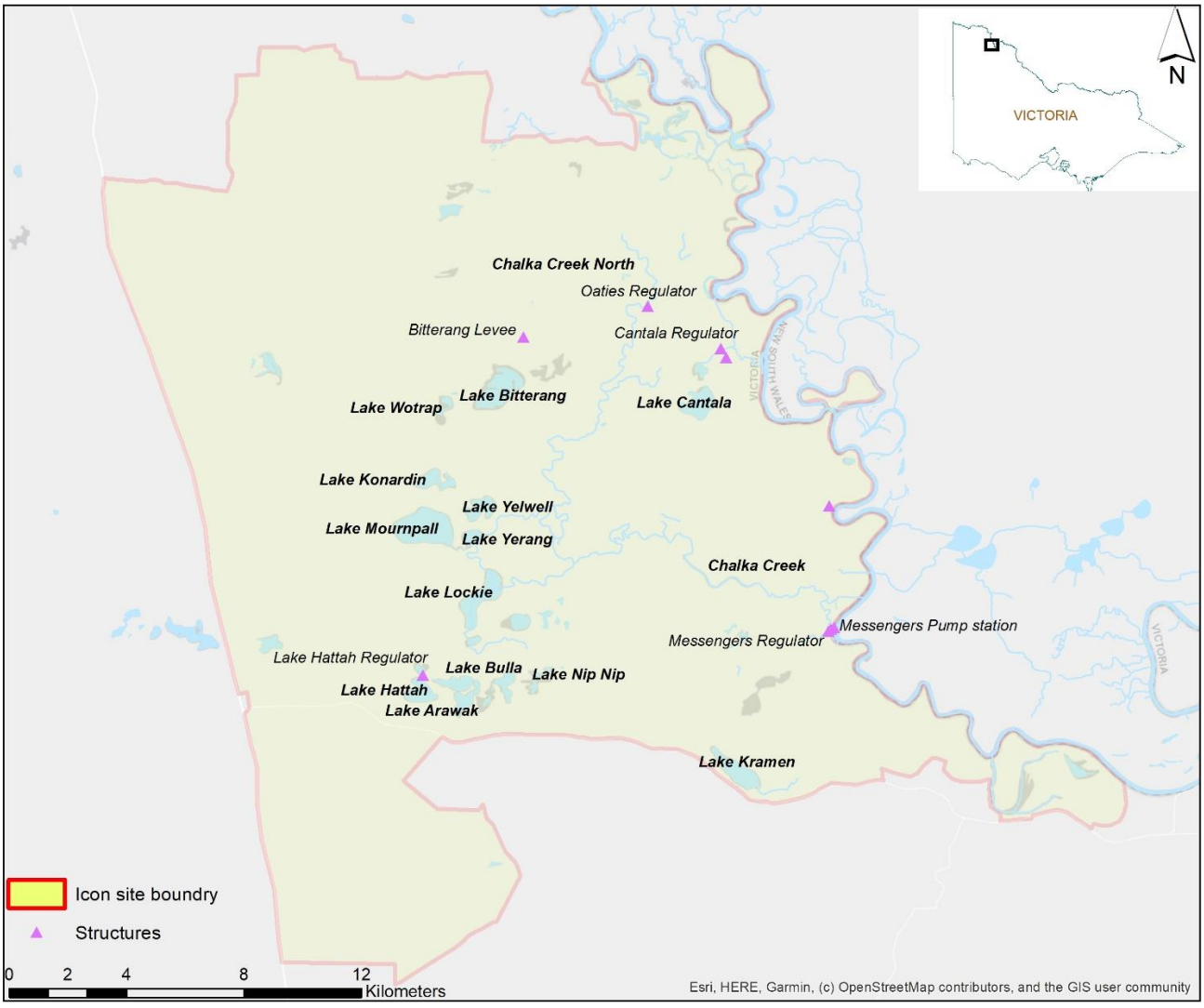

Figure 3.1. The Hattah Lakes Icon Site with key features identified.

Land status and management

The Hattah–Kulkyne National Park and Murray-Kulkyne Park combines three former pastoral runs – Kidd's Station, Gayfield and Mournpall – all of which were first taken up in 1847 (SKM 2004).

The rail line from Melbourne reached the Hattah township in 1903, with the link to Mildura completed the following year (SKM 2004). By 1908, Victorian Railways had constructed a pump station and tank on the southern shore of Lake Hattah to supply steam trains at the Hattah Station west of the icon site. It is thought that a channel linking lakes Lockie and Hattah was cut at the same time to improve water supply to Lake Hattah (SKM 2004).

The lakes have been a major water source for the surrounding area. A bank and regulator were constructed between Lake Hattah and Little Hattah to retain water in Lake Hattah, and a dam was constructed in the park to supply the Hattah township (SKM 2004). As early as 1914, the potential of Lake Hattah for irrigation supply was investigated but found to be inadequate. Water is no longer extracted from the lakes for any purpose.

During the 19th century, and much of the 20th century, the country was extensively grazed by sheep, cattle and rabbits, damaging the natural vegetation and soils. In 1915, a sanctuary was formed with an area of 178 square kilometres, later reserved as Hattah Lakes National Park on 7 June 1960. This reserve included the Hattah Lakes themselves (DNRE 1996), and in 1980, the adjacent Kulkyne State Forest was added to form Hattah–Kulkyne National Park. The remains of the Kulkyne State Forest now form the Murray-Kulkyne Park. Although the Murray-Kulkyne Park is incorporated into the greater national park, activities such as free camping and firewood collection for camping use are still permitted as they were prior to incorporation into the national park.

The national park is managed by Parks Victoria with the Mallee CMA acting as The Living Murray Icon Site Manager.

Climate

Historically, the climate of the MDB has been variable. This variability has led to patterns of dry and wet across the Basin, with years when there were substantial flood events (e.g. 1956) to extended dry or drought periods (e.g. the Millennium Drought). Climate change is likely increasing this variability, resulting in more frequent and extreme floods and droughts (MDBA 2010).

Hattah Lakes 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 328 mm in Ouyen. Average maximum temperatures are 31.5 °C in Summer and 16 °C in Winter, with high evaporation rates throughout the year. Consequently, 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 events resulted in widespread flooding during Spring 2016. Since then, well-below average rainfall to 2019 (worse than experienced during the Millennium Drought) resulted in a rapid shift toward drier conditions.

Site characteristics

The Hattah Lakes lie in the Robinvale Plains bioregion, The site's lakes range in size from less than 10 ha to about 200 ha. Surrounding vegetation communities range from those that require frequent flooding, such as river red gum woodland, to those that require less frequent inundation, such as black box woodland and lignum (*Duma florulenta*) shrubland. The lakes and creek lines provide important habitat for more than 50 waterbird species, including a number listed under international and national agreements. These include the Japan–

Australia (JAMBA), China-Australia (CAMBA), and Republic of Korea-Australia (RoKAMBA) migratory bird agreements, and the Directory of Important Wetlands Australia. Twelve of the Hattah lakes are listed as Wetlands of International Importance under the International Convention on Wetlands (Ramsar Convention), totalling 977 ha of wetland (DEPI 2013). These are:

- Lake Arawak (38 ha)
- Lake Bitterang (122 ha)
- Lake Brockie (30 ha)
- Lake Bulla (37 ha)
- Lake Cantala (84 ha)
- Lake Hattah (57 ha)
- Lake Konardin (53 ha)
- Lake Kramen (133 ha)
- Lake Lockie (131 ha)
- Lake Mournpall (181 ha)
- Lake Yelwell (60 ha)
- Lake Yerang (51 ha)

Australasian darter (*Anhinga novaehollandiae*) chicks in a nest, Chalka Creek (Source D Wood)

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 hydrology of the Hattah Lakes system is dependent on flows in the River Murray. Although rainfall can help to provide relief from water stress for many plants and animals, the Hattah Lakes as an ecological system is adapted to almost annual flows into the system. These adaptations would rely on the Spring flows to refresh the system and drive productivity in the lakes. Prior to regulation, water would have entered the system in most years. This would have either been as large overbank flood events all the way down to small inflows that would have reached a few of the lakes early in the flow path.

The natural flows were highly seasonal, with flows increasing from June to peak around October before decreasing during Summer and Autumn (Figure 4.1). Prior to the construction of TLM water management infrastructure, the sill at the entry to Chalka Creek allowed water to enter the system at 37,500 ML/d. From Figure 4.1 (below), this suggests water would most likely enter the system between August and January. The maximum flow suggests that the big flood events follow a similar seasonality, with the big flows occurring during Winter and continuing until the early Summer period.

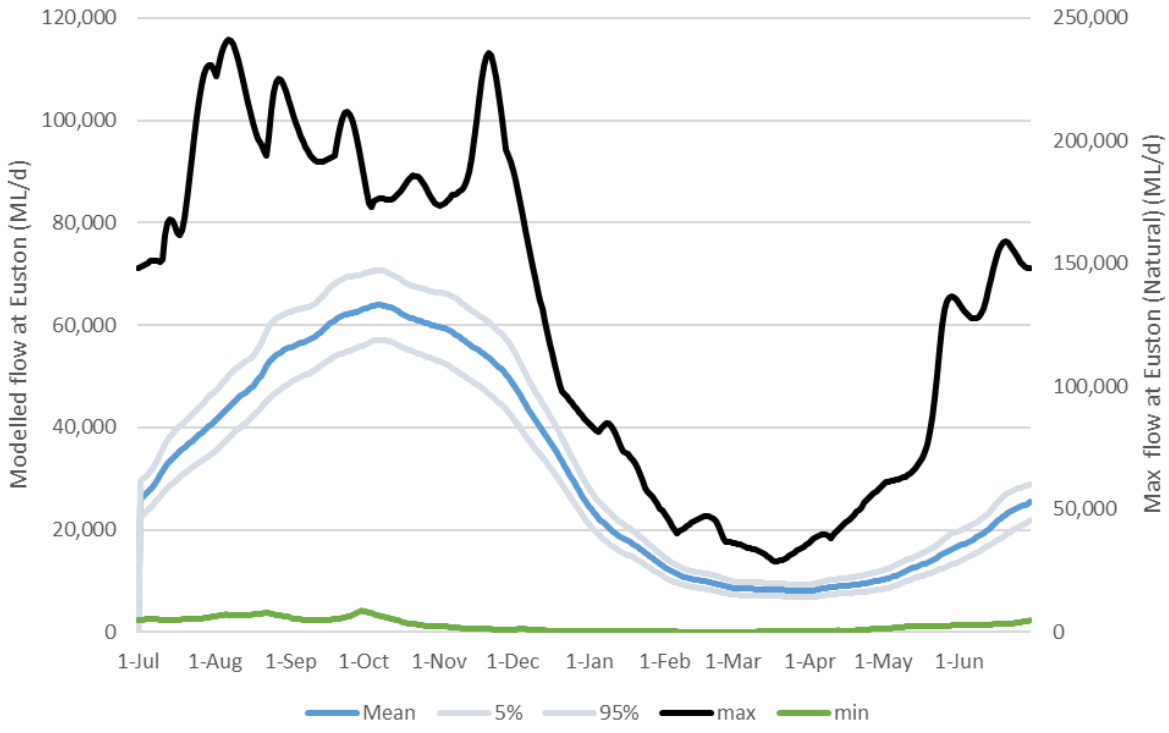

Figure 4.1. Modelled natural flows at Euston (Lock 15) showing the mean daily flow (left axis) at Euston with 95 per cent confidence intervals. The modelled absolute maximum and minimum flows (right axis) across the 114-year time period have also been included.

Post-regulation hydrology

The construction of storages to manage water demand has led to the regulation of the hydrology of the River Murray. The regulated hydrology has had detrimental effects along the river, including reductions to the magnitude, duration and frequency of overbank flows. Major storages have made it possible to capture water during wet periods and release it as needed during Summer or in droughts to meet consumptive and irrigation

needs. This has inverted the seasonality of peak flows in the system, and resulted in the loss of seasonal ecological cues.

The regulation of the River Murray for extractive purposes has had a profound effect on the Hattah Lakes system. The lack of connectivity between the lakes and the River Murray resulting in the complete drying of the lakes during the Millennium Drought, has had a detrimental effect on the ecosystem that is the Hattah Lakes. The lakes in the system now have less ability to retain water for an extended period of time for flora and fauna dependent on these refuges for survival.

One of the critical aspects that has been lost through flow regulation and extraction from the River Murray is the over bank flood events that inundate the Hattah Lakes floodplain. The loss of medium-to-large flood peaks has had a significant impact on vegetation communities. Under regulated conditions, the attenuation of the natural flood peaks means that there are now more small-peak events, as the water normally forming the medium-to-large peaks is extracted.

Under natural conditions, the water entering the Hattah Lakes system via Chalka Creek would have continued to flow for four months every year, on average (Table 4.1). However, under regulated conditions, the duration of these flows is shortened to six weeks. Sill lowering was undertaken at Chalka Creek in 2012 to reduce the threshold at which water will flow from the river to the lakes (~23,000 ML/d). Figure 4.2 shows the difference between the amount of water flowing past Euston in natural conditions and actual flows since 1930 following the completion of Lock and Weir 15.

Table 4.1. The frequency of key flows under various flow scenarios. The modelling has been developed under the natural inflow threshold to Chalka Creek of 37,500 ML/d at Euston.

River flow (GL/d)	Flood count (per cent years with flow peaks above threshold)			Effective flood (per cent years flow exceeds the threshold for at least three months)		
	Modelled pre-development	Modelled current	Median climate change scenario at year 2030	Modelled pre-development	Modelled current	Meadian climate change scenario at year 2030
40	82	47	37	48	20	11
60	59	31	22	21	7	3
75	46	23	12	16	7	3
100	36	12	8	19	8	3
150	18	6	2	4	2	1

Messengers pump station (Source: MCMA)

This reduction in flow has had a negative effect on the condition of plant communities beyond just the lakes, extending across the higher elevations of the floodplain. Prior to the delivery of environmental water to the Hattah Lakes floodplain, surveys revealed that 71 per cent of red gum and black box trees were in a poor or severely degraded condition (Cunningham et al. 2009).

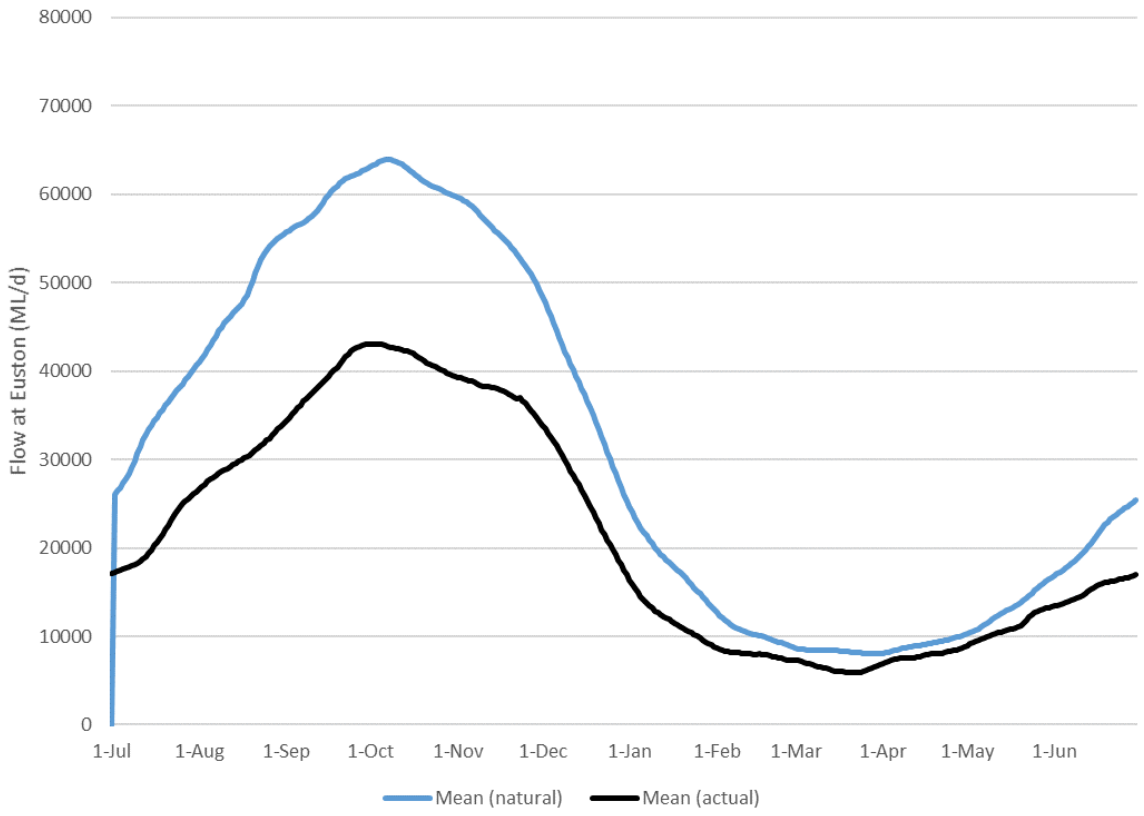

Figure 4.2. The mean daily modelled and actual flows at Euston, showing the attenuation of the flow at Euston as a result of regulation and extraction.

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-Wide 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 Hattah Lakes.

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The delivery of water for the environment across the floodplain is dependent upon water availability and the operation of infrastructure. The water delivery infrastructure at the Hattah Lakes Icon Site is designed to simulate a flood up to 45 m Australian Height Datum (AHD) across the floodplain.

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 4.2).

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 occurs through SCBEWC between multiple water holders, water managers and jurisdictions; and maximises the use of available water, enabling the use and re-use of water at multiple sites along the River Murray.

Table 4.2. Objectives under different water availability scenarios.

	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 sites for Hattah Lakes	• Semi-permanent wetlands	• Persistent temporary wetlands • Semi-permanent wetlands	• Wetlands • Fringing river red gum woodland • River red gum forest with flood-tolerant understorey	• Wetlands • Temporary wetlands • Black box woodland • Fringing river red gum woodland • River red gum forest with flood-tolerant understorey

5. Water-dependent values

Environmental values

The floodplain of the Hattah Lakes Icon Site consists of habitats ranging from purely aquatic to semi-arid woodland. It is this wide range of habitats that enhances the diversity of the icon site, resulting in the area being recognized for its environmental, cultural, social and economic values.

The declaration of the Hattah Lakes as a Ramsar site is in recognition of the unique nature of the series of interconnected semi-permanent and temporary wetlands in a semi-arid region. In turn, these wetlands are able to support a significant number of waterbirds and provide refuge during dry years when temporary wetlands dry. Away from the aquatic environments, the drier woodlands support a range of terrestrial species.

Fauna

Hattah-Kulkyne National Park is depended upon as a refuge for native fauna, as it exists as remnant habitat and a water source within an arid landscape dominated by agricultural land use. Over 250 fauna species have been recorded within Hattah-Kulkyne National Park. Of these species, 180 have been recorded over the past 12 years of monitoring (see Appendix 1 and 3). The species recorded include:

- 167 species of native birds
- 26 species of mammal
- 16 species of fish
- 32 species of reptile
- 7 species of frogs

Twenty-two of these species are listed as threatened in Victoria under the *Flora and Fauna Guarantee Act* (FFG) (Table 5.1). Six of these species are also listed under the *Environment Protection and Biodiversity Conservation Act* (EPBC), including silver perch (*Bidyanus bidyanus*) 'Critically Endangered', the Australian painted-snipe (*Rostratula australis*) and Mallee emu-wren (*Stipiturus mallee*) 'Endangered', and the regent parrot (*Polytelis anthrpeplus monarchoides*), malleefowl (*Leipoa ocellate*) and Murray cod (*Maccullochella peelii*) 'Vulnerable'. Four of these species have been recorded during TLM monitoring activities at the icon site, with all four depending upon environmental water delivery across the Hattah floodplain for their survival. Malleefowl and Mallee emu-wren do not usually inhabit the floodplain and so are unlikely to be directly impacted by floodplain inundation events.

The four water-dependant species listed above provide a good example of the range of hydrological requirements needed by fauna on the Hattah Lakes floodplain. Murray cod need flowing water habitat in the creeks and streams, painted snipe need wetlands with fringing vegetation and regent parrots need the red gums that, in turn, need periodic inundation to flourish.

Table 5.1. Fauna species listed as threatened under federal or state legislation that have been identified at the Hattah Lakes Icon Site. *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 2019).

REPTILES				
Common name	**Scintific name**	**EPBC**	**VRoTS**	**FFG**
Broad-shelled turtle	*Chelodina expansa*		en	L
Common long-necked turtle	*Chelodina longicollis*		dd	
River Murray turtle	*Emydura macquarii*		vu	L
Carpet python	*Morelia spilota metcalfei*		en	L
Lace monitor	*Varanus varius*		en	
MAMMALS				
Common name	**Scientific name**	**EPBC**	**VRoTS**	**FFG**
Southern myotis	*Myotis macropus*		nt	
Mitchell's hopping-mouse	*Notomys mitchelii*		nt	
FISH				
Common name	**Scientific name**	**EPBC**	**VRoTS**	**FFG**
Silver perch	*Bidyanus*	CE	vu	L
Un-specked hardyhead	*Craterocephalus stercusmuscarum fulvus*			L
Murray cod	*Maccullochella peelii*	VU	vu	L
Golden perch	*Macquaria ambigua*		nt	
Murray-Darling rainbowfish	*Melanotaenia fluviatilis*		vu	L
BIRDS				
Common name	**Scientific name**	**EPBC**	**VRoTS**	**FFG**
Common sandpiper	*Actitis hypoleucos*		vu	
Striated grasswren	*Amytornis striatus*		nt	
Australasian shoveler	*Anas rhynchotis*		vu	
Intermediate egret	*Ardea intermedia*		en	L
Eastern great egret	*Ardea modesta*		vu	L
Hardhead	*Aythya australis*		vu	
Musk duck	*Biziura lobata*		vu	
Whiskered tern	*Chlidonias hybridus javanicus*		nt	
Black-eared cuckoo	*Chrysococcyx osculans*		nt	
Chestnut quail-thrush	*Cinclosoma castanotus*		nt	
Brown treecreeper	*Climacteris picumnus*		nt	
Emu	*Dromaius novaehollandiae*		nt	
Little Egret	*Egretta garzetta*		en	L
White-bellied Sea-Eagle	*Haliaeetus leucogaster*		vu	L
Caspian Tern	*Hydroprogne caspia*		nt	L
Australian Little Bittern	*Ixobrychus dubius*		en	L
Malleefowl	*Leipoa ocellata*	VU	en	L
Major Mitchell's Cockatoo	*Lophocroa leadbeateri*		vu	L
Hooded Robin	*Melanodryas cucullata*		nt	L

BIRDS				
Common name	**Scientific name**	**EPBC**	**VRoTS**	**FFG**
Black-chinned honeyeater	*Melithreptus gularis*		nt	
Elegant parrot	*Neophema elegans*		vu	
Nankeen night heron	*Nycticorax caledonicus*		nt	
Crested bellbird	*Oreoica gutturalis*		nt	L
Blue-billed duck	*Oxyura australis*		en	L
Pied cormorant	*Phalacrocorax varius*		nt	
Royal spoonbill	*Platalea regia*		nt	
Glossy ibis	*Plegadis falcinellus*		nt	
Regent parrot	*Polytelis anthopeplus monarchoides*	VU	vu	L
Australian painted snipe	*Rostratula australis*	EN	cr	L
Freckled duck	*Stictonetta naevosa*		en	L
Mallee emu-wren	*Stipiturus mallee*	EN	en	L
Red-backed kingfisher	*Todiramphus pyrropygia*		nt	
Common greenshank	*Tringa nebularia*		vu	
Marsh sandpiper	*Tringa stagnatilis*		vu	

Apart from threatened species, the lake system supports large numbers of waterbirds and provides important breeding habitat for waterfowl, swans, cormorant, grebes and resident shorebirds when conditions are suitable. Criterion 3 of the Ramsar Convention indicates that the Hattah Lakes maintain regional biodiversity by providing important habitat for more than 50 species of waterbirds. Fifty-two species of waterbird have been recorded during TLM monitoring over the last ten years. Large numbers of hoary-headed grebes (*Poliocephalus poliocephalus*), freckled ducks (*Stictonetta naevosa*) (listed as threatened in Victoria under the *Flora and Fauna Guarantee Act*), Pacific black duck (*Anas superciliosa*), grey teal (*A. gracilis*), pink-eared duck (*Malacorhynchus membranaceus*), black-fronted dotterel (*Elseyornis melanops*), red-necked avocet (*Recurvirostra novaehollandiae*), great cormorant (*Phalocrocorax carbo*) and Australian pelican (*Pelecanus conspicillatus*) have been recorded occupying the lakes at any one time (DSE 2003, TLM condition monitoring 2006-2020).

Occasional sightings of migratory shorebirds are made. Although the Hattah Lakes is generally not considered a migratory shorebird refuge, it does occasionally provide alternate habitat for migratory shorebirds when suitable conditions occur. Many of the recorded migratory bird species are protected under international migratory bird agreements with Japan (JAMBA), China (CAMBA), Korea (ROKAMBA) and the Bonn Convention.

Under pre-regulated conditions, most lakes would have held permanent water for decades via frequent inflows and flooding. This hydrological regime would have supported mature fish populations, including large-bodied species such as golden perch (*Macquaria ambigua*) and Murray cod as well as a range of small-bodied fish species. The frequent connection to the River Murray would have allowed fish to move between the wetlands and the main channel. Sixteen native fish species have been reported from the lakes, of which four have conservation significance in Victoria and four are listed under the FFG (Appendix 1), including silver perch and Murray cod — which are also listed under the EPBC.

The FFG-listed carpet python (*Morelia spilota metcalfei*) has been identified from the Hattah Lakes, and shelters in hollows of river red gum and black box tree branches and fallen logs. Bats are the most species rich of the mammalian groups inhabiting Hattah-Kulkyne National Park, and it is suspected that the FFG-listed Corben's (south-eastern) long-eared bat (*Nyctophilus corbeni*) may inhabit the area (Atlas of Living Australia 2020).

Vegetation communities

Flood-dependent vegetation at Hattah Lakes comprises 10 Victorian Ecological Vegetation Classes. These range from wetland communities that require frequent flooding to those that require periodic inundation, such as lignum and black box-dominated communities. The bioregional conservation significance of the vegetation classes ranges from 'endangered' to 'least concern' (see Table 5.2).

Table 5.2. The flood dependent Ecological Vegetation Classes (EVCs) of the Hattah Lakes Icon Site and their conservation significance; Robinvale Plains Bioregion (DSE 2004).

EVC no.	EVC name	Bioregional conservation status
106	Grassy riverine forest	Depleted
811	Grassy riverine forest/floodway/pond/herbland complex	Depleted
813	Intermittent swampy woodland	Depleted
818	Shrubby riverine woodland	Least concern
295	Riverine grassy woodland	Depleted
823	Lignum swampy woodland	Depleted
103	Riverine chenopod woodland	Depleted
808	Lignum shrubland	Least concern
104	Lignum swamp	Vulnerable
107	Lakebed herbland	Depleted

Flora

The icon site supports over 450 flora species (see Appendix 3). This includes winged peppercress (*Lepidium monoplocoides*) and yellow swainson-pea (*Swainsona pyrophila*), listed as nationally endangered and vulnerable under the EPBC**.** An additional four species are also listed under the FFG. These include umbrella wattle (*Acacia oswaldii*), woolly scurf-pea (*Cullen pallidum)*, tough scurf-pea (*Cullen tenax*) and silky swainson-pea (*Swainsona sericea*) (Table 5.3). The species inhabiting Hattah Lakes vary in their water requirements, resulting in natural booms and busts in response to the flooding and drying cycle. During wet phases, aquatic and amphibious species are in abundance. Alternatively, during dry phases, the population of terrestrial species increases. The water regime can greatly impact the health and persistence of flora species at Hattah, as water availability needs to be timed with season (temperature/rainfall) as well as the activity of associated invertebrate's and fauna to maintain the processes of flowering, pollination, germination and recruitment.

Lake Mournpall following drawdown blanketed in knotweed (*Persicaria *spp.) (Source: MCMA)

Table 5.3. Listed flora species identified at Hattah Lakes. *Environment Protection and Biodiversity Conservation* (EPBC) *Act 1999*; EN=Endangered, VU=Vulnerable. Conservation status in Victoria (VRoTS); en=endangered, vu=vulnerable, r=rare, k=poorly known (DEPI 2014). FFG; L=Listed (DELWP 2019).

Common name (Vic)	Scientific name	EPBC	VRoTS	FFG
Umbrella wattle	*Acacia oswaldii*		vu	L
Common joyweed	*Alternanthera nodiflora*		k	
Jerry-jerry	*Ammannia multiflora*		vu	
Dark wire-grass	*Aristida calycina* var. *calycina*		r	
Tall kerosene grass	*Aristida holathera* var. *holathera*		vu	
Twin-leaf bedstraw	*Asperula gemella*		r	
Flat-top saltbush	*Atriplex lindleyi* subsp. *lindleyi*		k	
Mallee cucumber	*Austrobryonia micrantha*		r	
Spear-grass	*Austrostipa trichophylla*		r	
Azolla	*Bergia trimera*		vu	
Tah-vine	*Boerhavia coccinea*		r	
Wedge-leaf daisy	*Brachyscome cuneifolia*		k	
Strap purslane	*Calandrinia corrigioloides*		r	
Twining purslane	*Calandrinia volubilis*		r	
Blue burr-daisy	*Calotis cuneifolia*		r	
Wingwort	*Ceratogyne obionoides*		r	
	Chenopodium desertorum subsp. *rectum*		vu	
Broom milkwort	*Comesperma scoparium*		r	
Woolly scurf-pea	*Cullen pallidum*		en	L
Tough scurf-pea	*Cullen tenax*		en	L
Couch	*Cynodon dactylon*		k	
	Cyperus pygmaeus		vu	
Pale spike-sedge	*Eleocharis pallens*		k	
Cane grass	*Eragrostis australasica*		vu	
Purple love-grass	*Eragrostis lacunaria*		vu	
Bristly love-grass	*Eragrostis setifolia*		vu	
Spreading emu-bush	*Eremophila divaricata* subsp. *divaricata*		r	
Dwarf brooklime	*Gratiola pumilo*		r	
Inland club-sedge	*Isolepis australiensis*		k	
Bundled peppercress	*Leoidium fasciculatum*		k	
Winged peppercress	*Lepidium monoplocoides*	EN	en	L
Native peppercress	*Lepidium pseudohyssopifolium*		k	
Heathy bluebush	*Maireana oppositifolia*		r	
Woolly minuria	*Minuria denticulata*		r	
Slender daisy-bush	*Olearia passerinoides* subsp. *passerinoides*		r	
Spiked daisy-bush	*Olearia subspicata*		vu	
Upright adder's-tongue	*Ophioglossum polyphyllum*		vu	
Australian broomrape	*Orobanche cernua* var. *australiana*		vu	
Mallee pellitory	*Parietaria cardiostegia*		vu	
Spreading cress	*Phlegmatospermum eremaeum*		vu	

Common name (Vic)	Scientific name	EPBC	VRoTS	FFG
Lagoon spurge	*Phyllanthus lacunarius*		vu	
Knotted poa	*Poa drummondiana*		r	
Dwarf bitter-cress	*Rorippa eustylis*		r	
Glistening dock	*Rumex crystallinus*		vu	
Black roly-poly	*Sclerolaena muricata*		k	
Dark roly-poly	*Sclerolaena muricata* var. *semiglabra*		k	
Spear-fruit copperburr	*Sclerolaena patenticuspis*		vu	
Sand sida	*Sida ammophila*		vu	
Pin sida	*Sida fibulifera*		vu	
Twiggy sida	*Sida intricata*		vu	
Small-leaf swainson-pea	*Swainsona microphylla*		r	
Yellow swainson-pea	*Swainsona pyrophila*	VU	vu	
Silky swainson-pea	*Swainsona sericea*		vu	L
	Tetragonia moorei		k	
Sweet senugreek	*Trigonella suavissima*		r	
Needle grass	*Triraphis mollis*		r	
Dissected New Holland daisy	*Vittadina dissacta* var. *dissecta*		k	
Winged New Holland daisy	*Vittadinia pterochaeta*		vu	
Furrowed New Holland daisy	*Vittadinia sulcata*		k	

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, including 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 to 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 at Hattah Lakes, 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 Hattah Lakes and the River Murray has significance for downstream processes, particularly during periods of high flow.

Cultural values

‘The Hattah Lakes hold great significance to the local First Nations community, particularly because of the site’s location on the border between the Latji Latji and Jari Jari language groups (SKM 2007). Historically, the lakes would have provided an abundant and reliable source of food and water for Indigenous populations. Early observations suggest the area was densely populated in the 1830s and continually occupied until at least 1914

(SKM 2007). The local community maintains strong connections to the land and its traditional resources such as native species used for food and medicine (K. Stewart, pers. comm., 2011).

Eleven sites of significance are recorded on the Victorian Heritage Database (Heritage Victoria 2020), with more than 1,000 Indigenous archaeological sites at the Hattah Lakes Icon Site registered with Aboriginal Affairs Victoria (SKM 2009). These include burial sites, scarred trees, shell middens, artefact scatters, hearths and other topological sites. Additional sites were recorded during Cultural Heritage Management Plan surveys.

Aboriginal water objectives for the Hattah Lakes Icon Site have not yet been established; however, an assessment of the icon site's cultural and heritage value is planned to be conducted in 2021. This will involve working with community members to document Indigenous values from the Hattah Lakes, which are important to them and their culture. It is envisaged that this assessment will be undertaken a number of times across coming years, with the wetlands in different conditions (e.g. dry, wet, flooded) to catalogue the effect of change in values across time and space. Work to establishing a better understanding of Indigenous Australian values at the icon site is ongoing and new knowledge, including the cultural and heritage values assessment outcomes, is and will be incorporated into annual water planning as it becomes available. Values of the site identified at Talk Water on Country events include key plant species used for food, medicine and weaving and the importance of the site in the past for fishing and use of traditional fish traps. Due to the close link between cultural values/use and the health of the Hattah Lakes, it is predicted that the ecological benefits derived from environmental watering will also result in cultural benefits. The operation of works commissioned in 2012 have generated an overall increase in the condition of waterway and floodplain vegetation health at the Hattah Lakes. This is also assisting in improving the condition and abundance of native flora and fauna species at the lakes. In turn, this has helped maintain and increase populations of plants and animals of cultural importance of the region, as well as the landscape as a whole.

Recreation and economic values

Recreation and economic values are closely linked. The Hattah-Kulkyne National Park is a popular destination for tourists, attracting more than 70,000 visitors annually (DSE 2003). The direct economic value to the Hattah Lakes from recreation and tourism has been estimated at $1.5 million per year (Read and Sturgess, cited in DSE 2003). Common activities include camping, bushwalking, bird watching and, when the lakes hold water, swimming, kayaking and canoeing.

Visitor numbers are linked to the lakes being filled and floodplain inundation when access is available. Tourists are attracted to the Hattah Lakes when water is present as the full lakes add to the amenity value of the park. Recent visitor statistics are not available; however, anecdotal evidence from Parks Victoria staff indicates visitor numbers increased significantly (by greater than 50 per cent) since environmental water was pumped into the lakes from 2005-2010 (B. Rodgers, pers comm., 2011). In addition, Parks Victoria staff estimate that visitation dropped by 60 per cent during a period when all lakes were dried as part of planned management (L. Freeman pers comm., 2021).

The adaptation of some local businesses to tourism and recreation (i.e. ecotourism ventures) means that an increase in visitor numbers will likely correspond with increased revenue for these businesses and, therefore, an increase in the economic value of the Hattah Lakes from recreation and tourism. This is likely to have flow-on benefits to the broader business base in towns such as Mildura and Ouyen, especially if those with increased revenue spend locally. Information from the local Hattah Roadhouse just outside the park shows an increase in the business takings from park visitors during times when water is in the lakes.

6. Ecological objectives

Management goal

Based on an understanding of the Hattah Lakes 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 Hattah Lakes Icon Site is to:

> *'Improve biodiversity values of Hattah Lakes, maintaining wetland and floodplain communities 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 Plan (Butcher et al. 2019). The refined objectives for the Hattah Lakes 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 Hattah Lakes 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.

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 which are based on the original objectives and have been made SMART and or adapted to align with the Basin Plan Environmental Watering Plan objectives.

River red gum fringing Lake Mournpall (Source: MCMA).

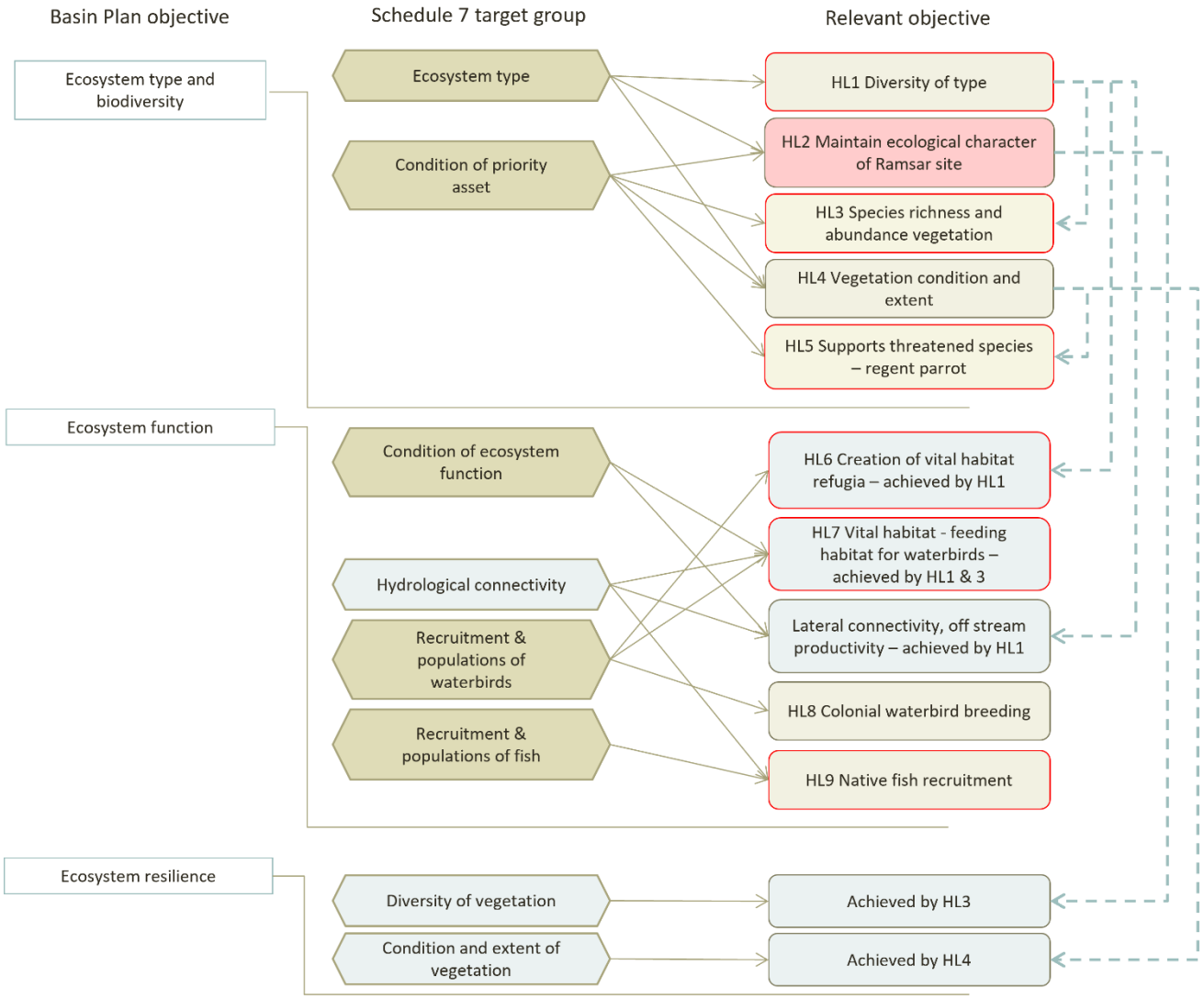


Figure 6.1. Basin Plan objectives, Schedule 7 target groups and relationship to ecological objectives for the Hattah Lakes Icon Site. HL1-9 equate to the objectives presented below. Those objectives which have a red outline, if met, will contribute to maintaining the ecological character of the Ramsar site.

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

Table 6.1. Mapping Hattah Lakes 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 2019), and Long-term Watering Plan (LTWP) Victorian Murray objectives (DELWP 2015).

EWMP objectives	Basin Plan EWP objective	Relevant Schedule 7 target	Relevant BWS QEEO^	LTWP objective*
HL1: Diversity of ecosystem type	8.05,2(a) 8.05,3(b) 8.06,3(a)	-Ecosystem type -Condition of priority assets – Ramsar -Condition of priority assets – supports significant biodiversity		LTWPVM1
HL2: Maintain ecological character of the Ramsar site	8.05,2(a)	-Condition of priority assets – Ramsar		
HL3: Species richness and abundance of aquatic vegetation	8.05,3(b)	-Ecosystem type -Extent and contiguousness of native – water-dependent vegetation -Condition of ecosystem function – creation of vital habitat -Condition of water-dependent vegetation -Condition of priority assets – supports biodiversity	BWS11	LTWPVM2 LTWPVM4
HL4: Condition and extent of floodplain vegetation	8.05,3(b)	-Ecosystem type -Recruitment and populations of native water-dependent vegetation -Condition of water-dependent vegetation -Condition of priority assets – supports biodiversity	BWS10 BWS11 BWS12 BWS13	LTWPVM5 LTWPVM6 LTWPVM7 LTWPVM8
HL5: Support threatened species	8.05,3(a) 8.06,6(b)	-Condition of priority assets – listed species -Condition of priority assets – vital habitat		
HL6: Create refugia for waterbirds in dry periods	8.05,3(a) 8.06,6(b)	-Condition of priority assets – refugium	BWS15	
HL7: Create vital habitat – feeding habitat for waterbirds	8.05,3(a) 8.06,6(b)	-Condition of priority assets – vital habitat	BWS15	LTWPVM12 LTWPVM13
HL8: Colonial 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	LTWPVM10
HL9: Native fish recruitment	8.06,6(a)	-Recruitment and populations of native fish -Condition of priority ecosystem functions -vital habitat (feeding and breeding)	BWS20 BWS24	LTWPVM15

^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 Hattah Lakes 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 situated 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 HL1: Diversity of ecosystem type

> *By 2030, maintain a diversity of freshwater ecosystem types within the Hattah Lakes Icon Site, including semi-permanent lakes, persistent temporary wetlands, floodplain woodlands, shrublands, and episodic wetlands (Lake Kramen).*

Targets for Objective HL1

Maintain a variable hydrograph to support a range of aquatic ecosystem types including:

- By 2030, maintain an annual return interval (ARI) of 8 in 10 years on average to fill semi-permanent lakes, achieved by flows of 40,000 ML/d for 60 days at Lock 15 (fills, Hattah, Bulla, Yerang, and Mournpall, Lake Lockie*, Little Hattah*). Alternatively, use the infrastructure including the pump station to provide inflows to the system, maintaining variability around 42.5 m AHD to simulate the pre-regulation conditions. This will fill semi-permanent lakes and temporary lakes on the flow path and inundate fringing vegetation of river red gum and black box woodlands.
- By 2030, maintain an ARI of 5 in 10 years (on average) to fill persistent temporary wetlands achieved by flows of 50,000 ML/d for 60 days (at Lock 15), or through the use of the pump station to simulate a similar event. This event fills Brockie, Tullamook, Boich, Nip, Konardin, Roonki, Yelwell, Arawak, and will inundate some lower lying red gum woodlands.
- By 2030, maintain an ARI of 1 in 6 (on average) of 70,000 ML/day for 42 days (at Lock 15) to fill Lake's Bitterang and Cantala[#]. Alternatively, pump to provide large floods (up to 45 m AHD) one in eight years, inundating river red gum and black box woodlands.
- By 2030, maintain an ARI of 1 in 8 (on average) of natural events to support episodic filling of Lake Kramen achieved by flows of 152,000 ML/d for 30 days at Lock 15. Alternatively, pump to achieve episodic filling of Lake Kramen (to 46.3 m AHD) one year in eight.

Note: Lake Lockie, Lake Yerang and Lake Little Hattah will fill every time water flows through to the semi-permanent lakes as they form part of the flow path prior to water reaching the other lakes.

[#] Lake Cantala fills directly from the River Murray on high flow events through Cantala Creek and at flows greater than 70,000 ML/d. However, it is the last of the lakes to receive water during managed events.

Rationale for watering regime

The targets are equivalent to the water requirements needed to support the various types of aquatic ecosystems present within the Hattah Lakes Icon Site. The hydrological targets have been developed based on modelled flow return frequencies under pre-regulation conditions (Ecological Associates 2007).

The watering requirements to support a diversity of ecosystem type are detailed in Table 6.2.

Table 6.2. Watering regimes for the objective HL1 for the Hattah Lakes system. Flow requirement is based on the modelled pre-regulation condition.

Wetland type	Flow (ML/day)	Duration (days)	Timing	Frequency	Maximum inter-flood period
Semi-permanent wetlands	40,000	Up to 60	Spring	8 in 10 years	3 years
Temporary wetlands	50,000	Up to 60	Spring	5 in 10 years	4 years
Persistent temporary wetlands	70,000	Up to 42	Spring	1 in 6 years	10 years
Episodic	152,000	Up to 30	Winter-Spring	1 in 8 years	12 years

Condition of priority environmental asset

Objective HL2: Maintain ecological character of the Ramsar site

By 2030, maintain the ecological character of the Hattah-Kulkyne Lakes Ramsar site.

Targets for Objective HL2

No additional target set. This objective will be achieved in part by the targets set for objective's HL1, 3, 5, 6 and 9.

Rationale for watering regime

The Hattah-Kulkyne Lakes Ramsar site incorporates 12 lakes (to high water mark). They are considered significant as a good example of a series of large, hydrologically connected, permanent and intermittent sequentially filled floodplain lakes, supporting a number of threatened species and communities including the regent parrot, winged peppercress and lakebed herbland Ecological Vegetation Class (EVC).

Species richness is high across several groups of biota including plants and waterbirds, being comparable to several other Ramsar sites in the Murray-Darling Basin. The Hattah-Kulkyne Lakes Ramsar site provides habitat for over 50 species of wetland birds, of which 34 have been recorded breeding within the site. In addition, the site supports a number of migratory species, notably waterbirds and fish, with 12 waterbirds listed as migratory under the EPBC Act as well as under international migratory species treaties.

The site is also considered important for fish breeding. The Ramsar site is considered an important nursery area for native fish. Recruitment of juveniles back into the adult population is dependent on the water levels of the lakes being maintained, and for large-bodied river specialists there needs to be reconnection to the River Murray for species to return to the riverine habitat. Small-bodied wetland specialists breed in the site.

This objective is a new objective for the Hattah Lakes Icon Site and addresses the importance of the Ramsar listing.

The water requirements for maintaining the ecological character of the Ramsar site will be achieved by meeting the watering regime for HL1, 3, 5, 6 and 9.

Objective HL3: Species richness and abundance of aquatic vegetation

Improve species richness and abundance of native water-dependent floodplain and wetland aquatic vegetation at the Hattah Lakes Icon Site by 2030.

Targets for Objective HL3

Reference targets for floodplain water responsive vegetation species richness maintained or improved at three flood return frequencies for the Hattah Lakes Icon Site by 2030 (lower, mid and upper floodplain; Brown et al. 2016).

- Lower floodplain water responsive species richness 80th percentile is ≥ 6.15
- Mid floodplain water responsive species richness 80th percentile is ≥ 5.95
- High floodplain water responsive species richness 80th percentile is ≥ 1.6

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

- Lower floodplain water responsive species abundance 80th percentile is ≥ 37.35
- Mid floodplain water responsive species abundance 80th percentile is ≥ 22.9
- High floodplain water responsive species abundance 80th percentile is ≥ 7.15

Reference targets for wetland water responsive vegetation species richness maintained or improved across semi-permanent, persistent temporary and episodic wetlands; Brown et al. 2016).

- Semi-permanent wetlands water responsive species richness 80th percentile is ≥ 3.86
- Persistent temporary wetlands water responsive species richness 80th percentile is ≥ 3.07
- Episodic wetland (Lake Kramen) water responsive species richness 80th percentile is ≥ 3.84

Reference targets for wetland water responsive species abundance maintained or improved across semi-permanent, persistent temporary and episodic wetlands (see Brown et al. 2016):

- Semi-permanent wetlands water responsive species abundance 80th percentile is ≥ 23.86
- Persistent temporary wetlands water responsive species abundance 80th percentile is ≥ 20.28
- Episodic wetland (Lake Kramen) water responsive species abundance 80th percentile is ≥ 27.48

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 Hattah Lakes Icon Site provides habitat for a diverse and extensive range of vegetation species and communities. A number of vegetation classes (Ecological Vegetation Classes) found at Hattah Lakes have recognised conservation status in Victoria, with a number of these requiring flooding to maintain their character. Additionally, a high number of individual species of state and national conservation status are also recorded, with a number of these requiring inundation to support life-cycle requirements.

Wetland plant communities respond to a gradient of hydrological conditions determined by water regime that can vary from fully inundated to seldom inundated. Aspects of the hydrology such as water depth, duration of inundation, frequency, rate of filling and drying, timing and predictability of flood and dry phases all interact to determine the patterns and zonation of wetland and floodplain plant communities.

Adopting a watering regime that maintains a variable inundation regime across a range of aquatic ecosystem types within the icon site will provide conditions suitable for the range of plant functional groups. The ability to maintain a range of inundation conditions from standing water to dry floodplain across any year will develop a mosaic of vegetation communities and increase the species richness at the icon site.

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 Hattah Lakes condition monitoring floodplain and wetland understory vegetation data.

The water requirements for improving species richness and abundance of vegetation will be achieved by meeting the watering regime for HL1 in Table 6.2.

Objective HL4: Condition and extent of floodplain vegetation

*Improve condition and maintain extent 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 Hattah Lakes Icon Site by 2030.*

Targets for Objective HL4

- In standardised transects that span the floodplain elevation gradient and existing spatial distribution, 70 per cent of river red gum trees will have a Tree Condition Index ≥ 10 (Wallace et al. 2020) and annual mortality < 1 per cent.
- In standardised transects that span the floodplain elevation gradient and existing spatial distribution, 70 per cent of black box will have a Tree Condition Index ≥ 10 (Wallace et al. 2020) and annual mortality < 1 per cent.
- Population curves for river red gum and 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 ≥ 0.80 for red gum and ≥ 0.79 for black box.
- In standardised transects that span the floodplain elevation gradient and existing spatial distribution, ≥ 70 per cent of lignum plants will have a Lignum Condition Index (LCI) ≥ 4.
- Maintain 3,000 ha of river red gum, 1,300 ha of black box and 1200 ha of lignum across the Hattah Lakes Icon Site (based on 2006 extent data as per Investment Proposal).

Rationale for watering regime

Riparian forests, floodplain forests and floodplain woodlands are reliant on flooding to maintain their growth, and to recharge and refresh soil water and groundwater (Roberts and Marston 2011). Each major structural form has different flooding requirements and in part reflects their position on the floodplain. The understory species composition can also vary depending on wetting frequencies and should be considered in setting watering regimes, particularly for black box woodlands (Roberts and Marston 2011). Mature river red gum trees (*Eucalyptus camaldulensis*) provide structural habitat in the icon site, and provide tree hollows for a range of birds, mammals and reptiles to use, including the EPBC-listed regent parrot (*Polytelis anthopeplus monarchoides*) for nesting (see HL5). In addition to hollows, branches provide perches and roosts for waterbirds and raptors.

Objectives relating to river red gum and black box have been associated with the Hattah Lakes 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 and 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 Hattah 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, with flooding being the main driver of growth, and flooding frequency influencing the size and vigour of individual shrubs (Roberts and Marston 2011). They have been identified as an ecologically significant floodplain shrub and play an important role in floodplain processes (Roberts and Marston 2011). Lignum has separate male and female plants, which can differ in response to environmental factors (Roberts and Marston 2011). Targets relating to lignum were initially developed using historic TLM condition monitoring data as part of an earlier refinement process (Robinson 2014).

The watering requirements to support condition and extent of floodplain vegetation are detailed in Table 6.3.

Table 6.3. Watering regimes for the objective HL4 for the Hattah Lakes system.

Community	Depth (m)	Flow (ML/day)	Duration (days)	Timing	Frequency	Maximum inter-flood period
River red gum	< 2	50,000 or managed equivalent	Maintenance: 2-4 months	Spring	6 in 10 years Consecutive years for seed germination	3 years
Black box woodland	< 1	70,000 or managed equivalent	Maintenance: 2-6 months	Spring	1-3 in 10 years	3-7 years
Lignum	< 1	70,000 or managed equivalent	Maintenance: 3-6 months. Maximum of 6 months for Floodplain grassy wetland (EVC 808). Maximum of 4 months for Lignum swampy woodland (EVC 823).	Spring	1-3 in 10 years (vigorous growth) 3-5 in 10 years (healthy shrubs) 5-7 in 10 years (maintain vigour)	Dry period minimum 6 months, maximum 7-10 years

Objective HL5: Support threatened species

*By 2030, improve biodiversity at Hattah Lakes by supporting the life-cycle of the EPBC-listed regent parrot (*Polytelis anthopeplus monarchoides*).*

Targets for Objective HL5

- Improve, and maintain adult breeding populations of the regent parrot (*Polytelis anthopeplus monarchoides*) at the Hattah Lakes Icon Site by 20 per cent from 500 individuals by 2030.

Rationale for watering regime

The habitat requirements of the regent parrot include both river red gum and Mallee woodland. They require Mallee woodland within 20 kilometres of the riverine habitat, preferably less than five kilometres for foraging during breeding. In addition, they require treed flight paths between the two main habitat types as they avoid flying in open areas. They use hollow-bearing river red gum trees close to water (within 120 metres) for breeding

(Baker-Gabb and Hurley 2010). Nesting trees are usually large (approximately 30 metres tall) healthy mature river red gums with lots of hollows for nesting.

The population of regent parrots at Hattah Lakes is the largest of the remaining three populations in Victoria. During the non-breeding season, birds typically move away from the riverine breeding habitat; however at Hattah, the birds can be found all year round (Baker-Gabb and Hurley 2010). A number of sightings have been made of small flocks feeding along Chalka Creek between Lake Lockie and Mournpall (Butcher and Hale 2011). The species has also been seen to feed on seeds of various plants near Lake Kramen, taking advantage of the regeneration from the 2014 environmental watering event (Loyn and Duston 2018).

The watering regime proposed in HL1 provides the means to improve treed habitats that the parrots use for nesting and as safety during their foraging movements e.g. the black box woodland at Lake Kramen. In addition, the water regimes improve the lakebed herbland during drawdown, and recent evidence suggests that this herbland is used by flocks of regent parrots for feeding.

This objective, and associated target is new for the Hattah Lakes Icon Site, and has been developed to support the threatened regent parrot, and iconic species of Hattah Lakes.

The watering requirements for threatened species are met by the watering regimes for HL1 in Table 6.2.

Regent parrot (*Polytelis anthopeplus monarchoides*) utilising a nesting hollow in a river red gum (Source: MCMA).

Ecosystem function

Condition of priority ecosystem functions

Objective HL6: Create refugia for waterbirds in dry periods

Provide refugia to support the long-term survival and resilience of waterbirds, including during drought, to allow for subsequent re-colonisation beyond Hattah Lakes by 2030.

Targets for Objective HL6

- Maintain Lake Mournpall and Lake Hattah at least 50 per cent full for up to 18 months during periods of extended dry conditions (measured as three consecutive years of below average annual rainfall of 334 mm at Ouyen) and or drought (Bureau of Meteorology 2010).

Rationale for watering regime

Lake Mournpall and Lake Hattah are the two deepest lakes in the system and therefore maintain water for the longest period of time. As a result, they are considered the most suited to providing refugia during dry periods. When full, Lake's Mournpall and Hattah take 2-3 years to dry. Water flows into these two lakes very early in the passage of water through the system, with only three shallow temporary lakes earlier in the flow path. This adds to the relative ease of providing water to the two lakes, and means that water-use is minimised to maintain the lakes as a refuge.

This target has been newly developed with the understanding of the importance of providing water as refuge during drought. The superior ability of Lake's Mournpall and Hattah to retain water gives them the greatest capacity to provide drought refuge.

The watering requirements to support vital habitat/refuge are detailed in Table 6.4.

Table 6.4. Watering regimes for the objective HL6 for the Hattah Lakes system.

Community	Depth (m)	Flow (ML/day)	Duration	Timing	Frequency	Maximum inter-flood period
At least 1 of Lake Hattah or Lake Mournpall	2	N/A	18 months	Spring	Determined by antecedent conditions	0 years
HL6 will be achieved through targeted water delivery via pumps to provide water to Lake Hattah and Lake Mournpall if required. Should HL1 be implemented, HL6 will be achieved.						

Objective HL7: Create vital habitat – feeding habitat for waterbirds

By 2030, maintain or improve biodiversity at Hattah Lakes by ensuring that feeding habitat for the dominant guilds of waterbirds, most notably waterfowl, herbivores and piscivores, are supported.

Targets for Objective HL7

- Support feeding habitat for waterfowl, herbivores and piscivores of waterbirds, 8 years in 10, with the following common species recorded annually: Australian pelican (*Pelecanus conspicillatus*), Australian wood duck (*Chenonetta jubata*), black-winged stilt (*Himantopus himantopus*), Australian darter (*Anhinga novaehollandiae*), great cormorant (*Phalacrocorax carbo*), great crested grebe (*Podiceps cristatus),* little black cormorant (*Phalacrocorax sulcirostris*), masked lapwing (*Vanellus miles*), Pacific black duck (*Anas superciliosa*), 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).

Rationale for watering regime

The hydrological diversity across the Hattah Lakes 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 relevant to the species commonly found at the Hattah Lakes 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

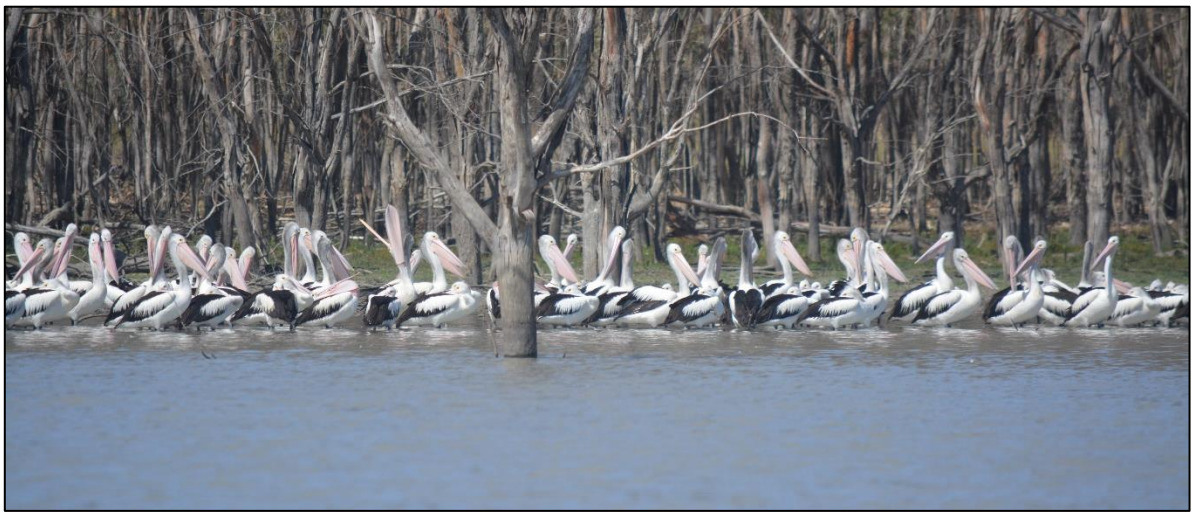
The most relevant feeding guilds at the site are those that feed in shallow and deep water and areas away from wetland habitats. Deep water habitats are provided by the semi-permanent wetlands in the Hattah Lakes system. These habitats support a large proportion of the fish-eating species and diving specialists, including members of the ducks, grebes, cormorants, terns and pelicans. Deep water habitats are also found in the main channel of the River Murray, including the weir pools.

Those that feed in the shallow habitat and or in mud will be reliant on seasonal and intermittent wetlands and inundated floodplain areas for foraging. This guild often supports the largest number of species (60 species or 85 per cent or total species at Menindee Lakes – Jaensch 2002), and takes advantage of both the wet and drying phase in temporary wetlands.

The watering regime in HL1 should provide the range of water depths that can be used by a variety of waterbirds for feeding, particularly fish-eating birds, ducks and grebes and both large waders and their smaller counterparts.

As part of new (2020) target development, ‘Common’ species for the Hattah Lakes Icon Site have been determined from condition monitoring waterbird data. The habitat requirements are 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 for HL1 (Table 6.2).



Australian pelicans (*Pelecanus conspicillatus*), a common species found at Hattah Lakes (Source: MCMA)

Recruitment and populations of waterbirds

Objective HL8: Colonial waterbird breeding

> *By 2030, protect and restore ecosystem functions of water-dependent ecosystems that support successful colonial nesting waterbird species at Hattah Lakes by providing conditions for breeding and fledging at least three times every 10 years.*

Targets for Objective HL8

Increased frequency in successful breeding (recruitment into adult population – i.e. fledging) of one or more of the listed colonial nesting species three years in 10, when conditions are favourable:

- Australian white Ibis (*Threskiornis molucca*), glossy ibis (*Plegadis falcinellus*), great egret (*Ardea modesta*), intermediate egret (*Ardea intermedia*), Australian darter (*Anhinga novaehollandiae*), great cormorant (*Phalacrocorax carbo*), little black cormorant (*Phalacrocorax sulcirostris*) little pied cormorant (*Microcarbo melanoleucos*), white-necked heron (*Ardea pacifica*), yellow spoonbill (*Platalea flavipes*), and royal spoonbill (*Platalea regia*).

Rationale for watering regime

Breeding events of colonial waterbirds should be placed in the regional context for breeding events, as it is unlikely that breeding will occur in every year at the Hattah Lakes Icon Site. The absence of large colonies of breeding birds in Hattah Lakes, particularly in years of high rainfall or flood events, may result from dispersion behaviour of birds as a result of increased temporary wetlands at the regional or national scale. Species that are known to have bred at the site through direct observations or nest evidence include the Australasian darter and several cormorant species (as above) (Cook and Jolly 2010; GHD 2021).

Maintaining suitable habitat for waterbird breeding and feeding will be the main mechanism for achieving the targets for waterbirds. Achieving suitable habitat will rely on establishing the correct hydrological regime as discussed in the vegetation section that provides the appropriate inundation levels and duration, and supports vegetation for nesting. The different guilds of birds require different hydrological conditions, ranging from open water, through to reed beds and flooded lignum shrublands, and good quality river red gum through to drying shallow water. The flow through Chalka Creek and the lakes and wetland should be able to maintain a mosaic of habitats, to cater for all the guilds during any 2-3-year period.

Breeding habitat is defined as including a water regime that allows successful recruitment of young into the adult population. Cormorants and the Australasian darter exhibit irregular breeding, and are capable of laying at any time of year if conditions are suitable, but typically do so in Spring and Summer. Darters may nest within loose colonies with other waterbirds that exhibit colonial nesting such as cormorants. Nests are often lodged in the fork of a tree or on horizontal branches above water. Chicks can swim after about four weeks and start to fly at about 50 days (Jaensch 2002).

The watering requirements to support colonial waterbird breeding are detailed in Table 6.5.

Table 6.5. Watering regimes for the objective HL8 for the Hattah Lakes system.

Community	Depth	Flow (ML/day)	Duration (days)	Timing	Frequency	Maximum inter-flood period
Australasian darter and cormorant species	Deep (> 2 m)	N/A	Lag time 9 months (min. 3 months) Flood: 12 months	Max. flood: Spring – Summer Breeding: September to May	Small floods 1-2 years Large floods 4 years	1-3 years
HL8 will be achieved by delivering on HL1 watering regimes.						

Recruitment and populations of native fish

Objective HL: Native fish recruitment

Maintain recruitment of populations of small-bodied native fish and presence of large-bodied native fish at Hattah Lakes by 2030.

Targets for Objective HL9

- 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*); 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 ≥ 0.5 in 80 per cent of sampling events (see Brown et al. 2016).

Rationale for watering regime

Foraging generalists, such as carp gudgeon are less dependent upon large flooding events for recruitment and may benefit from lower flows. These species may, however, benefit from numerous small-scale watering events during the spawning period to assist in habitat availability. Small generalist species are also likely to recruit in channel as well as in wetlands.

Providing the range of inflows into the lake system, including Spring fresh flows will help provide the cues needed for small-bodied fish recruitment. The inundation of temporary wetlands will also provide the productivity needed to support breeding and recruitment events. Additionally, and importantly, the life-history requirements of key large-bodied fish species means 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 (e.g. golden perch), 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 were further refined (Brown et al. 2016) following application and testing of the initial targets. This process was undertaken using TLM condition monitoring data.

The watering requirements to support small-bodied fish recruitment and presence of large-bodied species will be achieved if HL1 (Table 6.2) is achieved.

7. Water delivery infrastructure

To deliver improved hydrological regimes to Hattah Lakes, a series of watering infrastructures were built, and one was refurbished under TLM (completed in 2012). The infrastructures include regulators to hold water on the floodplain, if required, and a pump station to deliver water to the icon site. The pump station consists of seven variable-speed pumps that can deliver a total of around 1000 ML/day. High points in the bed of Chalka Creek have been lowered to improve delivery to the lakes, and the offtake to Chalka Creek has also been lowered to allow water to enter from the River Murray at flows of about 23,000 ML/d at Euston. A number of stop banks allow control over the water flow to assist in meeting inundation extent at the Hattah Lakes Icon Site. These stop banks help prevent water from flowing back to the river before the desired inundation extent is achieved.

Table 7.1 outlines the structures and their function in delivering water across the floodplain. These structures can manipulate water delivery to meet the objectives under any water availability scenario.

Table 7.1 The completed infrastructure and its function for environmental watering across the Hattah Lakes Icon Site.

Works	Function
Pumping station at Messenger's Crossing	This pumping station is used to deliver water to the floodplain in the absence of sufficient natural inflows. Pumping is required because of the height difference between the Chalka Creek sill and usual water levels in the River Murray. The pumps have sufficient capacity to replicate natural flooding events to a peak of 45 m Australian Height Datum (AHD) at a rate of rise and fall that matches medium-to-large natural flood peaks. The pumps can also be used to top up natural inflows, to maximise environmental benefits and optimise the use of environmental water.
Sill lowering in Chalka Creek south	Lowering sills in the creek to 41.75 m AHD has reduced the inflow threshold from 37,600 ML/d to 23,000 ML/d, increasing the frequency of natural inflows.
Messenger's regulator	This regulator prevents water returning to the river during managed flood events, as the pump station delivers water from the River Murray to Chalka Creek upstream of the Messenger's Regulator. The regulator will remain open to allow inflows during natural flood events. It also contributes to the drawdown of the floodplain in large, managed flood events, and has a release capacity of up to 450 ML/d.
Oatey's regulator	This regulator, when closed, allows water to be retained in the Hattah Lakes to a target level of 45 m AHD (pumped or natural inflow). It also controls outflows from the Hattah Lakes region via Chalka Creek north back to the River Murray, and has a regulated release capacity of up to 250 ML/d.
Cantala regulator	This regulator is operated to assist filling of the lakes during planned watering (natural or pumped), up to 45 m AHD, by preventing water draining to the River Murray through Cantala Creek. Regulator gates are to remain open to allow inflows from the River Murray during high flow events. No releases to the River Murray are planned at this location due to the steep return path to the river and the high risk of erosion.
Little Hattah regulator	The regulator between Lake Little Hattah and Lake Hattah has been in place since 1966, and was refurbished during the recent works and measures program (2014). It retains its original function to control levels of water between the two lakes if required.
Kramen Regulator	This small regulator is used during pumping to Lake Kramen. It houses the outfall pipe from the pump station and directs the flow of water down Kramen Creek.
Breakout stop bank	This stop bank prevents uncontrolled escape of water from Chalka Creek to the River Murray across low lying floodplain prior to reaching the target inundation level of 45 m AHD.
Bitterang stop bank	This stop bank retains water in the target inundation area by preventing flow to Lake Boolca and the Dry Lakes to the north of Lake Bitterang during operation of the maximum inundation scenario.
Cantala stop bank	This stop bank will prevent uncontrolled draining of water to the River Murray via Cantala Creek.

The infrastructure is designed to allow inundation to a maximum of 45 m AHD. The regulators hold water on the floodplain, with the Oatey's and Messengers regulators used to manage the return flow and drawdown off the floodplain. The added ability to control return flows to the River Murray means that drawdown can be managed to provide a more natural hydrograph.

The management scenarios have allowed managers to provide similar inundation frequencies across the floodplain without the equivalent natural flow in the River Murray.

Operation of the infrastructure at the Hattah Lakes is categorised into five main watering scenarios:

- Natural flood (all structures open to allow floodwaters to enter and recede without impediment)
- Increased frequency of natural inflows (sill lowering in Chalka Creek)
- Enhanced duration and extent of natural floods (close regulators at natural flood peak to hold water on the floodplain for longer, inundation extent may be increased via pumping additional water onto the floodplain)
- Fully managed flood (shut regulators and pump the lakes full)
- Periodic drying of lakes (allow the lakes to dry naturally)

These are general scenarios that link broad ecological outcomes to hydrological outcomes. The three general scenarios are filling the lakes to retention level, inundating red gum woodlands (43.5 m AHD) and inundating black box woodland (45 m AHD) (Figure 7.1). These are not fixed operating scenarios, but provide a range of small, medium and large flood events within which ecological objectives can be targeted.

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 to allow Basin Plan environmental outcomes to be achieved with less water. Part of this program is the mechanism with which water savings can be made through the building or improvement of river or water management structures.

Through the Sustainable Diversion Limit Adjustment Mechanism, environmental works projects have been identified for the Hattah Lakes North 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 project is in Stage 1 (*pre-construction)* with detailed designs complete. The next step is obtaining regulatory and cultural approvals, which involves extensive consultation with Traditional Owner's and the broader community over an 18-month period. The project requires environmental impact assessment (Environmental Effects Statement) under the Environment Effects Act 1978 (Vic), and has been determined a controlled action under the EPBC (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.

The works will include the construction of three regulators, 1.3 km of levees, and a causeway along with infrastructure to support temporary pumps. This will allow for the inundation of 1,130 hectares of the floodplain. The extended area of potential inundation through the Victorian Murray Floodplain Restoration Project (VMFRP) is included for reference (Figure 7.1).

Once operational, the new infrastructure and existing TLM infrastructure will be managed concurrently to improve environmental watering capacity across the broader Hattah Lakes site. 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.

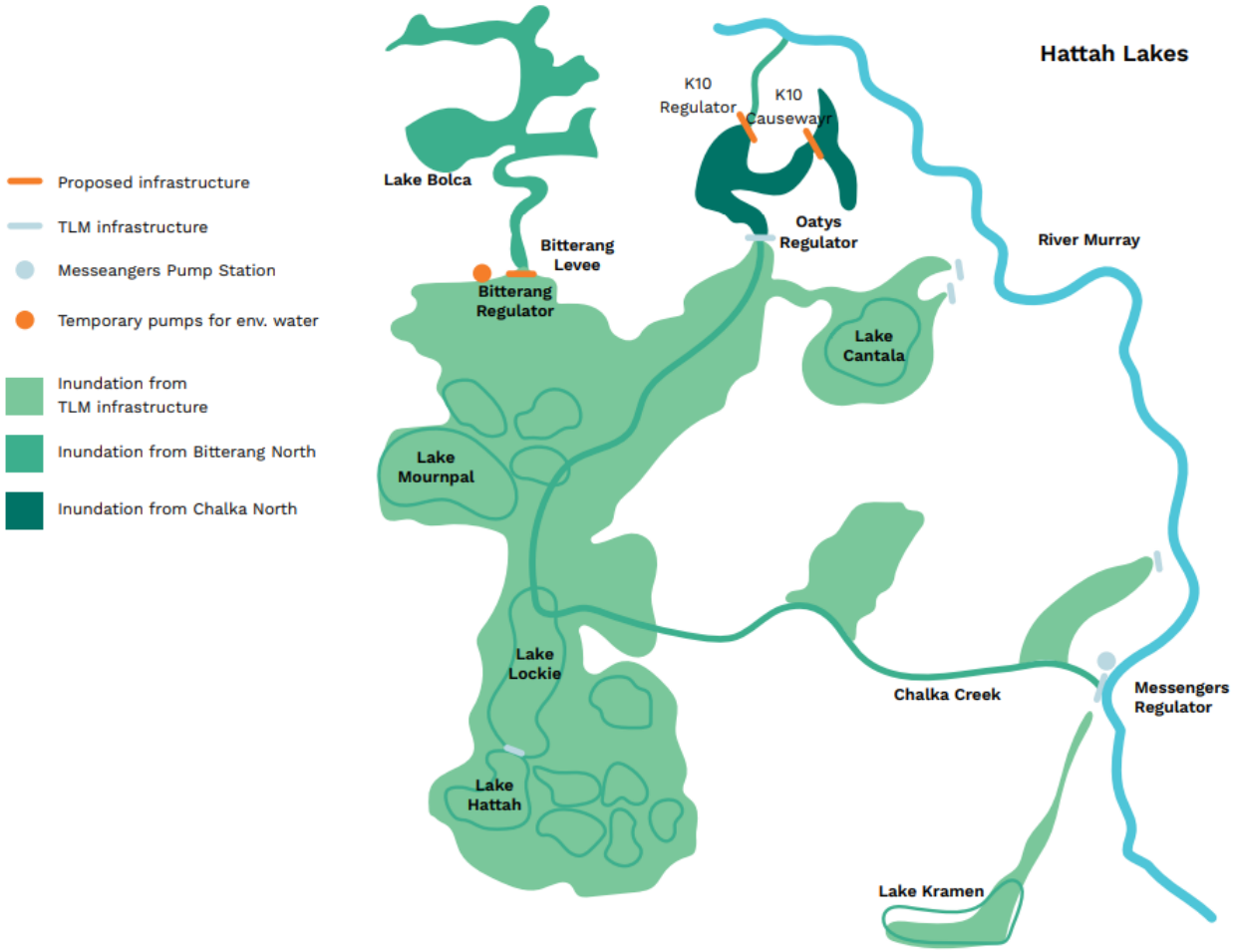


Figure 7.1. Proposed works at Hattah Lakes, including areas of inundation.

To find further detail and up-to-date information, please contact the appropriate project teams (Victorian projects; https://www.vmfrp.com.au/).

8. Managing risks to achieving objectives

While there are clear benefits to restoring a more natural water regime, there are a number of potential threats that must be considered in the planning and delivery of water for the environment. A risk assessment has been undertaken with regard to the adverse effects on the environment, which could potentially occur during environmental watering delivery at the Hattah Lakes 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 Hattah Lakes. (*risk determined from Likelihood × Consequence as per risk matrix in Appendix 5 – Risk description and matrixError! Reference source not found.**)**

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 Adaptive management
Reduction in hydrodynamic diversity	Unlikely	Moderate	M	Targeted investigation Ongoing monitoring Adaptive management
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 Adaptive management
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.
Mismatching fish/waterbird breeding cues/recruitment and general ecological requirements	Possible	Moderate	M	Clear objectives guiding inundation (targeting birds or fish or individual species) Monitoring and targeted investigation Adaptive management
Mismatch 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 Adaptive management
Insufficient water regime to meet water-dependant community	Unlikely	Moderate	M	Maintain long-term inundation scenarios to inundate Water Regime Classes (WRC) at the appropriate time interval

Threat	Likelihood	Consequence	Risk*	Management measure
requirements resulting in a community shift				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
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 inundation will benefit) Identify options and practicality of returning fish to river
Barriers to fish (and aquatic fauna) movement	Unlikely	Moderate	M	Appropriate design and operation of fish passages (i.e. fishways) Monitoring and targeted investigation Adaptive management
Enhancing carp and other pest fish recruitment conditions	Likely	Major	E	Clear objectives guiding inundation (is to benefit native species) Shift timing (outside breeding period) or use preventative measures (carp screen) to prevent recruitment and colonisation Monitoring and targeted investigation Adaptive management
Flow regime favouring high risk invasive plant species (e.g. noogoora burr)	Likely	Moderate	H	Clear objectives guiding inundation (is to benefit native species) Shift timing to prevent recruitment (outside germination period) Monitoring and targeted investigation Adaptive management
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

Threat	Likelihood	Consequence	Risk*	Management measure
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 Adaptive management

Black swans (*Cygnus atratus*) nesting on Lake Kramen (Source: MCMA).

9. Demonstrating outcomes

Environmental monitoring

A range of monitoring programs and activities are used to assess progress towards meeting the Hattah 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, which 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 Hattah Lakes Icon Site.

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

- tree condition;
- tree population structure;
- understorey plant assemblages, including wetland and floodplain species, and targeted surveys to assess lignum condition;
- fish community surveys; and
- waterbirds.

These assessments are used to determine shifts in species compositions, 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 Hattah Lakes 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 30 trees in Summer every year. This assessment is used to determine tree condition and is compared with a point of reference. This provides a means of tracking progress towards, or away from the ecological objectives relevant to the icon site for river red gum and black box.

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 (100-1200 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 Hattah Lakes Icon Site, lignum shrublands 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 whether progress towards or away from the ecological objectives is being achieved over time.

Wetland understorey

Since 2007, understorey wetland vegetation monitoring sites across semi-permanent, persistent temporary and episodic wetlands have been assessed annually at the icon site. Assessments at each wetland are undertaken across a number of transects between the base of the wetlands and top of their banks. At pre-determined elevations (quadrats) along each transect, presence of species is recorded though a series of cells. This information is compared against a point of reference index which was developed for species richness and species abundance. This reference provides a means of assessing the spatio-temporal patterns in wetland understorey species, and is ultimately used to determine whether there is progress towards, or away from the ecological objectives.

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.

Fish community

At the Hattah Lakes Icon Site, a number of fixed monitoring sites have been established across various wetlands, anabranches and the River Murray. Surveys are conducted annually in Autumn using a combination of methods and sampling equipment, including boat electrofishing, backpack electrofishing, 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 and help to determine whether progress towards, or away from the ecological objectives for the icon site, are being achieved.

Waterbirds

Trends in waterbird populations have been investigated across Hattah Lakes for a number of years. Permanent monitoring sites have been established at a number of 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 offset monitoring

Monitoring undertaken as part of the condition monitoring is also used for reporting on offset 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 Hattah Lakes. Offset survey monitoring was undertaken in year two (2014-15) and year five (2018-19), and will be completed in year 10 (2022-23) 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 the icon site, as well as other systems 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 a number of components of an environmental watering event, including abiotic factors such as water quality, groundwater 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 can be used to direct future management at an asset.

A number of intervention monitoring projects have been undertaken across the Hattah Lakes 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

A number of vegetation programs have been investigated at Hattah, with black box health, seed fall and modelling in response to environmental watering undertaken between 2014 and 2020. Across a similar timeframe, understorey vegetation has changed in response to environmental watering, with modelling being undertaken using data collected to predict future changes. During operation of the pumps in 2013-14, transmission of propagules was studied.

Fish

A number of fish projects have occurred in response to environmental watering and in conjunction with the operation of the pumps. These have included investigations of the transmission of fish (larval and adult) through the pumps (2013-14), and investigations of the movement patterns of carp and native species in response to manipulation of water (pumping and drawdown) within the system and adjacent River Murray (2015-2017).

Birds

Since 2013, surveys of floodplain woodland bird communities have been conducted across Hattah Lakes in response to environmental watering, to assess the bird communities across varied vegetation types. Targeted surveys investigating regent parrot abundance and nesting box usage and condition occurred between 2013 and 2018. Waterbird surveys between 2015 and 2016, and condition monitoring surveys, have investigated response to environmental watering.

Frogs

From 2009-2014, infrequent monitoring of frog and tadpole populations in response to environmental watering events occurred at the Hattah Lakes Icon Site.

Ecosystem processes

During 2018-19, investigation into the broader ecosystem/community of the wetlands was undertaken. Sampling looked at multiple levels of the food chain including vegetation, fish, macroinvertebrates and zooplankton. During 2019-20, floodplain carbon loads were determined. These will contribute to future blackwater modelling, and therefore inform watering events.

Adaptive management

An adaptive approach is critical in managing water-dependent ecosystems, as it enables waterway, 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 Table 9.1 and Figure 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 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).

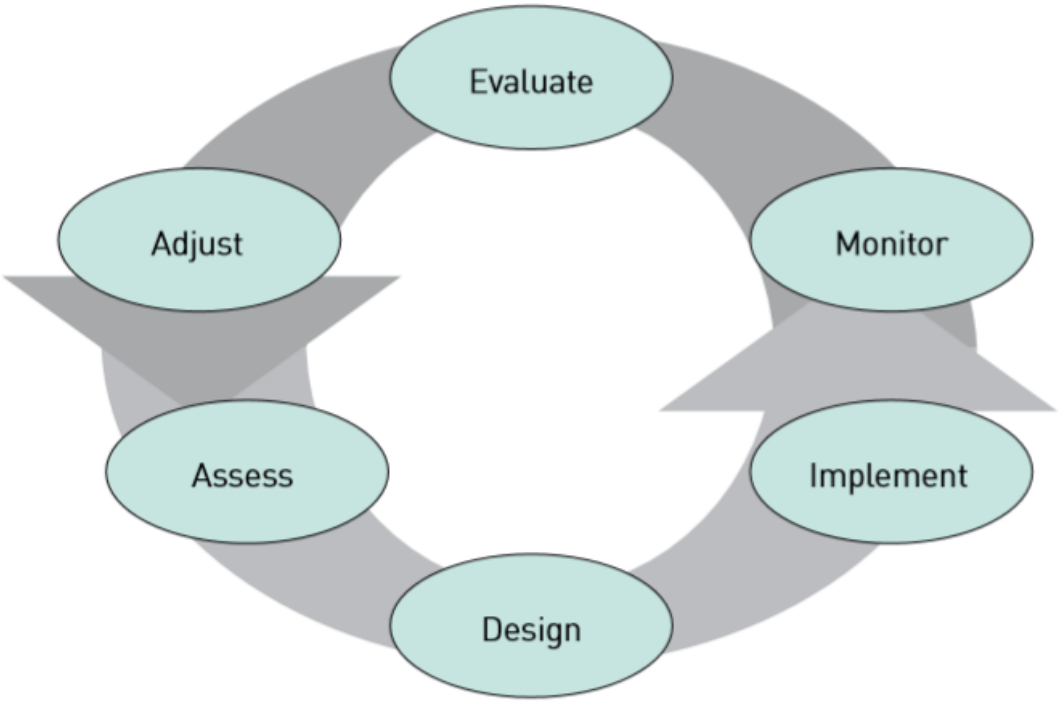


Figure 9.1. The adaptive management cycle.

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*
GL	Gigalitres
JAMBA	Japan-Australia Migratory Bird Agreement
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
PEA	Priority Ecosystem Assets
PEF	Priority Ecosystem Functions
POE	Probability of Exceedance
QEEO	Quantified Environmental Expected Outcomes
RoKAMBA	Republic of Korea-Australia Migratory Bird Agreement
SCBEWC	Southern Connected Basin Environmental Water Committee
TLM	The Living Murray
VEWH	Victorian Environmental Water Holder
VMFRP	Victorian Murray Floodplain Restoration Project
WRC	Water Regime Class

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Appendix 1 – Fauna species list

List of fauna species recorded from Hattah Lakes including conservation status. Environment Protection and Biodiversity Conservation (EPBC) Act 1999; CE=Critically Endangered, EN=Endangered, VU=Vulnerable. FFG; L=Listed (DELWP 2019). Conservation status in Victoria (VRoTS); cr=critically endangered, en=endangered, vu=vulnerable, nt=near threatened, dd=data deficient (DSE 2013). Non-native species*. Shaded rows indicate species listed in the Atlas of Living Australia, while the non-shaded species were those recorded during TLM monitoring activities.

REPTILES				
Common name	**Scientific name**	**EPBC**	**VRoTS**	**FFG**
Nobbi dragon	*Amphibolurus nobbi coggeri*			
Coral snake	*Brachyurophis australis*			
Broad-shelled turtle	*Chelodina expansa*		en	L
Common long-necked turtle	*Chelodina longicollis*		dd	
Marbled gecko	*Christinus marmoratus*			
Carnaby's wall skink	*Cryptoblepharus carnabyi*			
Murray striped skink	*Ctenotus brachyonyx*			
Mallee dragon	*Ctenophorus fordi*			
Regal striped skink	*Ctenotus regius*			
Southern legless lizard	*Delma australis*			
Butler's legless lizard	*Delma butleri*			
Tessellated gecko	*Diplodactylus tessellatus*			
Wood gecko	*Diplodactylus vittatus*			
Macquarie turtle	*Emydura macquarii*		vu	L
Tree delta	*Gehyra variegata*			
Bougainville's skink	*Lerista bougainvillii*			
Spotted burrowing skink	*Lerista punctatovittata*			
Desert skink	*Liopholis inornata*			
Beaded gecko	*Lucasium damaeus*			
Grey's skink	*Menetia greyii*			
Murray-Darling carpet python	*Morelia spilota metcalfei*		en	L
Boulenger's skink	*Morethia boulangeri*			
Mitchell's short-tailed snake	*Parasuta nigriceps*			
Eastern brown snake	*Pseudonaja textilis*			
West Australian blind snake	*Ramphotyphlops australis*			
West Australian dark-spined blind snake	*Ramphotyphlops bicolor*			
Peter's blind snake	*Ramphotyphlops bituberculatus*			
Southern spiny-tailed gecko	*Strophurus intermedius*			
Stumpy-tailed lizard	*Tiliqua rugosa*			
Sand goanna	*Varanus gouldii*			
Lace monitor	*Varanus varius*		en	

MAMMALS				
Common name	**Scientific name**	**EPBC**	**VRoTS**	**FFG**
White-striped free-tailed bat	*Austronomus australis*			
Gould's wattle bat	*Chalinolobus gouldii*			
Chocolate wattled bat	*Chalinolobus morio*			
Water rat	*Hydroys chrysogaster*			
European hare	*Lepus europeaus*			
Western grey kangaroo	*Macropus fuliginosus*			
Red kangaroo	*Macropus rufus*			
Southern bent-wing bat	*Miniopterus orianae bassanii*			
Southern freetail bat	*Mormoperus planiceps*			
Southern freetail bat	*Mormopterus* sp.			
House mouse	*Mus musculus*			
Southern myotis	*Myotis macropus*		nt	
Mitchell's hopping-mouse	*Notomys mitchelii*		nt	
	Nyctophilus sp.			
Lesser long-eared bat	*Nyctophilius geoffoyi*			
Greater long-eared bat	*Nyctophilus timoriensis*			
European rabbit	*Oryctolagus cuniculus*			
Inland broad-nosed bat	*Scotorepens balstoni*			
Pig (feral)	*Sus scrofa*			
Short-beaked echidna	*Tachyglossus aculeatus*			
White-striped freetail bat	*Tadarida australis*			
Brushtail possum	*Trichosurus vulpecular*			
Inland forest bat	*Vespadelus baverstocki*			
Southern forest bat	*Vespadelus regulus*			
Little forest bat	*Vespadelus vulturnus*			
Red fox	*Vulpes*			
Black (swamp) wallaby	*Wallabia bicolour*			

FISH				
Common name	**Scientific Name**	**EPBC**	**VRoTS**	**FFG**
Silver perch	*Bidyanus*	CE	vu	L
Goldfish	*Carassius auratus*			
Un-specked hardyhead	*Craterocephalus stercusmuscarum fulvus*			L
Common carp	*Cyprinus carpio*			
Eastern mosquitofish	*Gambusia holbrooki*			
Carp gudgeon	*Hypseleotris* sp.			
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*			

FISH				
Common name	**Scientific Name**	**EPBC**	**VRoTS**	**FFG**
Bony herring	*Nematalosa erebi*			
Redfin	*Perca fluviatilis*			
Flathead gudgeon	*Philypnodon grandiceps*			
Dwarf flathead gudgeon	*Philypnodon macrostomus*			
Australian smelt	*Retropinna semoni*			

FROGS				
Common name	**Scientific name**	**EPBC**	**VRoTS**	**FFG**
Eastern sign-bearing froglet	*Crinia parinsignifera*			
Eastern common froglet	*Crinia signifera*			
Eastern banjo frog	*Limnodynastes dumerilii*			
Barking marsh frog	*Limnodynastes fletcheri*			
Spotted marsh frog	*Limnodynastes tasmaniensis*			
Peron's tree frog	*Litoria peroni*			
Common spadefoot toad	*Neobrachus sudelli*			

BIRDS				
Common name	**Scientific name**	**EPBC**	**VRoTS**	**FFG**
Spiny-cheeked honeyeater	*Acanthagenys rufogularis*			
Inland thornbill	*Acanthiza apicalis*			
Yellow-rumped thornbill	*Acanthiza chrysorrhoa*			
Yellow thornbill	*Acanthiza nana*			
Chestnut-rumped thornbill	*Acanthiza uropygialis*			
Brown goshawk	*Accipiter fasciatus*			
Collared sparrowhawk	*Accipiter cirrhocephalus*			
Common sandpiper	*Actitis hypoleucos*		vu	
Australian owlet-nightjar	*Aegotheles cristatus*			
Striated grasswren	*Amytornis striatus*		nt	
Chestnut teal	*Anas castanea*			
Grey teal	*Anas gracilis*			
Northern mallard	*Anas platyrhynchos*			
Australasian shoveler	*Anas rhynchotis*		vu	
Pacific black duck	*Anas superciliosa*			
Australasian darter	*Anhinga novaehollandiae*			
Red wattlebird	*Anthochaera carunculata*			
Australasian pipit	*Anthus novaeseelandiae*			
Southern whiteface	*Aphelocephala leucopsis*			
Fork-tailed swift	*Apus pacificus*			
Wedge-tailed eagle	*Aquila audax*			
Intermediate egret	*Ardea intermedia*		en	L
Eastern great egret	*Ardea modesta*		vu	L
White-necked heron	*Ardea pacifica*			

BIRDS				
Common name	**Scientific name**	**EPBC**	**VRoTS**	**FFG**
Masked woodswallow	*Artamus personatus*			
White-browed woodswallow	*Artamus superciliosus*			
Hardhead	*Aythya australis*		vu	
Australian ringneck	*Barnardius zonarius*			
Mallee ringneck	*Barnardius zonarius barnardi*			
Musk duck	*Biziura lobata*		vu	
Sulphur-crested cockatoo	*Cacatua galerita*			
Corella	*Cacatua sanguinea*			
Little corella	*Cacatua sanguinea*			
Pallid cuckoo	*Cacomantis pallidus*			
Sharp-tailed sandpiper	*Calidris acuminata*			
Red-capped plover	*Charadrius ruficapillus*			
Australian wood duck	*Chenonetta jubata*			
Whiskered tern	*Chlidonias hybridus javanicus*		nt	
Silver gull	*Chroicocephalus novaehollandiae*			
Horsfield's bronze cuckoo	*Chrysococcyx basalis*			
Black-eared cuckoo	*Chrysococcyx osculans*		nt	
Rufous songlark	*Cincloramphus mathewsi*			
Chestnut quail-thrush	*Cinclosoma castanotus*		nt	
Swamp harrier	*Circus approximans*			
Banded stilt	*Cladorhynchus leucocephalus*			
Brown treecreeper	*Climacteris picumnus*		nt	
Grey shrike-thrush	*Colluricincla harmonica*			
Black-faced cuckoo-shrike	*Coracina novaehollandiae*			
White-winged chough	*Corcorax melanorhamphos*			
Little crow	*Corvus bennetti*			
Australian raven	*Corvus coronoides*			
Little raven	*Corvus mellori*			
Pied butcherbird	*Cracticus nigrogularis*			
Australian magpie	*Cracticus tibicen*			
Grey butcherbird	*Cracticus torquatus*			
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-shouldered kite	*Elanus axillaris*			
Black-fronted dotterel	*Elseyornis melanops*			

BIRDS				
Common name	**Scientific name**	**EPBC**	**VRoTS**	**FFG**
Blue-faced honeyeater	*Entomyzon cyanotis*			
Galah	*Eolophus roseicapilla*			
White-fronted chat	*Epthianura albifrons*			
Red-kneed dotterel	*Erythrogonys cinctus*			
Brown falcon	*Falco berigora*			
Nankeen kestrel	*Falco cenchroides*			
Australian hobby	*Falco longipennis*			
Peregrine falcon	*Falco peregrinus*			
Ringneck parrots	fam. *Psittacidae* gen. *Barnardius*			
Eurasian coot	*Fulica atra*			
Dusky moorhen	*Gallinula tenebrosa*			
Singing honeyeater	*Gavicalis virescens*			
Tree dtella	*Gehyra variegata*			
Gull-billed tern	*Gelochelidon nilotica*			
Peaceful dove	*Geopelia striata*			
Magpie-lark	*Grallina cyanoleuca*			
White-bellied sea-eagle	*Haliaeetus leucogaster*		vu	L
Whistling kite	*Haliastur sphenurus*			
Little eagle	*Hieraaetus morphnoides*			
Black-winged stilt	*Himantopus*			
Welcome swallow	*Hirundo neoxena*			
Caspian tern	*Hydroprogne caspia*		nt	L
Australian little bittern	*Ixobrychus dubius*		en	L
White-winged triller	*Lalage sueurii*			
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*			
Major Mitchell's cockatoo	*Lophocroa leadbeateri*		vu	L
Pink-eared duck	*Malacorhynchus membranaceus*			
Splendid fairy-wren	*Malurus splendens*			
Yellow-throated miner	*Manorina flavigula*			
Noisy miner	*Manorina melanocephala*			
Hooded robin	*Melanodryas cucullata*		nt	L
Brown-headed honeyeater	*Melithreptus brevirostris*			
Black-chinned honeyeater	*Melithreptus gularis*		nt	
Budgerigar	*Melopsittacus undulatus*			
Rainbow bee-eater	*Merops ornatus*			
Little pied cormorant	*Microcarbo melanoleucos*			
Jacky winter	*Microeca fascinans*			

BIRDS				
Common name	**Scientific name**	**EPBC**	**VRoTS**	**FFG**
Black kite	*Milvus migrans*			
Restless flycatcher	*Myiagra inquieta*			
Elegant parrot	*Neophema elegans*		vu	
Southern boobook	*Ninox novaeseelandiae*			
Blue bonnet	*Northiella haematogaster*			
Nankeen night heron	*Nycticorax caledonicus*		nt	
Cockatiel	*Nymphicus hollandicus*			
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*			
Yellow-rumped pardalote	*Pardalotus punctatus xanthopyge*			
Striated pardalote	*Pardalotus striatus*			
Australian pelican	*Pelecanus conspicillatus*			
Fairy martin	*Petrochelidon ariel*			
Tree martin	*Petrochelidon nigricans*			
Red-capped robin	*Petroica goodenovii*			
Great cormorant	*Phalacrocorax carbo*			
Little Black cormorant	*Phalacrocorax sulcirostris*			
Pied cormorant	*Phalacrocorax varius*		nt	
Bronze-winged pigeon	*Phaps chalcoptera*			
Little friarbird	*Philemon citreogularis*			
White-fronted honeyeater	*Phylidonyris albifrons*			
Yellow-billed spoonbill	*Platalea flavipes*			
Royal spoonbill	*Platalea regia*		nt	
Crimson rosella	*Platycercus elegans*			
Yellow rosella	*Platycercus elegans flaveolus*			
Striped honeyeater	*Plectorhyncha lanceolata*			
Glossy ibis	*Plegadis falcinellus*		nt	
Great crested grebe	*Podiceps cristatus*			
Hoary-headed grebe	*Poliocephalus*			
Regent parrot	*Polytelis anthopeplus monarchoides*	VU	vu	L
Chestnut-crowned babbler	*Pomatostomus ruficeps*			
White-browed babbler	*Pomatostomus superciliosus*			
Purple swamphen	*Porphyrio*			
Red-rumped parrot	*Psephotus haematonotus*			
Mulga parrot	*Psephotus varius*			
White-plumed honeyeater	*Ptilotula penicillata*			

BIRDS				
Common name	**Scientific name**	**EPBC**	**VRoTS**	**FFG**
Red-necked avocet	*Recurvirostra novaehollandiae*			
Grey fantail	*Rhipidura albiscapa*			
Willie wagtail	*Rhipidura leucophrys*			
Australian painted snipe	*Rostratula australis*	EN	cr	L
Weebill	*Smicrornis brevirostris*			
Freckled duck	*Stictonetta naevosa*		en	L
Mallee emu-wren	*Stipiturus mallee*	EN	en	L
Grey currawong	*Strepera versicolor*			
Apostlebird	*Struthidea cinerea*			L
Australasian grebe	*Tachybaptus novaehollandiae*			
Australian shelduck	*Tadorna tadornoides*			
Australian white ibis	*Threskiornis molucca*			
Straw-necked ibis	*Threskiornis spinicollis*			
Red-backed kingfisher	*Todiramphus pyrropygia*		nt	
Sacred kingfisher	*Todiramphus sanctus*			
Black-tailed native-hen	*Tribonyx ventralis*			
Common greenshank	*Tringa nebularia*		vu	
Marsh sandpiper	*Tringa stagnatilis*		vu	
Masked lapwing	*Vanellus miles*			
Banded lapwing	*Vanellus tricolor*			

Appendix 2 – Ecological Vegetation Classes

Ecological Vegetation Classes (EVCs) found across Hattah Lakes and their conservation status (DSE 2004).

EVC no.	EVC name	Conservation status
106	Grassy riverine forest	Depleted
811	Grassy riverine forest/floodway/pond/herbland complex	Depleted
813	Intermittent swampy woodland	Depleted
818	Shrubby riverine woodland	Least concern
295	Riverine grassy woodland	Depleted
823	Lignum swampy woodland	Depleted
103	Riverine chenodod woodland	Depleted
808	Lignum shrubland	Least concern
104	Lignum swamp	Vulnerable
107	Lakebed herbland	Depleted
158	Chenopod Mallee	Least concern
810	Floodway pond herbland	Depleted
91	Loamy sands Mallee	Least concern
96	Ridged plains Mallee	Endangered
97	Semi-arid woodland	Vulnerable
824	Woorinen Mallee	Vulnerable
86	Woorinen sands Mallee	Depleted

Appendix 3 – Flora species list

Appendix 3 lists all flora species recorded in the Hattah Lakes Icon Site. Environment Protection and Biodiversity Conservation (EPBC) Act 1999; EN=Endangered, VU=Vulnerable. Conservation status in Victoria (VRoTS); en=endangered, vu=vulnerable, r=rare, k=poorly known (DEPI 2014). FFG; L=Listed (DELWP 2019). Non-native species*. Shaded rows indicate species listed in the Atlas of Living Australia, while the non-shaded species were those recorded during TLM monitoring activities.

Common name (Vic)	Scientific name	EPBC	VRoTS	FFG
Chingma lantern	*Abutilon theophrasti*			
Harrow wattle	*Acacia acanthoclada* subsp. *acanthoclada*			
Grey wattle	*Acacia brachybotrya*			
Hall's wattle	*Acacia halliana*			
Small cooba	*Acacia ligulata*			
Manna wattle	*Acacia microcarpa* s.l.			
Umbrella wattle	*Acacia oswaldii*		vu	L
Nealie	*Acacia rigens*			
Eumong	*Acacia stenophylla*			
Dwarf nealie	*Acacia wilhelmiana*			
Flannel cudweed	*Actinobole uliginosum*			
Silver hair grass	*Aira cupaniana*			
Austral bugle	*Ajuga australis*			
Cattle bush	*Alectryon oleifolius* subsp. *canescens*			
Algae	Algae			
Marsh fox-tail	*Alopecurus geniculatus*			
Lesser joyweed	*Alternanthera denticulata*			
Common joyweed	*Alternanthera nodiflora*		k	
Joyweed	*Alternanthera* sp.			
Jerry-jerry	*Ammannia multiflora*		vu	
Long grey-beard grass	*Amphipogon caricinus* var. *caricinus*			
Wire-leaf mistletoe	*Amyema preissii*			
Common wheat-grass	*Anthosachne scabra* s.l.			
Cape weed	*Arctotheca calendula*			
Dark wire-grass	*Aristida calycina* var. *calycina*		r	
Tall kerosene grass	*Aristida holathera* var. *holathera*		vu	
Common woodruff	*Asperula conferta*			
Twin-leaf bedstraw	*Asperula gemella*		r	
Onion weed	*Asphodelus fistulosus*			
Daisy	Asteraceae			
	Asteraceae (exotic)			
Small saltbush	*Atriplex eardleyae*			
Slender-fruit saltbush	*Atriplex leptocarpa*			
Flat-top saltbush	*Atriplex lindleyi*		k	
Corky saltbush	*Atriplex lindleyi* subsp. *inflata*			

Common name (Vic)	Scientific name	EPBC	VRoTS	FFG
Fan saltbush	*Atriplex pseudocampanulata*			
Mat saltbush	*Atriplex pumilio*			
Berry saltbush	*Atriplex semibaccata*			
Kidney saltbush	*Atriplex stipitata*			
Sprawling saltbush	*Atriplex suberecta*			
Mallee cucumber	*Austrobryonia micrantha*		r	
Bristly wallaby-grass	*Austrodanthonia setacea*			
Wallaby-grass	*Austrodanthonia* sp.			
Graceful spear-grass	*Austrostipa acrociliata*			
	Austrostipa drummondii			
Feather spear-grass	*Austrostipa elegantissima*			
Supple spear-grass	*Austrostipa mollis*			
Balcarra spear-grass	*Austrostipa nitida*			
Knotty spear-grass	*Austrostipa nodosa*			
Rough spear-grass	*Austrostipa scabra*			
Spear-grass	*Austrostipa trichophylla*		r	
Pacific azolla	*Azolla filiculoides*			
Azolla	*Bergia trimera*		vu	
Sweet apple-berry	*Billardiera cymosa* s.l.			
Dwarf beauty-heads	*Blennospora drummondii*			
Tah-vine	*Boerhavia coccinea*		r	
	Boerhavia dominii			
Variable daisy	*Brachyscome ciliaris*			
Wedge-leaf daisy	*Brachyscome cuneifolia*		k	
Hard-head daisy	*Brachyscome lineariloba*			
Woodland swamp-daisy	*Brachyscome paludicola*			
Rayless daisy	*Brachyscome perpusilla*			
Mustard/Turnip	*Brassica* sp.			
Mediterranean turnip	*Brassica tournefortii*			
Indian mustard	*Brassica x juncea*			
Great brome	*Bromus diandrus*			
Red brome	*Bromus rubens*			
Leek lily	*Bulbine semibarbata*			
Strap purslane	*Calandrinia corrigioloides*		r	
Small purslane	*Calandrinia eremaea*			
Twining purslane	*Calandrinia volubilis*		r	
Slender cypress-pine	*Callitris gracilis*			
Scrub cypress-pine	*Callitris verrucosa*			
Pale beauty-heads	*Calocephalus sonderi*			
Garland lily	*Calostemma purpureum* s.l.			
Blue burr-daisy	*Calotis cuneifolia*		r	
Tangled burr-daisy	*Calotis erinacea*			

Common name (Vic)	Scientific name	EPBC	VRoTS	FFG
Hairy burr-daisy	*Calotis hispidula*			
Winged slender-thistle	*Carduus tenuiflorus*			
Malta thistle	*Centaurea melitensis*			
St Barnabys thistle	*Centaurea solstitialis*			
Slender centaury	*Centaurium tenuiflorum*			
Common sneezeweed	*Centipeda cunninghamii*			
Spreading sneezeweed	*Centipeda minima*			
Wiry centrolepis	*Centrolepis polygyna*			
Wingwort	*Ceratogyne obionoides*		r	
Cottony saltbush	*Chenopodium curvispicatum*			
Frosted goosefoot	*Chenopodium desertorum*			
	Chenopodium desertorum subsp. *rectum*		vu	
	Chenopodium melanocarpum			
Nitre goosefoot	*Chenopodium nitrariaceum*			
Windmill grass	*Chloris truncata*			
Skeleton weed	*Chondrilla juncea*			
Common everlasting	*Chrysocephalum apiculatum* s.l.			
Groundheads	*Chthonocephalus pseudevax*			
Spear thistle	*Cirsium vulgare*			
Small-leaved clematis	*Clematis microphylla*			
Bell-fruit tree	*Codonocarpus cotinifolius*			
Broom milkwort	*Comesperma scoparium*		r	
Pink bindweed	*Convolvulus erubescens*			
Grassy bindweed	*Convolvulus remotus*			
Common correa	*Correa reflexa*			
Ferny cotula	*Cotula bipinnata*			
Dense crassula	*Crassula colorata*			
Sieber crassula	*Crassula sieberiana*			
Rosinweed	*Cressa australis*			
Silky cryptandra	*Cryptandra magniflora*			
Paddy melon	*Cucumis myriocarpus* subsp. *leptodermis*			
Woolly scurf-pea	*Cullen pallidum*		en	L
Tough scurf-pea	*Cullen tenax*		en	L
Field dodder	*Cuscuta campestris*			
Austral bear's-ear	*Cymbonotus preissianus*			
Couch	*Cynodon dactylon*		k	
Australian hound's-tongue	*Cynoglossum australe*			
Dirty dora	*Cyperus difformis*			
	Cyperus gilesii			
Spiny flat-sedge	*Cyperus gymnocaulos*			
	Cyperus pygmaeus		vu	
Small-leaf ray-flower	*Cyphanthera myosotidea*			

Common name (Vic)	Scientific name	EPBC	VRoTS	FFG
Grooved dampiera	*Dampiera lanceolata* var. *lanceolata*			
Velvet dampiera	*Dampiera marifolia*			
Australian carrot	*Daucus glochidiatus*			
Mallee bitter-pea	*Daviesia arenaria*			
Black-anther flax-lily	*Dianella revoluta*			
Wall rocket	*Diplotaxis muralis*			
Rounded noon-flower	*Disphyma crassifolium* subsp. *clavellatum*			
Hard-head saltbush	*Dissocarpus paradoxus*			
Stinkwort	*Dittrichia graveolens*			
Small hop-bush	*Dodonaea bursariifolia*			
Slender hop-bush	*Dodonaea viscosa subsp angustissima*			
Tangled lignum	*Duma florulenta*			
Crested goosefoot	*Dysphania cristata*			
Globular pigweed	*Dysphania glomulifera*			
Clammy goosefoot	*Dysphania pumilio*			
Yellow twin-heads	*Eclipta platyglossa*			
Nodding saltbush	*Einadia nutans*			
Waterwort	*Elatine gratioloides*			
Pale spike-sedge	*Eleocharis pallens*		k	
Small spike-sedge	*Eleocharis pusilla*			
Spiny emex	*Emex australis*			
Ruby saltbush	*Enchylaena tomentosa*			
Common bottle-washers	*Enneapogon avenaceus*			
	Enneapogon nigricans			
Curly windmill grass	*Enteropogon acicularis*			
	Enteropogon ramosus			
Cane grass	*Eragrostis australasica*		vu	
Mallee love-grass	*Eragrostis dielsii*			
Purple love-grass	*Eragrostis lacunaria*		vu	
Bristly love-grass	*Eragrostis setifolia*		vu	
Spreading emu-bush	*Eremophila divaricata* subsp. *divaricata*		r	
Common emu-bush	*Eremophila glabra*			
Flaxleaf fleabane	*Erigeron bonariense*			
Tall fleabane	*Erigeron sumatrensis*			
Common heron's-bill	*Erodium cicutarium*			
Blue heron's-bill	*Erodium crinitum*			
River red-gum	*Eucalyptus camaldulensis*			
Yellow mallee	*Eucalyptus costata*			
Dumosa mallee	*Eucalyptus dumosa*			
Yorrell	*Eucalyptus gracilis*			
Black box	*Eucalyptus largiflorens*			
Slender-leaf mallee	*Eucalyptus leptophylla*			

Common name (Vic)	Scientific name	EPBC	VRoTS	FFG
Grey mallee	*Eucalyptus socialis*			
Annual cudweed	*Euchiton sphaericus*			
Flat spurge	*Euphorbia dallachyana*			
Common eutaxia	*Eutaxia microphylla*			
Leafless ballart	*Exocarpos aphyllus*			
Broom ballart	*Exocarpos sparteus*			
Wall fumitory	*Fumaria muralis* subsp. *muralis*			
Common cord-moss	*Funaria hygrometrica*			
Desert saw-sedge	*Gahnia lanigera*			
Earth cress	*Geococcus pusillus*			
Hairy carpet-weed	*Glinus lotoides*			
Slender carpet-weed	*Glinus oppositifolius*			
Golden pennants	*Glischrocaryon behrii*			
Small mud-mat	*Glossostigma elatinoides*			
Southern liquorice	*Glycyrrhiza acanthocarpa*			
Silky goodenia	*Goodenia fascicularis*			
Pale goodenia	*Goodenia glauca*			
Slender goodenia	*Goodenia gracilis*			
Spreading goodenia	*Goodenia heteromera*			
Cut-leaf goodenia	*Goodenia pinnatifida*			
Small-flower goodenia	*Goodenia pusilliflora*			
Sandhill goodenia	*Goodenia willisiana*			
	Gratiola pubescens			
Dwarf brooklime	*Gratiola pumilo*		r	
Comb grevillea	*Grevillea huegelii*			
Desert grevillea	*Grevillea pterosperma*			
	Gunniopsis septifraga			
Hooked needlewood	*Hakea tephrosperma*			
Rough halgania	*Halgania cyanea*			
Rough raspwort	*Haloragis aspera*			
May smocks	*Harmsiodoxa blennodioides*			
Short cress	*Harmsiodoxa brevipes* var. *brevipes*			
Satin everlasting	*Helichrysum leucopsideum*			
Jersey cudweed	*Helichrysum luteoalbum*			
Blue heliotrope	*Heliotropium amplexicaule*			
Smooth heliotrope	*Heliotropium curassavicum*			
Common heliotrope	*Heliotropium europaeum*			
Creeping heliotrope	*Heliotropium supinum*			
Erect guinea-flower	*Hibbertia riparia*			
Twiggy guinea-flower	*Hibbertia virgata*			
Northern barley-grass	*Hordeum glaucum*			
Barley-grass	*Hordeum leporinum*			

Common name (Vic)	Scientific name	EPBC	VRoTS	FFG
	Hordeum murinum			
Oval purse	*Hornungia procumbens*			
Moss sunray	*Hyalosperma demissum*			
Shrub violet	*Hybanthus floribundus* subsp. *floribundus*			
Trefoil pennywort	*Hydrocotyle medicaginoides*			
Small St John's wort	*Hypericum gramineum*			
Smooth cat's-ear	*Hypochaeris glabra*			
Cat's ear	*Hypochaeris radicata*			
Grass cushion	*Isoetopsis graminifolia*			
Inland club-sedge	*Isolepis australiensis*		k	
Grassy club-sedge	*Isolepis hookeriana*			
Little club-sedge	*Isolepis marginata*			
Toad rush	*Juncus bufonius*			
Finger rush	*Juncus subsecundus*			
Common blown-grass	*Lachnagrostis filiformis*			
Prickly lettuce	*Lactuca serriola*			
Golden-top	*Lamarckia aurea*			
	Laphangium luteoalbum			
Thorny lawrencia	*Lawrencia squamata*			
Common duckweed	*Lemna disperma*			
Hairy hawkbit	*Leontodon taraxacoides* subsp. *taraxacoides*			
Bundled peppercress	*Lepidium fasciculatum*		k	
Winged peppercress	*Lepidum monoplocoides*	EN	en	L
Native peppercress	*Lepidium pseudohyssopifolium*		k	
Sticky sword-sedge	*Lepidosperma viscidum*			
Mallee tea-tree	*Leptospermum coriaceum*			
Heart-leaf beard-heath	*Leucopogon cordifolius*			
Winged sea-lavender	*Limonium lobatum*			
Notch-leaf sea-lavender	*Limonium sinuatum*			
Austral mudwort	*Limosella australis*			
Poison pratia	*Lobelia concolor*			
Woolly mat-rush	*Lomandra leucocephala* subsp. *robusta*			
Tall wheat-grass	*Lophopyrum ponticum*			
Red bird's-foot trefoil	*Lotus cruentus*			
Clove-strip	*Ludwigia peploides* subsp. *montevidensis*			
Pimpernal	*Lysimachia arvensis*			
Small loosestrife	*Lythrum hyssopifolia*			
Grey bluebush	*Maireana appressa*			
Short-leaf bluebush	*Maireana brevifolia*			
Black cotton-bush	*Maireana decalvans*			
Rosy bluebush	*Maireana erioclada*			
	Maireana humillima			

Common name (Vic)	Scientific name	EPBC	VRoTS	FFG
Heathy bluebush	*Maireana oppositifolia*		r	
Hairy bluebush	*Maireana pentagona*			
Erect bluebush	*Maireana pentatropis*			
Satiny bluebush	*Maireana turbinata*			
Small-flower mallow	*Malva parviflora*			
Australian hollyhock	*Malva preissiana*			
	Malva weinmanniana			
Horehound	*Marrubium vulgare*			
Narrow-leaf nardoo	*Marsilea costulifera*			
Common nardoo	*Marsilea drummondii*			
Cut-leaf medic	*Medicago laciniata* var. *laciniata*			
Little medic	*Medicago minima*			
Burr medic	*Medicago polymorpha*			
Moonah	*Melaleuca lanceolata*			
Sweet melilot	*Melilotus indicus*			
River mint	*Mentha australis*			
Common ice-plant	*Mesembryanthemum crystallinum*			
Small ice-plant	*Mesembryanthemum nodiflorum*			
Common bow-flower	*Millotia muelleri*			
Broad-leaf millotia	*Millotia myosotidifolia*			
Tiny bow-flower	*Millotia perpusilla*			
Woolly minuria	*Minuria denticulata*		r	
	Monoculus monstrosus			
Thread iris	*Moraea setifolia*			
Weeping lignum	*Muehlenbeckia diclina* subsp. *diclina*			
Creeping myoporum	*Myoporum parvifolium*			
Sugarwood	*Myoporum platycarpum*			
Mousetail	*Myosurus australis*			
Woolly-heads	*Myriocephalus rhizocephalus*			
Red water-milfoil	*Myriophyllum verrucosum*			
Tree tobacco	*Nicotiana glauca*			
	Nicotiana occidentalis			
Velvet tobacco	*Nicotiana velutina*			
Club-moss daisy-bush	*Olearia lepidophylla*			
Mueller daisy-bush	*Olearia muelleri*			
Slender daisy-bush	*Olearia passerinoides* subsp. *passerinoides*		r	
Pimelea daisy-bush	*Olearia pimeleoides*			
Azure daisy-bush	*Olearia rudis*			
Spiked daisy-bush	*Olearia subspicata*		vu	
Burr stickseed	*Omphalolappula concava*			
Austral adder's tounge	*Ophioglossum lusitanicum*			
Upright adder's-tongue	*Ophioglossum polyphyllum*		vu	

Common name (Vic)	Scientific name	EPBC	VRoTS	FFG
Australian broomrape	*Orobanche cernua* var. *australiana*		vu	
Lesser broomrape	*Orobanche minor*			
Babbagia	*Osteocarpum acropterum* var. *deminutum*			
Bonefruit	*Osteocarpum salsuginosum*			
Swamp lily	*Ottelia ovalifolia* subsp. *ovalifolia*			
Grassland wood-sorrel	*Oxalis perennans*			
Sand cress	*Pachymitus cardaminoides*			
Opium poppy	*Papaver somniferum*			
Coast barb-grass	*Parapholis incurva*			
Mallee pellitory	*Parietaria cardiostegia*		vu	
Shade pellitory	*Parietaria debilis*			
Warrego Summer-grass	*Paspalidium jubiflorum*			
Water couch	*Paspalum distichum*			
False hair-grass	*Pentameris airoides* subsp. *airoides*			
Slender knotweed	*Persicaria decipiens*			
Pale knotweed	*Persicaria lapathifolia*			
Creeping knotweed	*Persicaria prostrata*			
	Petrorhagia nanteuilii			
Paradoxical canary-grass	*Phalaris paradoxa*			
Desert phebalium	*Phebalium bullatum*			
Spreading cress	*Phlegmatospermum eremaeum*		vu	
Fog-fruit	*Phyla nodiflora*			
Lagoon spurge	*Phyllanthus lacunarius*		vu	
Annual rice-flower	*Pimelea trichostachya*			
Weeping pittosporum	*Pittosporum angustifolium*			
Clay plantain	*Plantago cunninghamii*			
Dark plantain	*Plantago drummondii*			
Crowned plantain	*Plantago turrifera*			
Annual meadow-grass	*Poa annua*			
Knotted poa	*Poa drummondiana*		r	
Forde poa	*Poa fordeana*			
Wiry podolepis	*Podolepis capillaris*			
Delicate podolepis	*Podolepis tepperi*			
Sticky long-heads	*Podotheca angustifolia*			
Stiff cup-flower	*Pogonolepis muelleriana*			
Poached-eggs daisy	*Polycalymma stuartii*			
Prostrate knotweed	*Polygonum aviculare*			
Small knotweed	*Polygonum plebeium*			
Small poranthera	*Poranthera microphylla*			
Common purslane	*Portulaca oleracea*			
Furrowed pondweed	*Potamogeton sulcatus*			
Spiny mud-grass	*Pseudoraphis spinescens*			

Common name (Vic)	Scientific name	EPBC	VRoTS	FFG
Wiry noon-flower	*Psilocaulon granulicaule*			
Earth moss	*Pterygoneurum ovatum*			
Rabbit tails	*Ptilotus seminudus*			
Inland buttercup	*Ranunculus pentandrus* var. *platycarpus*			
Giant mustard	*Rapistrum rugosum*			
False sow-thistle	*Reichardia tingitana*			
Hedge saltbush	*Rhagodia spinescens*			
Paper sunray	*Rhodanthe corymbiflora*			
Musk sunray	*Rhodanthe moschata*			
Pygmy sunray	*Rhodanthe pygmaea*			
Clay sunray	*Rhodanthe stuartiana*			
Dwarf bitter-cress	*Rorippa eustylis*		r	
Jagged bitter-cress	*Rorippa laciniata*			
Marsh yellow-cress	*Rorippa palustris*			
Tiny bristle-grass	*Rostraria pumila*			
Slender dock	*Rumex brownii*			
Glistening dock	*Rumex crystallinus*		vu	
Narrow-leaf dock	*Rumex tenax*			
Common wallaby-grass	*Rytidosperma caespitosum*			
	Rytidosperma setaceum			
Prickly saltwort	*Salsola tragus*			
Wild sage	*Salvia verbenaca*			
Sweet quandong	*Santalum acuminatum*			
Beaded glasswort	*Sarcocornia quinqueflora*			
Spiked centaury	*Schenkia australis*			
Arabian grass	*Schismus barbatus*			
Cushion knawel	*Scleranthus minusculus*			
	Scleroblitum atriplicinum			
Short-wing saltbush	*Sclerochlamys brachyptera*			
Grey copperburr	*Sclerolaena diacantha*			
Black roly-poly	*Sclerolaena muricata*		k	
Dark roly-poly	*Sclerolaena muricata* var. *semiglabra*		k	
Grey roly-poly	*Sclerolaena muricata* var. *villosa*			
Limestone copperburr	*Sclerolaena obliquicuspis*			
Mallee copperburr	*Sclerolaena parviflora*			
Spear-fruit copperburr	*Sclerolaena patenticuspis*		vu	
Star bluebush	*Sclerolaena stelligera*			
Streaked copperburr	*Sclerolaena tricuspis*			
Slender groundsel	*Senecio glossanthus*			
Variable groundsel	*Senecio pinnatifolius*			
Cotton fireweed	*Senecio quadridentatus*			
Tall fireweed	*Senecio runcinifolius*			

Common name (Vic)	Scientific name	EPBC	VRoTS	FFG
Desert cassia	*Senna artemisioides*			
Sand sida	*Sida ammophila*		vu	
Variable sida	*Sida corrugata*			
Pin sida	*Sida fibulifera*		vu	
Twiggy sida	*Sida intricata*		vu	
	Sida petrophila			
Narrow-leaf sida	*Sida trichopoda*			
Mallee catchfly	*Silene apetala*			
French catchfly	*Silene gallica*			
Portuguese catchfly	*Silene longicaulis*			
Mediterranean catchfly	*Silene nocturna*			
Smooth mustard	*Sisymbrium erysimoides*			
London rocket	*Sisymbrium irio*			
Quena	*Solanum esuriale*			
Black nightshade	*Solanum nigrum*			
Rough sow-thistle	*Sonchus asper*			
Common sow-thistle	*Sonchus oleraceus*			
Lesser sand-spurrey	*Spergularia diandra*			
	Spergularia marina			
Red sand-spurrey	*Spergularia rubra*			
Spreading nut-heads	*Sphaeromorphaea littoralis*			
Creamy stackhousia	*Stackhousia monogyna*			
	Stellaria media			
Lesser chickweed	*Stellaria pallida*			
	Stelligera endecaspinis			
Blue rod	*Stemodia florulenta*			
	Stemodia glabella			
Narrow thread-petal	*Stenopetalum lineare*			
Pea thread-petal	*Stenopetalum sphaerocarpum*			
Berry seablite	*Suaeda baccifera*			
Small-leaf swainson-pea	*Swainsona microphylla*		r	
Yellow swainson-pea	*Swainsona pyrophila*	VU	vu	
Silky swainson-pea	*Swainsona sericea*		vu	L
Blackseed glasswort	*Tecticornia pergranulata*			
Slender glasswort	*Tecticornia tenuis*			
Flat templetonia	*Templetonia rossii*			
Desert spinach	*Tetragonia eremaea*			
Annual spinach	*Tetragonia moorei*		k	
New Zealand spinach	*Tetragonia tetragonioides*			
Grey germander	*Teucrium racemosum*			
Mallee fringe-lily	*Thysanotus baueri*			
Purple trachymene	*Trachymene cyanopetala*			

Common name (Vic)	Scientific name	EPBC	VRoTS	FFG
Mallee rush-lily	*Tricoryne tenella*			
Hare's-foot clover	*Trifolium arvense* var. *arvense*			
Hop clover	*Trifolium campestre* var. *campestre*			
Woolly clover	*Trifolium tomentosum* var. *tomentosum*			
Spurred arrowgrass	*Triglochin calcitrapa*			
Sweet fenugreek	*Trigonella suavissima*		r	
Porcupine grass	*Triodia scariosa*			
Common sunray	*Triptilodiscus pygmaeus*			
Needle grass	*Triraphis mollis*		r	
Small nettle	*Urtica urens*			
Eel grass	*Vallisneria americana* var. *americana*			
Purple-top verbena	*Verbena bonariensis*			
Common verbena	*Verbena officinalis*			
Trailing verbena	*Verbena supina*			
Three-flower vetch	*Vicia monantha* subsp. *triflora*			
Annual New Holland daisy	*Vittadinia cervicularis*			
	Vittadinia cervicularis var. *cervicularis*			
	Vittadinia cervicularis var. *subcervicularis*			
Fuzzy New Holland daisy	*Vittadinia cuneata*			
Dissected New Holland daisy	*Vittadinia dissecta*		k	
	Vittadinia eremaea			
Woolly New Holland daisy	*Vittadinia gracilis*			
Winged New Holland daisy	*Vittadinia pterochaeta*		vu	
Furrowed New Holland daisy	*Vittadinia sulcata*		k	
Squirrel-tail fescue	*Vulpia bromoides*			
Rat's-tail fescue	*Vulpia myuros*			
River bluebell	*Wahlenbergia fluminalis*			
Annual bluebell	*Wahlenbergia gracilenta*			
Orange immortelle	*Waitzia acuminata* var. *acuminata*			
Stiff westringia	*Westringia rigida*			
Common early nancy	*Wurmbea dioica*			
Noogoora burr	*Xanthium occidentale*			
	Xanthium orientale			
Bathurst burr	*Xanthium spinosum*			
Noogoora burr species aggregate	*Xanthium strumarium*			
Sand twin-leaf	*Zygophyllum ammophilum*			
Pointed twin-leaf	*Zygophyllum apiculatum*			
Shrubby twin-leaf	*Zygophyllum aurantiacum* subsp. *aurantiacum*			
Climbing twin-leaf	*Zygophyllum eremaeum*			
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 LTWP

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 5 – 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