GOULBURN BROKEN CATCHMENT MANAGEMENT AUTHORITY

Barmah-Millewa Forest Environmental Water Management Plan

July 2023

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It should be noted that specific reference to funding levels in this strategy are for indicative purposes only. The level of Government investment in this plan is contingent on budgets and government priorities.

Cover Image

Steamer Plain in Barmah National Park with Moira Grass following e-water management (17/11/2005; Keith Ward)

Acknowledgement of Country

Goulburn Broken Catchment Management Authority 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.

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

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Executive Summary

This Environmental Water Management Plan (EWMP) summarises the water-dependent values, environmental objectives, and environmental watering requirements needed to achieve environmental objectives on floodplains within the Barmah-Millewa Forest Icon Site. It is an update of the 2012 EWMP for Barmah-Millewa Forest that reflects the ongoing management of Barmah-Millewa Forest as one of The Living Murray (TLM) Icon Sites, a Ramsar wetland site of international importance, and to ensure consistency with the Basin Plan as well as Commonwealth and State government environmental water management processes.

Asset overview

Barmah-Millewa Forest is a TLM Icon Site that is reserved as the Barmah National Park and Murray River Reserve in Victoria, and as part of the Murray Valley National Park in New South Wales. It is a continuous forest and wetland system that includes a mosaic of permanent and semi-permanent wetlands, as well as river red gum forest and box woodlands on higher elevation floodplain areas.

Impacts of river regulation on hydrology

River regulation and diversion of water to meet consumptive demand has impacted the natural hydrological regime at Barmah Millewa Forest. Specific consequences of changes in the frequency, duration, variability and timing of water delivery (Goulburn Broken CMA 2015, MDBA 2015) are that:

- The frequency of winter-spring floods has been greatly reduced; for example, floods that once occurred every 2 – 3 years now occur about every 6–8 years and those that occurred about 1 in 10 years now occur about once every 25–30 years.
- The duration of inundation of river red gum forest has reduced from an average of five months to two months per year.
- The timing of flooding has shifted from predominantly winter-spring to now include undesirable small floods in summer.
- The maximum length of dry periods has increased six-fold.
- The variability of river flows has reduced: under natural conditions, monthly flows vary between 100 GL and 980 GL/ month; under current regulated conditions they vary between 110 GL and 400 GL/ month.
- The volume of river flows has reduced: downstream of Yarrawonga, diversions reduce annual flow by 25% compared to natural conditions.

Environmental values

Wetlands and waterways on the floodplain are a vital component of the landscape at Barmah-Millewa Forest, supporting a vast array of plants and animals which may vary greatly with the type of wetland/waterway system. Twenty-seven aquatic ecosystem types have been recorded across the entire site, which along with the vegetation communities supported provides essential habitat for maintaining populations of water-dependent fauna species. Other ecological functions provided by floodplain complexes include water filtration, slowing surface water flow to reduce soil erosion, flood mitigation and reducing nutrient input into waterways. Protecting the ecological functioning of wetlands ensures these vital services are maintained.

Barmah-Millewa Forest is a known biodiversity hotspot. Records from the Victorian Biodiversity Atlas (VBA)/NatureKit (for Barmah) and NSW's BioNet (for Millewa) (June 2023) listed over 300 animal and over 650 plant species. The high number of species is consistent with previous reports of biodiversity (e.g., Loyn et al. 2002, Hale and Butcher 2011). Of note, the VBA and BioNet records included:

- Over 140 aquatic dependent plant species;
- Over 60 waterbird species;
- Over 25 fish species, including over 20 native species;
- Nine frog species;
- Three decapod species, including Murray spiny crayfish;
- Over 15 reptile species, including three turtle species;
- Over 25 native mammal species, including 15 species of bat.

The broader icon site is known to support a range of threatened species including at least:

- 21 nationally threatened species; and
- 31 state-listed fauna species.

Shared benefits

In addition to maintaining environmental values, watering at Barmah-Millewa will deliver additional social, economic, and cultural benefits. Examples include:

- Economic
    - improved water quality, reduced risk of blackwater and blue green algal blooms which reduces the treatment costs for downstream urban water authorities and reduces operational risk.
    - Water diversion through Barmah-Millewa Forest can alleviate some Barmah Choke channel capacity constraints for downstream irrigation and urban water demands.
- Recreation
    - Environmental water improves vegetation and water quality and consequently provides an attractive area for day visitors and campers with enhanced active (e.g., fishing, boating) and passive (e.g., birdwatching) recreational pursuits.
    - Environmental water improves the local environment and increases species richness in the riparian and floodplain area to retain or enhance natural assets that can be enjoyed by everyone and encourages community conservation and outdoor activities.

Importantly, the Icon Site is of high value to First Nations people and particularly the Yorta Yorta and Bangerang people and includes the presence of numerous cultural heritage sites and story lines. First Nations people have a long history of occupation at Barmah-Millewa and along the Murray River generally and have developed and maintained a comprehensive knowledge and understanding of Country developed over tens of thousands of years.

Managing water-related threats

The main threat to water-dependent values is altered water regime due to the presence and operation of dams, weirs and water consumption along the Murray River system. This has reduced the frequency and duration of floodplain inundation due to reduced Murray River flows; this effect can be exacerbated by the severity of drought and climate change across the southern Murray-Darling Basin.

River regulation has also caused large-scale riverbank erosion along the Murray and Edward rivers, especially along the Tocumwal, Barmah and Edward River chokes. The chokes are natural constrictions in the rivers and the natural levees, created over thousands of years, have produced a perched stream effect where water levels in the river are higher than the surrounding floodplain forests. The chokes and natural levees are significant natural and cultural assets for the river system and help to naturally regulate flows into Barmah-Millewa Forest. Degradation of the chokes and natural levees is a major threat to the ecological character and cultural values of the rivers and forests. Large volumes of silt are being deposited throughout the forests. Many key wetlands within the forests, including the 500-hectare Moira Lake, have become much shallower due to sedimentation and is a direct result of riverbank erosion.

Other high-priority threats include the impact of invasive species, particularly grazing, foraging and disturbance by feral herbivores.

Climate change is an emerging threat that can exacerbate threats to environmental values, such as those listed above. In particular, shifting rainfall and runoff patterns in tributary catchments (e.g., Kiewa, Ovens) has led to reduced inflows to the Murray River (HARC 2021).

Management goal

Given its status as a Ramsar wetland and recognition under TLM as an Icon Site, the management goals for Barmah-Millewa Forest are to:

- Maintain or improve the site's ecological character, and
- Maintain a healthy River Murray system, sustaining communities and preserving unique values.

Environmental objectives and targets

Fourteen detailed environmental objectives (and associated targets) are presented:

- BMF1_2023 Contribute to the maintenance of the ecological character of the Barmah Forest and Central Murray Ramsar sites.
- BMF2_2023 Continue to support key life cycle stages for migratory waterbirds listed under international treaties.
- BMF3_2023 A positive trajectory in the condition of representative ecosystem types (i.e., Water Regime Classes/ANAE) at Barmah-Millewa Forest by 2033.
- BMF4_2023 By 2033, maintain the presence of threatened water-dependent species that are recorded on a regular basis at Barmah-Millewa Forest icon site.

- BMF5_2023 By 2033, a positive trajectory in the condition of native non-woody aquatic vegetation in permanent river and creek, temporary river and creek, temporary marsh and permanent lake WRCs at Barmah-Millewa Forest.
- BMF6_2023 A positive trajectory in condition of native woody vegetation associated with river red gum forest and woodlands and box woodlands WRCs at Barmah-Millewa Forest by 2033.
- BMF7_2023 Restore representative subpopulations of native water dependent biota at Barmah-Millewa Forest, by 2033.
- BMF8_2023 By 2033, regularly support waterfowl breeding and small-scale colonial breeding events at Barmah-Millewa Forest icon site.
- BMF9_2023 By 2033, maintain or increase representative species richness of shallow-water and deep-water feeding guilds of waterbird (F2 and F3, respectively, after Jaensch 2002) at Barmah-Millewa Forest.
- BMF10_2023 By 2033 support successful breeding and recruitment of native fish across the whole Barmah-Millewa Forest in permanent and temporary riverine WRCs.
- BMF11_2023 By 2033 support successful breeding and recruitment of frogs at Barmah-Millewa Forest.
- BMF12_2023 By 2033, support access to habitat for small bodied fish and movement of large bodied riverine native fish by ensuring that flow sequences, and inundation and recession events, meet ecological requirements of key species in Barmah-Millewa Forest.
- BMF13_2023 By 2033, regularly provide refugia to support the long-term survival of water-dependent biota on the managed floodplain of the Barmah-Millewa Forest icon site and Gulpa Creek during drought.
- BMF14_2023 By 2033, mitigate the impact of invasive species and feral animals on floodplain and wetland ecosystems and native water-dependent species at Barmah-Millewa Forest icon site.

These environmental objectives will be achieved in large part by delivering, as far as possible, the flooding requirements of Barmah-Millewa Forest, along with implementation of complementary management activities (e.g., invasive species control) to enable the achievement of outcomes that water delivery alone cannot achieve.

Environmental watering requirements

Without environmental watering, the combined and accumulative impacts of river regulation and recurring drought have the potential to push floodplain ecosystems (and the species they support) beyond their capacity to cope with (resist) or recover from (resilience) disturbance.

Environmental watering regimes are proposed to meet the environmental objectives set for Barmah-Millewa, based on the watering needs of the WRCs present.

Environmental water delivery infrastructure

Water delivery infrastructure exists across Barmah-Millewa Forest, with additional infrastructure planned in Millewa Forest under the Basin Plan SDLAM program, and separately through the installation of a regulator at Kynmer Creek (Barmah Forest). Thus environmental water can be delivered across the floodplain using a mixture of infrastructure (e.g., water regulators, fishways, containment banks – see Section 9.1).

Demonstrating outcomes and managing for uncertainty

A significant monitoring and evaluation effort already occurs at Barmah-Millewa Forest under TLM and other complementary programs. Details of the monitoring and evaluation addressing the environmental objectives and targets are presented in Section 10.1.

Knowledge gaps to be filled

The partners involved in managing water delivery at Barmah-Millewa Forest can gain additional insights to inform future adaptive management by addressing knowledge gaps, particularly those related to optimizing the volume and delivery of water across the Icon site and the response of target flora and fauna to water delivery.

A series of knowledge gaps have been listed (Chapter 11) that if addressed will help to optimise water delivery across Barmah-Millewa Forest and assess environmental responses to water delivery.

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1 Introduction

This Environmental Water Management Plan (EWMP) has been prepared to document the long-term water management goals and objectives for Barmah Forest and Millewa Forest (Barmah-Millewa Forest), which together make up the Barmah-Millewa Icon Site as recognised under The Living Murray initiative.

This EWMP replaces the previous EWMP (MDBA 2012) and ongoing management of Barmah-Millewa Forest. It includes an update of its objectives and targets to be consistent with those of the Murray-Darling Basin Plan (the Basin Plan) (Commonwealth of Australia 2012) and the Victorian EWMP guidelines (DELWP 2022).

1.1 Environmental water policy, planning and management

1.1.1 Victoria

Environmental water in Victoria is managed as an integral part of the Victorian Government's Waterway Management Program (DELWP 2021c), including the Victorian Waterway Management Strategy (DEPI 2013) and Goulburn Broken Waterway Strategy (Goulburn Broken CMA 2014) (Figure 1), the latter of which identifies priorities for environmental water management over an eight-year planning period. The Victorian Catchment Management Authorities (CMAs), Department of Environment, Energy and Climate Action (DEECA, previously Department of Environment, Land, Water and Planning (DELWP)) and the Victorian Environmental Water Holder (VEWH) have worked together through an adaptive management process to develop EWMPs for watered assets throughout Victoria. The primary purpose of the plans is to provide a consistent set of documents that support Seasonal Watering Proposals to be submitted by CMAs to the VEWH annually (e.g., VEWH 2021). EWMPs are a foundational component of the Long-Term Watering Plans (LTWP, DELWP 2021a) for priority environmental assets, such as Barmah-Millewa Forest, guiding planning for environmental water delivery and outcomes for water-dependent ecosystems outlined in Part 2 of Chapter 8 of the Basin Plan.

1.1.2 New South Wales

Environmental water in New South Wales is managed by the Department of Planning and Environment (DPE) Environment and Heritage group through implementation of LTWPs, including the Murray-Lower Darling LTWP (DPIE 2020a, b), which set environmental watering objectives for five, 10 and 20 year time frames. The plans set objectives, targets and watering requirements for key plants, waterbirds, fish and system functions based on advice received from Environmental Water Advisory Groups (EWAGs). Annual water plans are prepared to prioritise the use of environmental water in the coming year, considering factors such as the recent climate conditions and water availability.

In NSW, water sharing plans set out planned environmental flow rules and contain other provisions for the protection and management of planned environmental water. These rules vary between valleys, and according to whether they are regulated or unregulated rivers or groundwater sources and focus on the objectives that are most important for each water source. The planned environmental flow rules in the water sharing plans include river flow objectives that are designed to:

- Limit extraction to protect a share of water for the environment,
- Replicate natural flow patterns or events to provide water when and where it will meet environmental needs.

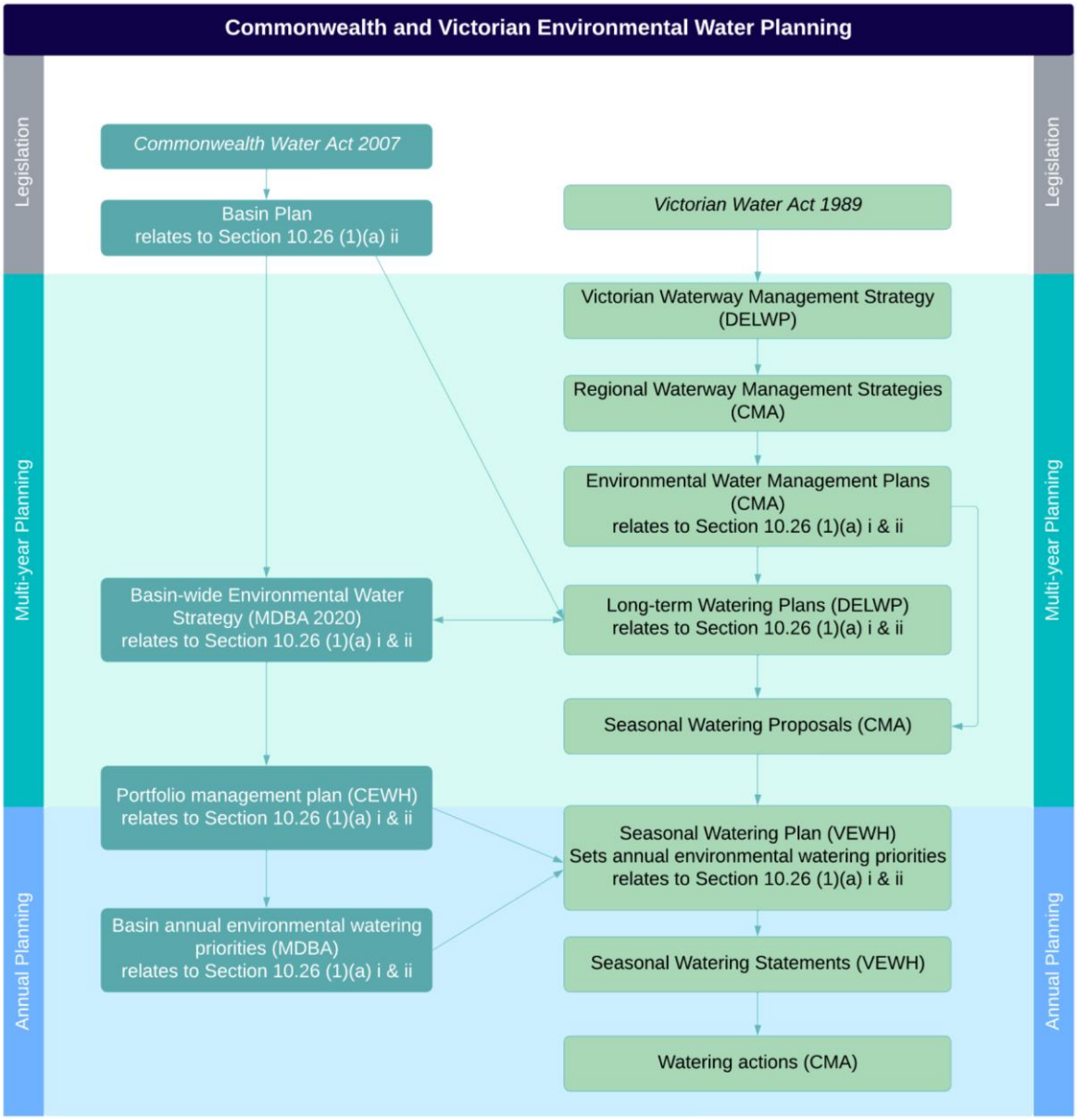


Figure 1: Relationship of the Barmah-Millewa Forest EWMP within Victoria's water regulatory, planning and management framework.

1.2 The Living Murray initiative and Murray-Darling Basin Plan

1.2.1 The Living Murray

The Living Murray (TLM) initiative 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 TLM has the long-term goal of achieving a healthy working Murray River system for the benefit of all Australians. TLM aims to improve the environmental health of six icon sites, including Barmah-Millewa Forest, chosen for their significant ecological, cultural, recreational, heritage and economic values.

TLM was established under the following instruments and is managed collaboratively by the partner governments (IGA 2004, 2009, Figure 2):

- 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, cited in IGA 2009);
- The Living Murray Business Plan 2007 (Business Plan, cited in IGA 2009);
- Further agreement (2009) on addressing water over-allocation and achieving environmental objectives in the Murray-Darling Basin (IGA 2009).

TLM has been used to support delivery of the Basin Plan since the latter came into effect in 2012. This has included the establishment of the Southern Connected Basin Environmental Watering Committee (SCBEWC). SCBEWC includes representatives from 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, consistent with the Basin Plan Environmental Watering Plan (Chapter 8 of the Basin Plan) and its objectives (MDBA 2020a). In addition to the coordination function, SCBEWC also makes decisions on the use of jointly held environmental water portfolios – The Living Murray portfolio, Murray River Unregulated Flows and Murray River Increased Flows, and The Living Murray's monitoring and Indigenous Partnership programs.

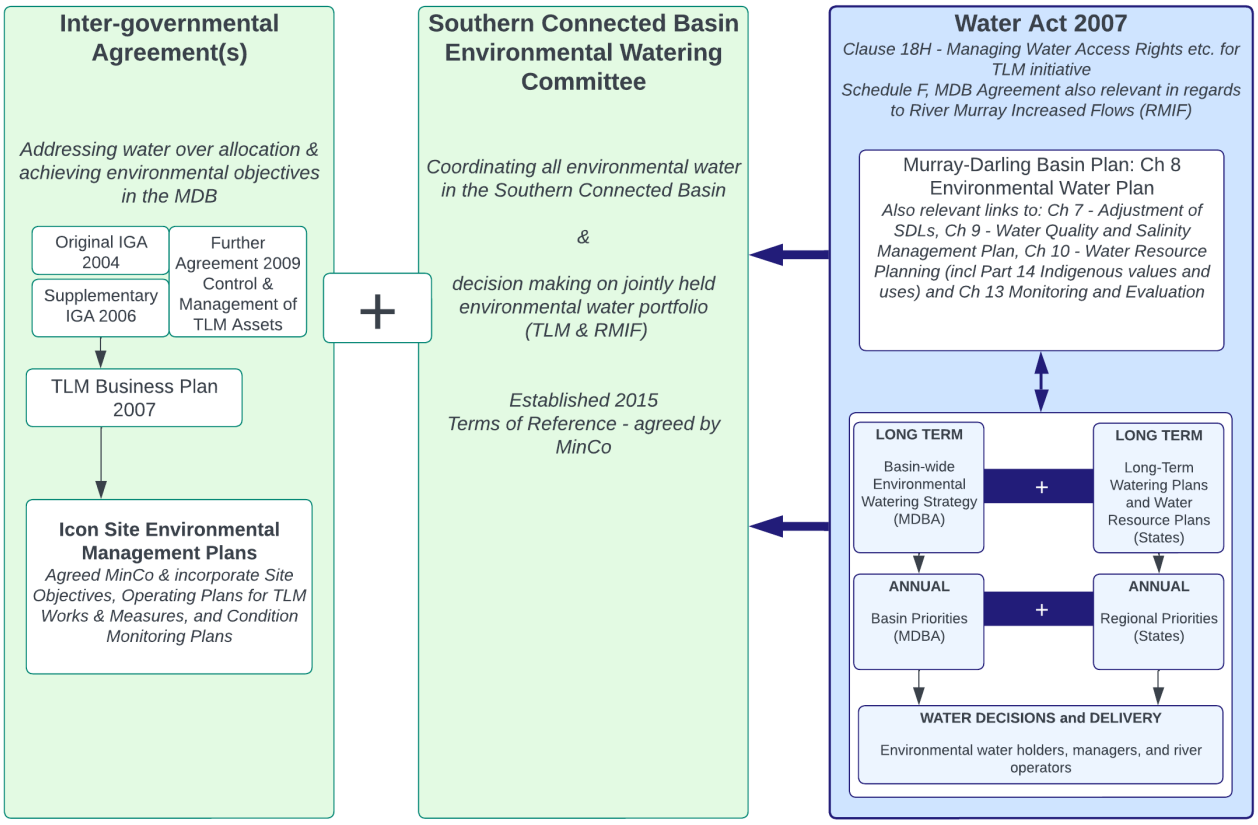


Figure 2: The Living Murray governance framework (Source: modified from Mallee CMA 2021).

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 (see Section 3.2).

1.2.2 Murray-Daring Basin Plan

In the Murray-Darling Basin, environmental water management is governed by the Murray-Darling Basin Plan (hereafter the Basin Plan) (Commonwealth of Australia 2012). A key element of the Basin Plan is the Sustainable Diversion Limit (SDL) for each water resource area (Victorian Murray LTWP area and New South Wales Murray and Lower Darling water resource plan area) indicating the amount of water that can be extracted for irrigation and other uses.

The Basin Plan allows for the MDBA to propose adjustments to the SDLs, which if approved are made by amendment of the Basin Plan under section 23B of the *Water Act 2007*. Known as the SDL Adjustment Mechanism (SDLAM), there are two avenues for adjustment of SDLs: supply measures and efficiency measures. Supply measures lead to an increase in the quantity of water available before take for consumptive use, either by making water available for environmental management without reducing consumptive take or by allowing environmental managers to achieve equivalent outcomes more efficiently, thus reducing the amount of water needed for the environment.

The intent of supply measures is to achieve equivalent environmental outcomes without needing to reduce consumptive take as much as originally anticipated in the Basin Plan (Commonwealth of Australia 2012). An efficiency measure is one that makes savings in the amount of water required for consumptive purposes; however, both must have neutral or improve neutral or improve socio-economic impact.

The Millewa Forest SDLAM project[1] (see also Section 1.2.3 below) is a supply measure project that aims to:

- Increase environmental flows from east to west of the system which will enable small-bodied fish to better migrate for breeding and feeding;
- Improve the ability to target environmental flows and reduce unseasonal flooding;
- Provide a drought refuge (areas that remain permanently wet) for floodplain vegetation;
- Improve the ability to manage water levels in Moira Lake to better reflect seasonal variations;
- Support the ecological habitats of endangered species to ensure their survival in the forest including bird species like the Australasian bittern.

Further information on environmental water management within Barmah-Millewa Forest is provided in Section 3.4.

1.2.3 Addressing constraints on water delivery

NSW and Victoria are also implementing constraints projects (often in partnership) via the Reconnecting River Country Program[2] and the Victorian Constraints Measures Program[3], respectively. These projects aim to achieve a balance of economic, social, cultural and environmental outcomes by improving

[1] https://www.dpie.nsw.gov.au/water/water-infrastructure-nsw/sdlam/murrumbidgee-and-murray-national-park-project/millewa-forest-project

[2] https://www.dpie.nsw.gov.au/water/water-infrastructure-nsw/sdlam/reconnecting-river-country-program#:~:text=The%20Reconnecting%20River%20Country%20Program%20aims%20to%20achieve%20a%20balance,improving%20wetland%20and%20floodplain%20connectivity.

[3] https://www.water.vic.gov.au/murray-darling-basin-plan/victorias-progress/projects/constraints-measures

wetland and floodplain connectivity. The projects focus on relaxing or removing some of the constraints or physical barriers that can affect the delivery or management of environmental water in areas of the southern-connected Murray–Darling Basin.

For example, the project on the Murray River from Yarrawonga to the Wakool River junction being undertaken by Reconnecting River Country program under SDLAM has the potential to prevent approximately 60 GL of water purchases, whilst still achieving environmental outcomes without negative economic consequences for southern Basin communities in NSW. It will enable water for the environment to be delivered more efficiently to connect rivers to floodplains more often without the need for further water purchases.

1.3 Barmah-Millewa Forest Environmental Water Management Plan

This EWMP replaces the environmental objectives, targets, and outcomes to be achieved with environmental watering at Barmah-Millewa Forest (MDBA 2012), consistent with the Murray-Darling Basin Plan objectives and outcomes (Commonwealth of Australia 2012), and aims to:

- Identify the long-term environmental objectives for wetland, floodplain and riverine ecosystems and specific watering requirements (frequency, duration, timing) needed to achieve those objectives;
- Establish links between identified ecological values and appropriate environmental watering objectives supported by monitoring programs and the identification of specific knowledge gaps;
- Provide for community consultation, including for the long-term objectives and water requirements of the wetland and floodplain ecosystems;
- Inform the development of seasonal watering proposals (i.e., by the Goulburn Broken CMA) and seasonal watering plans (i.e., by the VEWH); and
- Contribute to implementation of the Victorian Murray Long-Term Watering Plan (DELWP 2021a) and New South Wales Murray and Lower Darling Water Resource Plan (DPE 2020), consistent with Murray-Darling Basin Plan requirements.

This EWMP incorporates significant information from existing documents and, importantly, the body of knowledge built on 20 years of implementing TLM and management of Barmah-Millewa Forest. It represents the best available information available for the EWMP, and its implementation is considered to have a strong scientific basis.

2 Partnerships and consultation

During the development of this update to the Barmah-Millewa Forest EWMP, stakeholders were engaged and provided opportunity to have input (Table 1). Consultation is an ongoing process that the GB CMA and its NSW partners coordinate in association with environmental water management for the site.

Table 1 List of stakeholder and rights holders engaged in the development of the updated EWMP.

Name	Agency	Position
Nicola Watson	DCCEEW	
Susan Watson	DEECA	Senior Project Officer – TLM
Amy Scott	DEECA	Project Officer – TLM
Paul Childs	DPE	Senior Environmental Water Management Officer
Paula D'Santos	DPE	Senior Team Leader, Environmental Water & Floodplains
Keith Ward	GB CMA	Project Manager - TLM
Tim Barlow	GB CMA	Project Officer - TLM
Bill Mathews	MDBA	Assistant Director, Environmental Water Coordination
Cristina Vicente	MDBA	Senior Project Officer, Environmental Water Coordination
Brady Cronin	NPWS	Project Officer - TLM
Matt Crawford	NPWS	Project Officer - TLM
Wil Allen	NPWS	Senior Project Officer – West Branch Ecological Monitoring
Bruce Wehner	PV	Regional Planning Officer (Environment Land and Water)
Kathryn Stanislawski	PV	Program Leader – Ecological Water
Keith Chalmers	VEWH	Team Leader, Environmental Water Delivery
Jay Whittaker	YYNAC	Engagement & Coordination Manager
Sonia Cooper	YYNAC	Operations Manager

3 Asset overview

3.1 Catchment setting

The Barmah-Millewa Forest is the largest River Red Gum (*Eucalyptus camaldulensis*) forest in Australia, covering approximately 66,000 hectares of floodplain straddling the Victorian and New South Wales boarders between the townships of Tocumwal, Deniliquin and Echuca (Figure 3). The site is a continuous forest and wetland system reserved as the Barmah National Park and Murray River Park in Victoria, and as part of the Murray Valley National Park in New South Wales.

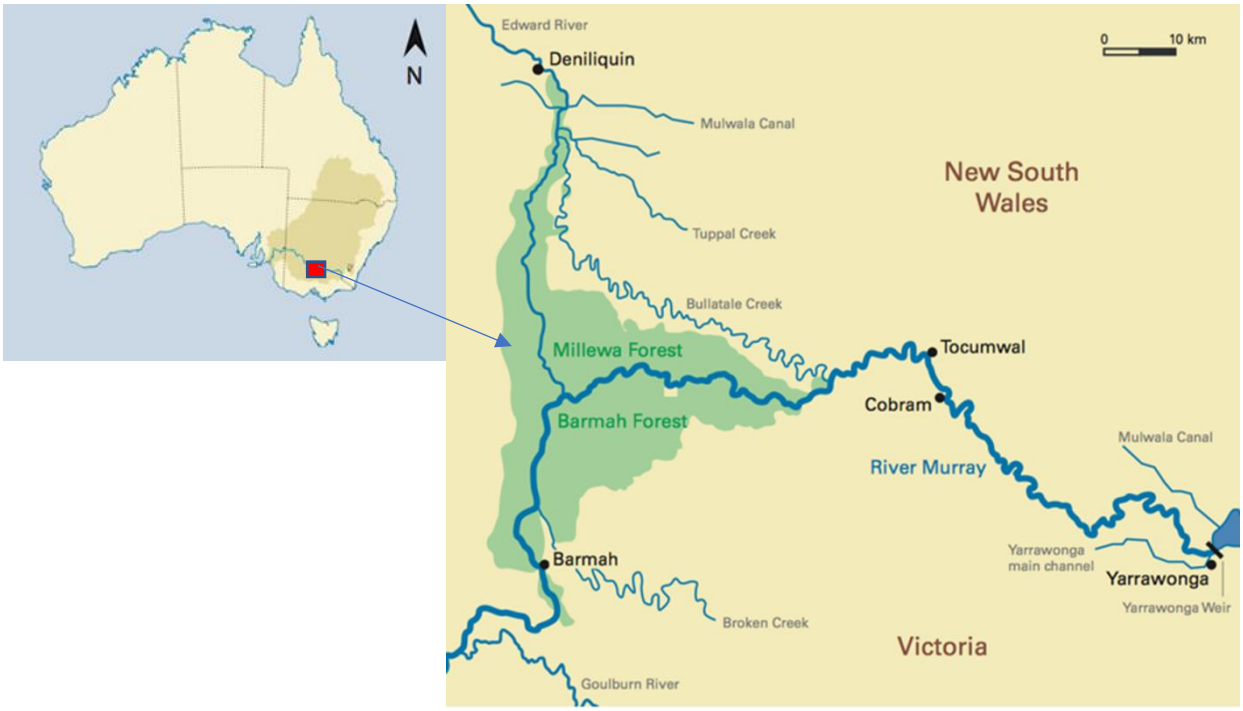


Figure 3: Location of Barmah-Millewa Forest (source: MDBA).

Throughout this document individual areas of the icon site will be discussed. In Victoria, Barmah Forest is listed separately under the Ramsar Convention as a Wetland of International Importance. The Barmah Forest portion of the icon site is predominantly covered by river red gum forests and woodlands and floodplain marshes (Hale and Butcher 2011). The Millewa Forest portion of the icon site is reserved as the Murray Valley National and Regional Parks comprising of the Millewa, Moira and Gulpa Island precincts (hereafter called Millewa Forest). Millewa Forest is comprised of Inland Riverine Forests, Inland Floodplain Woodlands, Floodplain Transition Woodlands, Riverine Sandhill Woodlands and Inland Floodplain Swamps (Keith 2004 cited in Borrell 2018). The Millewa group of forests are part of the Ramsar-listed NSW Central Murray Forests Ramsar site.

3.2 Land status and management

Barmah-Millewa Forest is predominantly national park, surrounded by agricultural land (Figure 4). The Barmah Forest component in Victoria covers 29,457 hectares, while the Millewa Forest component in New South Wales covers 36,543 hectares (MDBA 2012). Barmah Forest is located within the Moira Shire Local Government Area and the Goulburn Broken CMA region, while Millewa Forest is located

within the Murray River Local Government Area and the Murray Local Land Services region in New South Wales.

A full list of stakeholders involved with environmental water delivery and management at Barmah-Millewa Forest is provided in Table 2.

The Victorian Department of Energy, Environment and Climate Action (DEECA) coordinates the implementation of TLM in Victoria. Barmah Forest is jointly managed by Parks Victoria in partnership with the Yorta Yorta Traditional Owner Land Management Board (YYTOLMB 2020). The regional environmental water manager is the Goulburn Broken CMA; bulk water delivery in Victoria is managed by Goulburn-Murray Water. Millewa Forest is managed by the National Parks and Wildlife Service (NPWS) within the DPE; the regional water manager is WaterNSW.

Water delivery along the Murray River is managed by River Murray Operations of MDBA who manage water delivery within the Southern Connected Basin on behalf of Basin jurisdictions (New South Wales, Victoria and South Australia) in collaboration with Goulburn-Murray Water, WaterNSW and the Barmah-Millewa Operating Advisory Group convened by MDBA (e.g., MDBA 2020b).

Whilst managed predominantly as a single asset for environmental water delivery, Barmah-Millewa Forest is comprised of two wetlands listed under the Ramsar convention for wetlands of international significance (see also Section 5.1). Barmah Forest is listed as the Barmah Forest Ramsar site (Hale and Butcher 2011), while Millewa Forest is listed as part of the wider New South Wales Central Murray Forests Ramsar site (Harrington and Hale 2011). Management of Barmah-Millewa Forest also recognises bilateral international bird agreements, amongst other Australian, New South Wales and Victorian planning and regulation instruments (Table 3).

3.2.1 Management scale

The management scale for this EWMP is the floodplain and waterways of Barmah-Millewa Forest that can be inundated via existing infrastructure and water delivery arrangements (see Chapter 9).

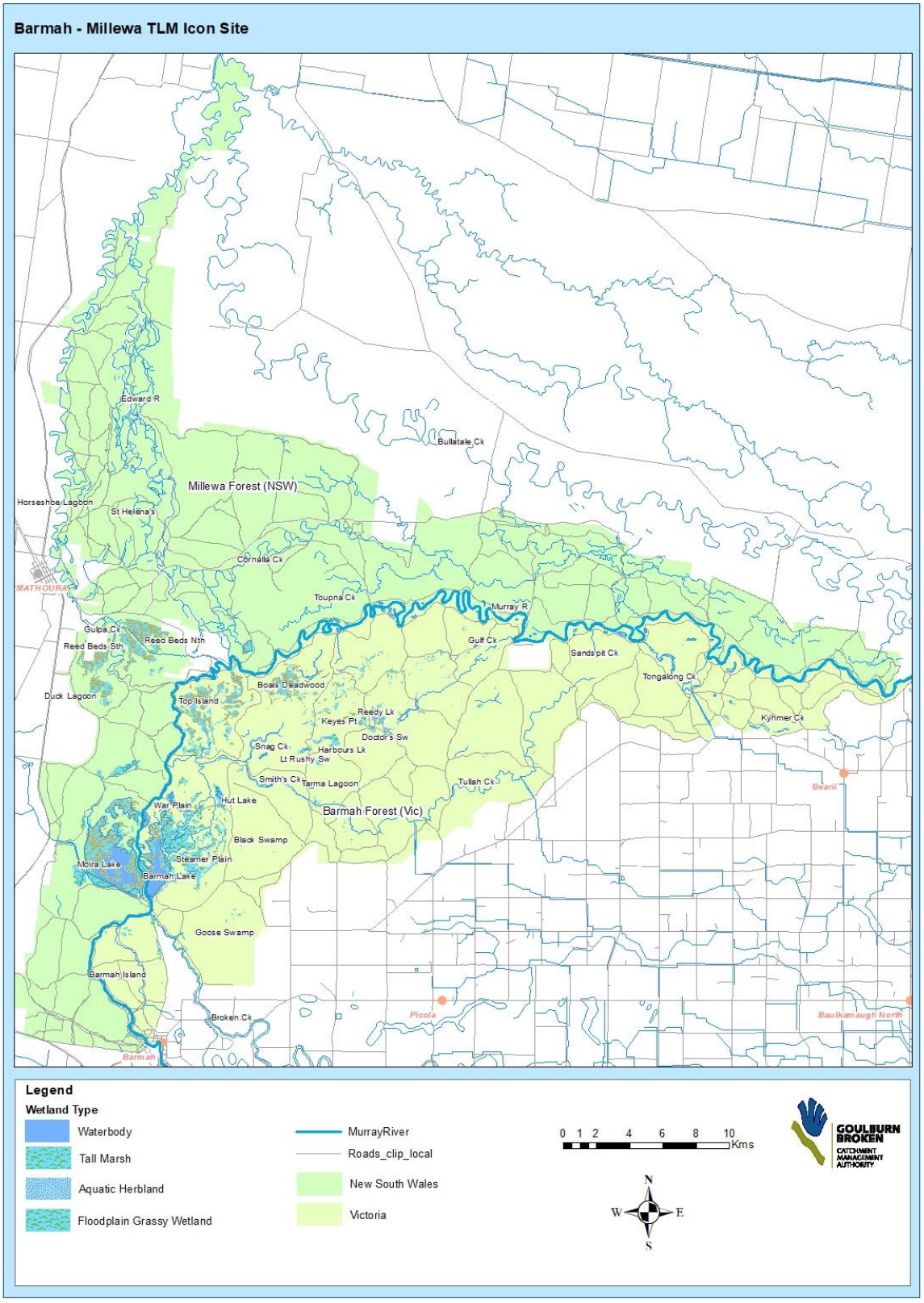


Figure 4: Location of the Barmah-Millewa Forest Icon Site and key wetlands therein.

Table 2: Stakeholders relevant to environmental water management at Barmah-Millewa Forest.

Stakeholder	Description and role
Commonwealth	
Murray–Darling Basin Authority	• Responsible for coordination at a TLM-wide level. Representatives on Integrated Coordinating Committee and Technical Advisory Committee. • Provides water delivery along the Murray River by River Murray Operations on behalf of Basin jurisdictions. • Supports and attends meetings from numerous groups associated with water delivery in the Southern Connected Basin, including the Southern Connected Basin Environmental Water Committee (SCBEWC), River Murray Water Liaison Working Group (WLWG) and the Barmah-Millewa Operating Advisory Group.
Department of Climate Change, Energy, the Environment and Water (Commonwealth)	• Commonwealth department that develops and implements national policy, programs and Water, Population and Communities legislation to protect and conserve Australia's environment and heritage. • Under the Water Act 2007 (Cwlth), the Commonwealth Environmental Water Holder was established to manage Commonwealth-acquired water entitlements used to protect or restore environmental assets. • Has representation on the SCBEWC and other state water management groups.
Victoria	
Department of Energy, Environment and Climate Action	• Responsible for implementing TLM Initiative in Victoria, the department is also a project and site owner for public land and manages approvals and referrals for the state. • It is represented on the SCBEWC and the Barmah-Millewa Operating Advisory Group.
Parks Victoria	• Parks Victoria is the land manager for Barmah National Park in accordance with the *National Parks Act 1975 (Vic.)*. • Operates in accordance with the Barmah National Park Joint Management Plan. • It has representatives on the Barmah-Millewa Operating Advisory Group.
Goulburn Broken Catchment Management Authority (Victoria)	• Goulburn Broken CMA is the Victorian icon site environmental water manager. • It is represented on the Barmah-Millewa Operating Advisory Group.
Goulburn–Murray Water (Victoria)	• This is the Victorian construction authority for TLM and is responsible for operation and maintenance of infrastructure built through TLM Initiative. • It has representatives on the WLWG and the Barmah-Millewa Operating Advisory Group.
Yorta Yorta Nation Aboriginal Corporation (Victoria)	• Recognised in Victoria as the Registered Aboriginal Party. • Victoria will ensure cooperative management of Barmah Forest with the Yorta Yorta people in land and water management decision-making relating to the protection, management and

Stakeholder	Description and role
	sustainability of their country, including cultural and environmental values. • Supports the Traditional Owner Land Management Board implementing the Joint Management Plan for Barmah National Park.
Victorian Environmental Water Holder	• Independent manager of Victorian environmental water entitlements. • It is represented on the SCBEWC and the Barmah-Millewa Operating Advisory Group. •
New South Wales	
Department of Planning and Environment (NSW) **Includes Environment and Heritage Group (EHG); National Parks and Wildlife Service (NPWS); Water Group (WG)**	The EHG is responsible for water in the environment and water licensing and Department of Premier and Cabinet (NSW) allocation. • It incorporates functions of the Murray Darling Wetland Working Group. • EHG coordinates the Murray–Lower Darling Environmental Water Advisory Group • EHG is represented on the SCBEWC and the Barmah-Millewa Operating Advisory Group.
	• NPWS is the land manager of Murray Valley National Park and Murray Valley Regional) Park - under the National Parks and Wildlife Act 1974 (NSW). • New South Wales icon site manager and water manager within forest boundaries. • Is represented at the Murray–Lower Darling Environmental Water Advisory Group and Barmah-Millewa Operating Advisory Group.
	• The WG implements the NSW Water Strategy that addresses water security and supply for both metropolitan and regional areas. • Responsible for water extraction in terms of planning and licensing under the Water Management Act 2000 (NSW); it leads the New South Wales commitment to the TLM Environmental Works and Measures Program and directs the operations of New South Wales. • NSW RiverBank.
Department of Primary Industries (NSW) **Includes Fish Research Group**	• Responsible for management of fish communities and aquatic habitats, including threatened species, populations and ecological communities. • Provides advice on biological requirements for fish in NSW South Wales and undertakes monitoring of fish communities.
WaterNSW	• WaterNSW is the NSW rural bulk water delivery construction authority that manages, operates and maintains NSW water regulation infrastructure. • Manages and operates MDBA-identified assets in accordance with the Murray–Darling Basin Agreement.
Murray Local Land Service (MLLS)	• MLLS is responsible for managing natural resource issues at the catchment scale (NSW) through engagement of regional

Stakeholder	Description and role
	communities, development of a catchment action plan and implementation of incentive programs. • Is represented at the Murray–Lower Darling Environmental Water Advisory Group and Barmah-Millewa Operating Advisory Group.
Traditional Owner representatives	• Cummeragunja Local Aboriginal Land Council. • Moama Local Aboriginal Land Council. • Bangerang Aboriginal Corporation. • (Yorta Yorta Nations Aboriginal Corporation – see above).

Table 3: Policy and planning instruments relevant to the management of Barmah-Millewa Forest.

	Instrument
Agreements	Ramsar Convention on Wetlands of International Importance China–Australia Migratory Bird Agreement (1986) Japan–Australia Migratory Bird Agreement (1974) Republic of Korea–Australia Migratory Bird Agreement (2007) The Bonn Convention on Migratory Species (1983) Intergovernmental Agreement on Addressing Water Over-allocation and Achieving Environmental Objectives in the Murray–Darling Basin (2004) Intergovernmental Agreement on Murray–Darling Basin Reform (2008)
Legislation	**Commonwealth** Water Act 2007 Environment Protection and Biodiversity Conservation Act 1999 Native Title Act 1993 **New South Wales** National Parks and Wildlife Act 1974 Threatened Species Conservation Act 1995 Crown Lands Act 1989 Environmental Planning and Assessment Act 1979 Fisheries Management Act 1994 Water Management Act 2000 **Victorian** Aboriginal Heritage Act 2006 Environmental Effects Act 1978 Flora and Fauna Guarantee Act 1988 Forests Act 1958 Planning and Environment Act 1987 Murray–Darling Basin Act 1993 National Parks Act 1975 and Parks Victoria Act 1998 Water Act 1989
Relevant Strategies and Plans	**Commonwealth** Murray-Darling Basin Plan (Commonwealth of Australia 2012) Basin-Wide Environmental Watering Strategy (MDBA 2020a) Murray Annual Operating Outlook (e.g., MDBA 2022a) **Victoria** Victorian Murray Long Term Watering Plan (DELWP 2021a)

	Instrument
	Victorian waterway management program (DELWP 2021c) Goulburn Broken regional catchment strategy 2021–2027 (Goulburn Broken CMA 2021) Goulburn Broken waterway management strategy (Goulburn Broken CMA 2014) Protection of Floodplain Marshes: Strategic Action Plan (Parks Victoria 2020) **New South Wales** New South Wales wetlands policy (DECCW 2010) Environmental water allocation account rules (NSW Government 2016) Trout cod and silver perch recovery plans (NSW DPI 2006) Priorities Action Statement - Actions for Lowland Murray River Aquatic Endangered Ecological Community[4] Murray Local Strategic Plan 2021-2026 (Murray LLS 2021) Delivering the Ramsar Convention in NSW (DECCW 2010) Millewa Fish Recovery Strategy (NPWS 2023) Statement of Management Intent – Murray Valley National Park and Murray Valley Regional Park (NSW OEH and NPWS 2014)

3.3 Asset characteristics

3.3.1 Climate

Barmah-Millewa Forest experiences a climate comprising cool and wet conditions in winter-spring and hot, dry conditions in summer and autumn (e.g., Hale and Butcher 2011). Annual rainfall at Echuca is 427.1 mm, with monthly average rainfall ranging from 25.7 mm in summer (February) to 42.6 mm in spring (October)[5]. Mean maximum monthly temperature ranges from 13.0 °C (July) to 31.0 °C (January). Mean minimum monthly temperature ranges from 3.8 °C (July) to 15.2 °C (January, February).

3.3.2 Geomorphology

The floodplain at Barmah-Millewa Forest is situated within the Murray Fans bioregion, which is characterised by a flat to gently undulating landscape on recent, unconsolidated sediments with evidence of former stream channels, braided old river meanders and paleochannels, and broad floodplains areas associated with the current river system and prior streams (DSE 2013, Hale and Butcher 2011).

The extensive floodplain forests are the result of a geologic fault line (Cadell fault) that created an uplifting of land about 25,000-45,000 years ago (Macpherson et al. 2012). Although only about 12 metres high, it is an important feature in this otherwise flat landscape, changing the flow path and pattern of the Murray River and creating the Edward–Wakool River system. The location where the Murray River cuts through to the Goulburn River channel is known as the Barmah Narrows, often referred to as the Barmah Choke because of its limited flow capacity.

The flow capacity of Barmah Choke has declined since the 1980s, which imposes a constraint on regulated flows supplied down-valley. Releases from Yarrawonga Weir must currently be kept below 8,500 ML/d to keep the water in the channel at Picnic Point; this is down 25% from the 11,300 ML/d that could be kept in

[4] https://www.dpi.nsw.gov.au/fishing/threatened-species/what-current/endangered-ecological-communities/murray-river-eec/priorities-action-statement-actions-for-lowland-murray-river-aquatic-endangered-ecological-community
[5] http://www.bom.gov.au/climate/averages/tables/cw_080015.shtml

the channel in the early 1980s (Grove 2020). Note that the volume of releases from Yarrawonga Weir may decline further over time (K. Ward, GBCMA, pers. comm.). The most likely cause for this decline is thought to be shallowing of the river channel due to ingress of coarse sand driven by regional and local land and river management practices, particularly from historical gold mining (Rutherfurd et al. 2020). The whole length of the river through the Barmah Forest has shallowed over the last 30 years, aggrading by 1.9 m at the upstream end and 0.70 m in the most downstream section of the Choke (about 10% decrease in area) (Rutherfurd et al. 2020). The total volume of sand stored between Yarrawonga and Barmah-Millewa Forest is over 20 million m^3, and the average total annual sand load transported into the 82km long Choke ranges between 130,000 m^3 in a normal flow year to 500,000 m^3 in a flood year (which translates into 2 – 9 cm of aggradation per year). Sediment transport through the Barmah-Millewa Forest will be a long-term issue (Grove 2020, Rutherfurd et al. 2020), as a large store of sediment remains in the river channel downstream of Yarrawonga Weir. This sediment is migrating downstream and without intervention will likely cause further reduction in conveyance through the Barmah Choke. Further reduction in channel capacity has since occurred, with MDBA now managing flows to a lower volume downstream of Yarrawonga (currently being refined).

3.3.3 Waterways

The forest floodplain vegetation communities include a range of habitats, including swamps and marshes, rush beds, lakes and billabongs, open grassland plains, river red gum forests, river red gum woodlands and black box woodlands (e.g., Hale and Butcher 2011). It relies on frequent flooding to maintain the health and diversity of habitats, and flora and fauna (MDBA 2012).

Barmah-Millewa Forest has an intricate arrangement of inflow sources and drainage routes which is governed by flow in the Murray River (i.e. regularity, extent, duration and season of flooding). During higher river flows, the Barmah Choke causes water to back up and break out across the floodplains of the Barmah and Millewa forests. This attenuates flood peaks, reducing the height of floods downstream. `1Relatively small changes in topography influence distribution and depth of flooding. Water passes over the forest floor as sheet flow in large floods and 'in creek' flow during smaller flood events as shown in Figure 5 below.

Other than the Murray River, the major waterways leaving Barmah-Millewa Forest include the Edward River and Gulpa Creek, both of which flow north from the Murray River from Picnic Point. Gulpa Creek runs along the western boundary of Millewa Forest, roughly parallel to the Edward River, and supplies an area of open plain/swamp and river red gum in the west of Millewa Forest, before outfalling into the Edward River further downstream. It does not contribute to flooding elsewhere in the forest.

Broken Creek is the main waterway that flows into the Murray River as it passes through Barmah Forest, out falling into the Murray River downstream of Barmah Lake. Broken Creek supplies the Goose Swamp area, but otherwise does not contribute to flooding within the forest.

Other creeks and anabranches that distribute water through Barmah-Millewa Forest include Gulf Creek, Budgee Creek, Tullah Creek, Black Engine Creek, Sandpit Creek, and Kynmer Creek in Victoria, as well as Aratula Creek, Toupna Creek, Tooralong Creek and Cornalla Creek in New South Wales.

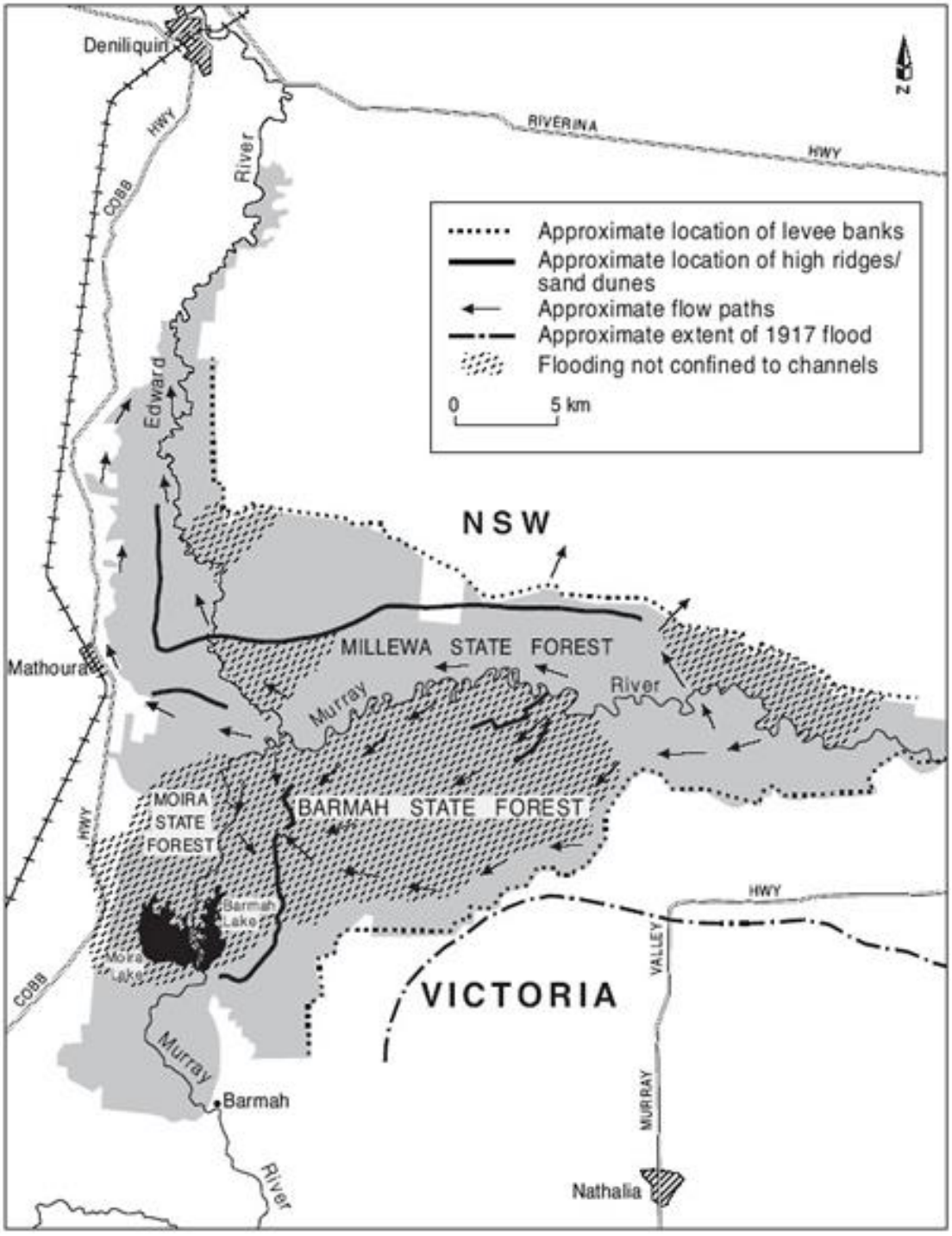


Figure 5: Key flow paths in and around Barmah-Millewa Forest (from Goulburn Broken CMA 2015).

A series of water management areas (WMAs, Figure 6) have been established to deal with the complex nature of waterways and water movement across Barmah-Millewa Forest (MDBA 2012). These WMAs in the past provided the basis for prioritising environmental water delivery to floodplain areas to achieve ecological objectives (see Chapter 7 and 8). Henceforth, environmental water management and delivery will be to meet the needs of water regime classes (see Section 3.3.5).

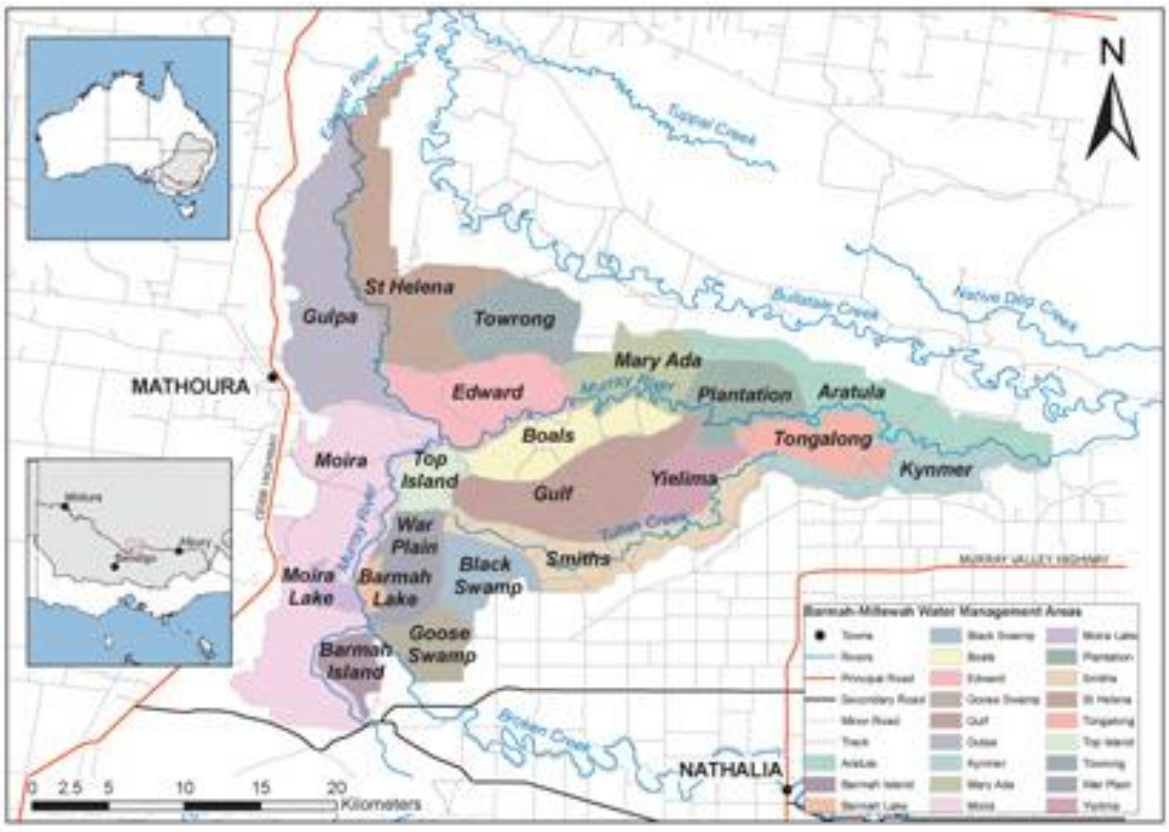


Figure 6. Barmah–Millewa water management area boundaries (from MDBA 2012).

3.3.4 Vegetation and wetland types

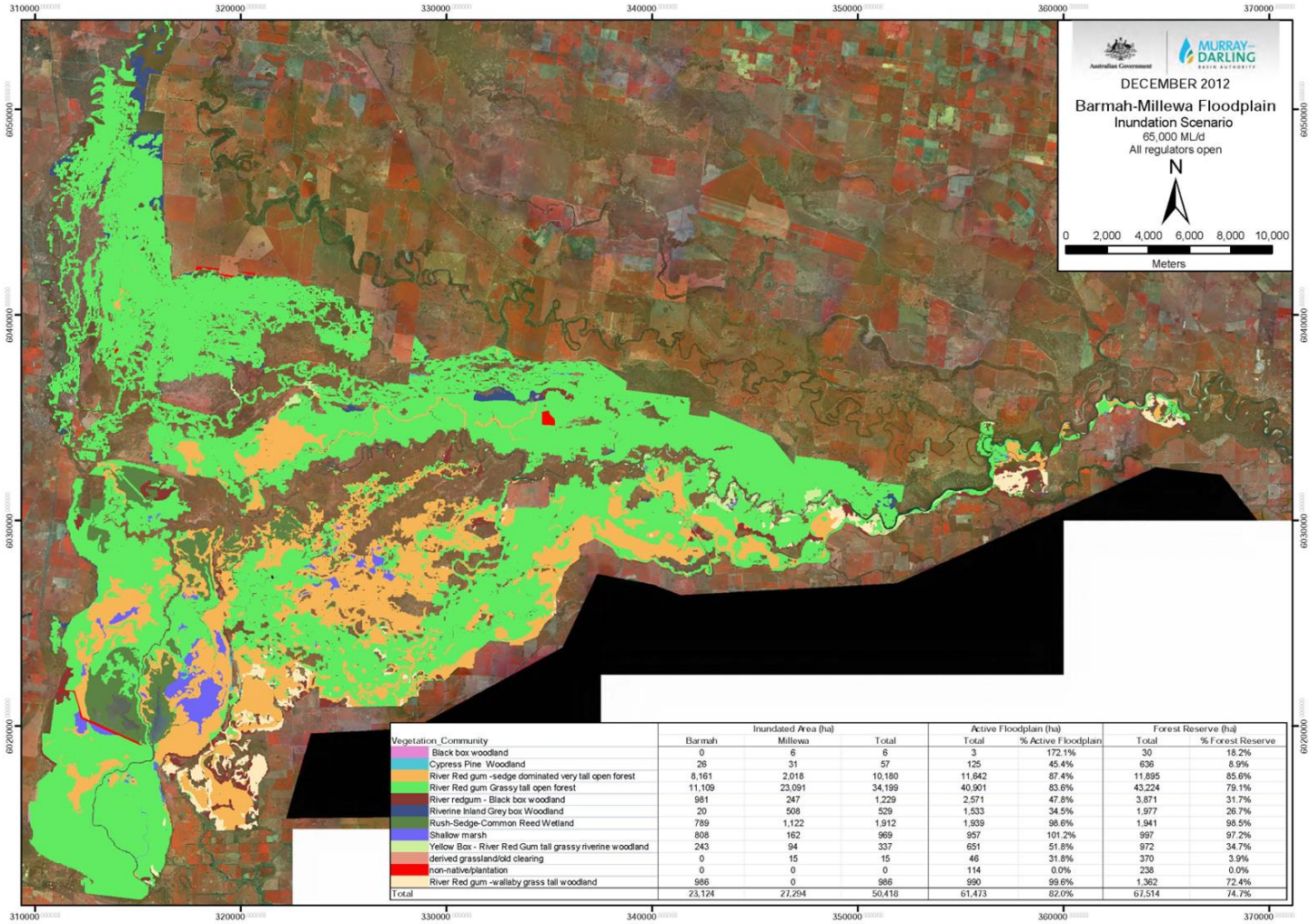
The Barmah–Millewa Forest is characterised by:

- Swamps and marshes in the lower elevated frequently flooded areas where water can pond.
- Rush beds surrounding the swamps and marshes, also generally in wetter areas.
- Deeper lakes and billabongs that provide important reed bed areas during large colonial waterbird-breeding events.
- Open grassland plains, including large plains of Moira grass. When flooded, these are highly significant as breeding and feeding habitat for colonial breeding water birds such as egrets, herons, spoonbills and marsh terns.
- River red gum (*Eucalyptus camaldulensis*) forest of various types and health, depending on inundation, with the lower elevation areas supporting larger and denser trees.
- Black box (*E. largiflorens*) Grey Box (*E. microcarpa*) and Yellow Box (*E. melliodora*) woodland in rarely flooded areas.
- Sandridge woodlands supporting Cypress-Pine, Buloke, Yellow Box and Grey Box

Vegetation communities have been used previously to describe the floodplain/wetland types that are inundated by flooding (Figure 7). Given differences in the scale and approach to mapping vegetation in New South Wales and Victoria (e.g., plant community type (PCT) in New South Wales and ecological

vegetation classes (EVCs) in Victoria), this EWMP update has adopted the Australian National Aquatic Ecosystem (ANAE) typology (Brooks 2021) to provide a consistent approach to assigning aquatic ecosystem types across Barmah-Millewa Forest (see Section 5.1.1).

Twenty-two PCTs have been recorded in the Millewa Forest in NSW (Appendix 1), whilst 90 EVCs have been recorded in Barmah Forest in Victoria (many of which are mosaics of individual EVCs).



Vegetation_Community	Inundated Area (ha)			Active Floodplain (ha)		Forest Reserve (ha)	
	Barmah	Millewa	Total	Total	% Active Floodplain	Total	% Forest Reserve
Black box woodland	0	6	6	3	172.1%	30	18.2%
Cypress Pine Woodland	26	31	57	125	45.4%	638	8.9%
River Red gum -sedge dominated very tall open forest	8,161	2,018	10,180	11,642	87.4%	11,895	85.6%
River Red gum Grassy tall open forest	11,109	23,091	34,199	40,901	83.6%	43,224	79.1%
River redgum - Black box woodland	981	247	1,229	2,571	47.8%	3,871	31.7%
Riverine Inland Grey box Woodland	20	508	529	1,533	34.5%	1,977	26.7%
Rush-Sedge-Common Reed Wetland	789	1,122	1,912	1,939	98.6%	1,941	98.5%
Shallow marsh	808	162	969	957	101.2%	997	97.2%
Yellow Box - River Red Gum tall grassy riverine woodland	243	94	337	651	51.8%	972	34.7%
derived grassland/old clearing	0	15	15	46	31.8%	370	3.9%
non-native/plantation	0	0	0	114	0.0%	238	0.0%
River Red gum -wallaby grass tall woodland	986	0	986	990	99.6%	1,362	72.4%
Total	23,124	27,294	50,418	61,473	82.0%	67,514	74.7%

Figure 7: Map of inundation extent in Barmah-Millewa Forest at flows of 65,000 ML/d in the Murray River (Source: Murray Darling Basin Authority).

3.3.5 Water regime classes

Three landscape components (Figure 8) were previously used to frame environmental watering objectives and targets for three forest zones of Barmah-Millewa Forest (Goulburn Broken CMA 2015):

- Lower terraces that are more frequently flooded (4,000-25,000 ML/d) and characterised by wetlands (including Moira grass floodplains) and watercourses;
- The mid terraces that are inundated in medium sized floods (20,000-60,000 ML/d) where the river red gum and yellow box communities can be found;
- The upper terraces that are only inundated during large flood events (>55,000 ML/day) where box woodlands occur.

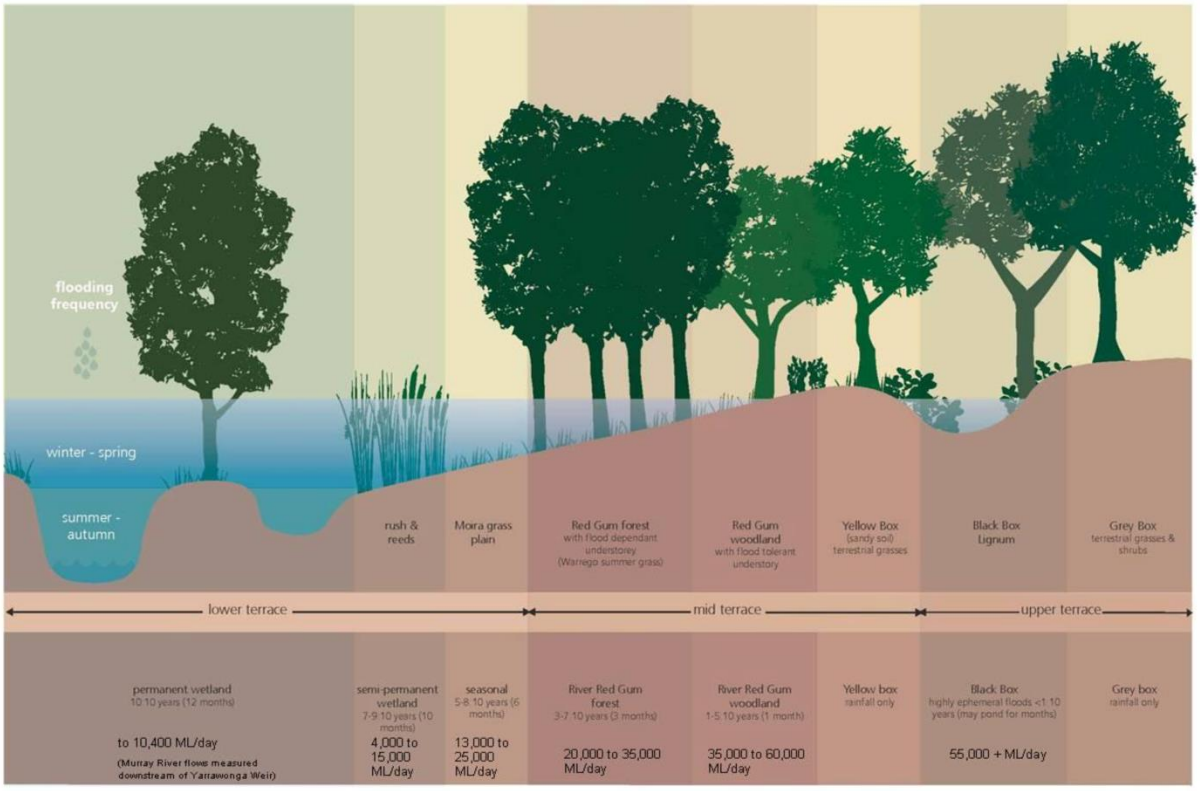


Figure 8: Cross-section of the Barmah-Millewa floodplain showing key vegetation communities and their water requirements (from Goulburn Broken CMA 2015)

These landscape components have been used as a basis to adopt a Water Regime Class (WRC) system which uses the ANAE classification typology, which improves line of sight to the Basin Plan objectives on maintaining representativeness of aquatic ecosystem types.

For the purposes of this EWMP update, 11 WRC have been identified for Barmah-Millewa Forest. The indicative EVCs and PCTs associated with each are listed in Table 4. The WRCs have been determined by considering the key vegetation communities and their water requirements (as per Figure 8 above) and the desired outcomes for vegetation condition. The WRCs are a combination of the ANAE classification

classes relating to ecosystem type, water permanency, vegetation type (i.e., non-woody or woody) and dominant vegetation structure (i.e., forest, woodland, etc.).

The watering requirements for each WRC are presented in Section 8.1.

Table 4: Water regime class and indicative EVCs and PCTs.

Water Regimes Class	Indicative EVCs	Indicative PCTs
Permanent rivers and creeks	EVC 810 – Floodway Pond Herbland EVC 945 Floodway herbland/Swamp Forest	
Temporary rivers and creeks	EVC 810 – Floodway Pond Herbland EVC 945 Floodway herbland/Swamp Forest	
Sedge/forb/grass floodplain	EVC 809 - Floodplain Grassy Wetland	
River red gum floodplain forest	EVC 106 - Grassy Riverine Forest EVC 812 - Grassy Riverine Forest/Riverine Swamp Forest Complex EVC 814 - Riverine Swamp Forest EVC 816 - Sedgy Riverine Forest	PCT 2 - River red gum-sedge dominated very tall open forest in frequently flooded forest PCT 5 - River red gum herbaceous-grassy very tall open forest
River red gum floodplain woodland	EVC 815 - Riverine Swampy Woodland EVC 56 - Floodplain Riparian Woodland	PCT 7 - River red gum - Warrego Grass - herbaceous riparian tall open forest
Box floodplain woodlands	EVC 103 - Riverine Chenopod Woodland EVC 803 - Plains Woodland EVC 823 - Lignum Swampy Woodland	PCT 13 - Black box - Lignum woodland PCT 74 - Yellow box - River red gum tall grassy riverine woodland PCT 237 - Riverine Western Grey Box grassy woodland
Permanent marsh	Billabong Aggregate EVC 821 - Tall Marsh	PCT 12 - Shallow marsh wetland of regularly flooded depressions on floodplains
Temporary swamps	EVC 814 - Riverine Swamp Forest EVC 815 - Riverine Swampy Woodland	
Temporary marshes	EVC 655 - Aquatic herbland EVC 804 - Rushy Riverine Swamp EVC 809 -Floodplain Grassy Wetland EVC 810 - Floodway Pond Herbland EVC 819 – Spike-sedge Wetland EVC 821 - Tall Marsh EVC 1077 - Sedgy Riverine Forest/Tall Marsh Complex	PCT 12 - Shallow marsh wetland of regularly flooded depressions on floodplains PCT 181 - Common Reed - Bushy Groundsel aquatic tall reedland grassland PCT 182 - Cumbungi rushland
Permanent lakes	EVC 107 - Lake Bed Herbland	
Temporary lakes	EVC 107 - Lake Bed Herbland EVC 810 - Floodway Pond Herbland EVC 809 - Floodplain Grassy Wetland Aquatic Herbland	

3.4 Environmental water sources

Environmental water for Barmah-Millewa Forest may be sourced from the water entitlements and their agencies listed in **Error! Reference source not found.**. Both New South Wales and Victoria supply water for the environment to Barmah-Millewa Forest in partnership with the Commonwealth Environmental Water Holder and The Living Murray program. In New South Wales, delivery occurs via the DPE and in Victoria via the VEWH. Decisions on the use of water entitlements are made by the relevant water holder, noting decisions on using water held by States for The Living Murray program are made by the Southern Connected Basin Environmental Watering Committee. Note that the MDBA does not own or hold environmental water. Environmental water holders work collaboratively to achieve environmental objectives, including objectives identified for the Barmah-Millewa Forest, by utilising the collective water holdings.

Of primary importance is the Barmah–Millewa Environmental Water Allocation (EWA), which is a rules-based allocation established in 1993 (MDBC 2012, Ecological Associates and SKM 2011), set aside specifically for Barmah-Millewa Forest. The Murray–Darling Basin Ministerial Council authorised a high-security environmental water entitlement of 100 GL/y, to be drawn equally from Victoria and New South Wales, and a low-security allocation of 50 GL (again to be contributed equally by the two states). Allocation may be 'borrowed' on 1 July each year by Victoria and New South Wales to support high-reliability allocations (up to 100%) and general security allocation (up to 30%, or up to 50% for exceptional circumstances) respectively, before being 'repaid' to the environment and available for delivery to Barmah-Millewa Forest. A maximum of 700 GL of the EWA can be carried over in storage. The EWA spills at Hume Dam when the maximum volume is reached and during wet years.

Table 5: Summary of environmental water sources available to Barmah-Millewa Forest.

Water holdings	Responsible agency or committee
Murray River Unregulated Flows	Southern Connected Basin Environmental Watering Committee, MDBA
River Murray Increased Flows	
Living Murray Program	
Barmah-Millewa Forest Environmental Water Allocation	NSW Department of Planning and Environment and Victorian Environmental Water Holder
New South Wales Adaptive Environmental Water and Planned Environmental Water allocations	NSW Department of Planning and Environment
Victorian River Murray Flora and Fauna Bulk Entitlement	Victorian Environmental Water Holder
Commonwealth held water shares	Commonwealth Environmental Water Holder

* Other sources of water may become available through water trading, donations or changes in water entitlements.

4 Hydrological regime and system operations

Barmah-Millewa Forest is situated in the central Murray River system, comprising the Murray River and its anabranches from Yarrawonga to the confluence with the Goulburn River at Echuca.

Restoring hydrological connectivity, (horizontally) between the Murray River and its floodplains and (vertically) between surface and groundwater flows, is an essential prerequisite for improving the health and biodiversity of river-floodplain ecosystems, like Barmah-Millewa Forest, and the biodiversity these habitats provide (e.g., Hale et al. 2011). A wetland's hydrology is determined by surface and groundwater inflows and outflows in addition to precipitation and evapotranspiration. Duration, frequency and seasonality (timing) are the main components of the hydrological regime for wetlands and rivers, floodplains and the wetlands they contain.

4.1 Groundwater

There are five aquifers in the West Goulburn Groundwater Management Area (GMA), four of which underlie Barmah National Park (G-MW 2017):

- Coonambidgal Formation, which is a Quaternary aquifer that is the youngest aquifer in the West Goulburn GMA. It comprises sands, gravels and clay of varying sizes and is associated with waterways. It is difficult to differentiate this formation from the underlying Shepparton Formation, so its thickness is not defined (GHD 2010).
- Shepparton Formation, which is an Upper Tertiary/Quaternary aquifer comprised of clay, silt and discontinuous sand lenses. The Shepparton Formation increases in thickness to the north of the GMA (i.e. near Barmah Forest) where it is over 100 m thick. Yields and groundwater salinity can be highly variable. It overlies either the Deep Lead (where present) or bedrock aquifers.
- Deep Lead, which is comprised of the Calivil Formation and the Renmark Group, is an ancient river bed consisting of coarse sand and gravel with some clay. The Deep Lead increases in thickness and depth from south to north within the GMA, occurring from around 50 to 110 metres beneath the surface in the north. The Deep Lead is higher yielding than the overlying Shepparton Formation.
- The Bedrock layer is mostly sedimentary shale, slate and sandstone with some intrusive granites. The Bedrock is a fractured rock aquifer, with variable yields and salinity.

Previous reports indicated that groundwater salinity in the upper Shepparton Formation that underlies Barmah National Park was typically less than 500 mg/L total dissolved solids (TDS) and less than the 1,000 and 3,500 mg/L TDS in the upper Shepparton Formation near the lower Goulburn River (GHD 2010), likely due to flooding of the forest and groundwater recharge. However, there has not been any active monitoring of groundwater levels or salinity across Barmah-Millewa Forest since 2012/13; monitoring was ceased due to declining groundwater levels during the Millennium Drought and in response to changed irrigation practices in the region.

Overall, groundwater is believed to be of secondary importance to surface flows to the condition of vegetation at Barmah-Millewa Forest. For example, Hale and Butcher (2011) reported that groundwater tables at the time of listing under the Ramsar convention (2008) were 11 to 14 metres below the surface in most areas. Hale and Butcher (2011) also noted that surface-groundwater connectivity along the Murray River is highly variable with both losing and gaining river reaches. Variation from reach to reach is likely to be due to a combination of river regulation, floodplain groundwater flow processes and

the influence of irrigation development. However, the direction of water movement is typically from the river to the groundwater aquifer.

While groundwater levels more than ten metres below the surface were unlikely to support river red gums (DSE 2008), the perched water tables along the streams and rivers are closer to the surface and may be important for river red gum health; however, the contribution of groundwater to maintaining tree health remains a knowledge gap (Hale and Butcher 2011).

4.2 Surface water

Since regulation of the Murray River, the frequency and magnitude of floods during winter and spring has decreased because rainfall in the upper catchments is caught in storage (Hume Dam, Dartmouth Dam) and then released in a more controlled stable-level to meet downstream irrigation and consumptive demand (Figure 9). River regulation now results in higher than natural summer-autumn flows, and lower than natural winter-spring flows and severely reduces the occurrence of small and medium-sized floods (e.g., MDBA 2015, Gippel and Blackham 2002, Thoms et al. 2000).

Flows downstream of Yarrawonga Weir, the major regulating structure above Barmah-Millewa Forest, are the cumulative result of flows released from Hume Dam and inflows from tributaries such as the Kiewa and Ovens rivers. The forest flooding that occurs during June to December is usually the result of rainfall in the Ovens and Kiewa catchments. These enter the Murray below Hume Dam, so their high flows cannot be stored. Lake Mulwala (formed by Yarrawonga Weir), located upstream of Barmah-Millewa Forest, is unable to store these flows as it is kept close to capacity to provide sufficient hydraulic head to operate the major irrigation supply channels. This results in high flows entering Barmah-Millewa Forest through low points and channel effluents and by spilling over the banks through sections of the forest affected by constrained channel capacity (e.g., Water Technology 2022; see also Section 3.3.2).

Hydrodynamic modelling for a range of stable river flows downstream of Yarrawonga (Water Technology 2011) has shown that:

- River flows of 10,400[6] ML/d downstream of Yarrawonga are retained within channel capacity if all forest regulators remain closed (apart from a few unregulated waterways that do not result in forest flooding).
- For flows between 10,400 and 18,000 ML/d, increasing numbers of regulators have to be opened or overbank flow in the river will result, potentially causing erosion and damaging roads. Flows up to 15,000 ML/d can generally be managed through either Barmah or Millewa Forest.
- Flows beyond 60,000 ML/d for one month are generally regarded as flooding all the floodplain within the icon site (which is ~95% of the area of the TLM reserve).

[6] Noting that the channel capacity has since decreased, affecting the previously recognised commence-to-flow thresholds (e.g., Ward 2009) for all Barmah-Millewa Forest waterways.

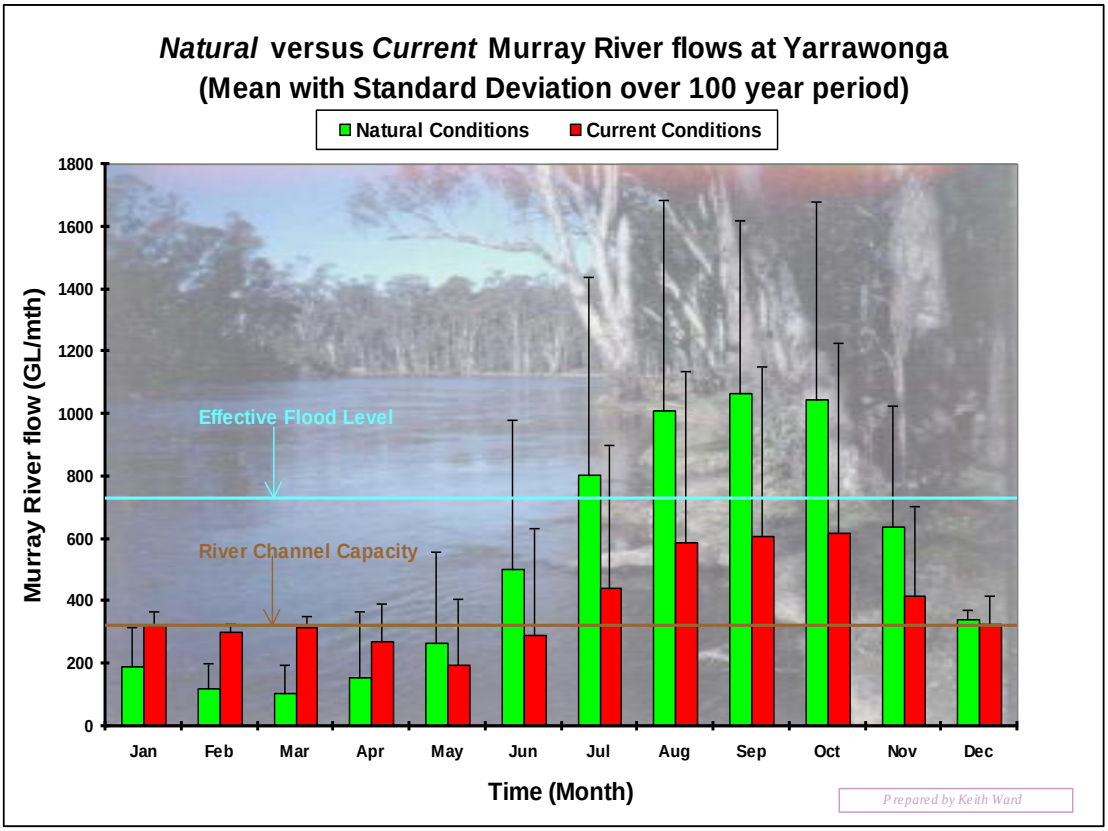


Figure 9. Comparison of current and modelled natural monthly flows in the Murray River at Yarrawonga (source: Goulburn Broken CMA 2015).

Note: monthly flows under Natural conditions reflect removal of the influence of dams, regulating structures and water diversions for agriculture and consumption, but with current land use and practices in place.

4.2.1 Effects of changed flow regime

Specific consequences of changes in the frequency, duration, variability and timing of river regulation (Goulburn Broken CMA 2015, MDBA 2015) are that:

- The frequency of winter-spring floods has been greatly reduced; for example, floods that once occurred every second year now occur about every 6–8 years and those that occurred every 10 years now occur about every 25–30 years.
- The duration of inundation of river red gum forest has reduced from an average of five months to two months per year.
- The timing of flooding has shifted from predominantly winter-spring to now include undesirable small floods in summer.
- The maximum length of dry periods has increased six-fold.
- The variability of river flows has reduced: under natural conditions, average monthly flows vary between 100 GL and 980 GL; under current regulated conditions they vary between 110 GL and 400 GL.
- The volume of river flows has reduced: downstream of Yarrawonga, diversions reduce annual flow by 25% compared to natural conditions.

Goulburn Broken CMA (2015) also noted that:

- A reduction in mean flood duration results in less time for the river to flow onto the floodplain hence the extent of flooding is reduced. Also, the time that water stays on the floodplain is shorter, so the time for the recharge of soil moisture is also reduced. Water is retained for a shorter time in wetlands and depressions before evaporating away, hence there is less time for plants to germinate (or re-grow), flower and set seed (and/or replenish reserves), especially for submerged and floating-leafed plants. The ecological consequences are potentially quite severe if accumulated over time.
- An increase in variability of flood duration can have serious effects on plant communities, as this is likely to favor species or communities with wide tolerances, or opportunists, at the expense of flood-dependent species.
- A shift in the timing of floods can result in a gradual alteration in the species composition of wetland plant communities.

5 Water dependent values

Wetlands and waterways on floodplains are a vital component of the landscape supporting a vast array of plants and animals which may vary greatly with the type of wetland/waterway system. The habitat provided by vegetation communities around wetlands is essential for maintaining populations of water dependent fauna species. Other ecological functions provided by floodplain complexes include water filtration, slowing surface water flow to reduce soil erosion, flood mitigation and reducing nutrient input into waterways. Protecting the ecological functioning of wetlands ensures these vital services are maintained. Recognising such values is important in terms of alignment of this EWMP with the objectives of the Basin Plan, which includes objectives related to the improvement of:

- Ecosystem type and biodiversity;
- Ecosystem function (e.g., breeding, recruitment, nutrient and carbon cycling);
- Ecosystem resilience to climate change and other risks and threats (i.e., the capacity to recover following disturbance).

Importantly, the Basin Plan also contains criteria for selection of priority ecosystem assets (PEAs) and priority ecosystem function (PEFs) for which environmental watering objectives will be developed (see Section 7.3). Acknowledging the environmental values and preparing environmental watering objectives for Barmah-Millewa Forest is also important in terms of implementing the LTWPs for the Victorian Murray (DELWP 2021a) and the Murray-Lower Darling (DPIE 2020a, b), and also required under the Basin Plan, as well as contributing to Australia's obligations under the Ramsar convention and other international waterbird agreements.

5.1 Environmental values

5.1.1 Ecosystem types

The ANAE typology (Brooks 2021) has been adopted to provide a consistent approach to assigning aquatic ecosystem types across Barmah-Millewa Forest. The areas of ecosystem types and vegetation groupings within the site boundary (supplied by Goulburn Broken CMA) were calculated in GIS using ANAE mapping for the Murray-Darling Basin (Brooks 2021), the Victorian Ecological Vegetation Classes (DEECA 2023) and NSW State Vegetation Type mapping (OEH 2017).

Twenty-seven aquatic ecosystem types have been recorded across the entire site (Table 6). Two river red gum ecosystem types (F1.2: River red gum forest riparian zone or floodplain and Pt1.1.2: Temporary river red gum swamp) dominate, together covering over 91% of Barmah-Millewa Forest. Other important aquatic ecosystems include tall emergent marsh (Pt2.1.2: Temporary tall emergent marsh and Pp2.1.2: Permanent tall emergent marsh) and Pt2.2.2: Temporary sedge/grass/forb marsh, the latter including extensive stands of the ecologically important Moira grass (*Pseudoraphis spinescens*) (e.g., Vivian et al. 2015).

Table 6. Aquatic ecosystem types across Barmah-Millewa Forest. Note that in NSW the dominant type is identified as floodplain, in Victorian the dominant system is the palustrine. This is an anomaly of the Victorian aquatic ecosystem classification and will be rectified in the near future.

ANAE type	Area (Hectares)	Percent coverage
F1.2: River red gum forest floodplain	33,467.36	52.84%
F1.4: River red gum woodland floodplain	57.36	0.09%
F1.8: Black box woodland floodplain	299.36	0.47%
F1.12: Woodland riparian zone or floodplain	675.93	1.07%
F2.2: Lignum shrubland floodplain	6.38	0.01%
F3.2: Sedge/forb/grassland floodplain	22.47	0.04%
F4: Unspecified floodplain	15.11	0.02%
Lp1.1: Permanent lake	406.44	0.64%
Lt1.1: Temporary lake	77.67	0.12%
Pp2.1.2: Permanent tall emergent marsh	601.57	0.95%
Pp2.3.2: Permanent grass marsh	2.35	0.00%
Pp2.4.2: Permanent forb marsh	5.88	0.01%
Pp4.2: Permanent wetland	475.27	0.75%
Pt1.1.2: Temporary river red gum swamp	24,281.20	38.34%
Pt1.2.2: Temporary black box swamp	85.83	0.14%
Pt1.6.2: Temporary woodland swamp	366.80	0.58%
Pt2.1.2: Temporary tall emergent marsh	721.38	1.14%
Pt2.2.2: Temporary sedge/grass/forb marsh	583.28	0.92%
Pt2.3.2: Freshwater meadow	100.30	0.16%
Pt3.1.2: Clay pan	4.23	0.01%
Pt4.2: Temporary wetland	124.24	0.20%
Rp1.2: Permanent transitional zone stream	1.16	0.00%
Rp1.4: Permanent lowland stream	578.51	0.91%
Rp1: Permanent stream	1.38	0.00%
Rt1.2: Temporary transitional zone stream	6.01	0.01%
Rt1.4: Temporary lowland stream	361.73	0.57%
Rt1: Temporary stream	3.68	0.01%

As noted in Section 3.3.5, the vegetation and wetland types present at Barmah-Millewa Forest have been consolidated in to the following WRCs to facilitate environmental water delivery, being aquatic ecosystems with particular watering requirements:

- Permanent rivers and creeks,
- Temporary rivers and creeks,
- Sedge/forb/grass floodplain,
- River red gum floodplain forest,
- River red gum floodplain woodland,
- Box floodplain woodlands,
- Permanent marsh,
- Temporary swamps,
- Temporary marshes,
- Permanent lakes,

- Temporary lakes.

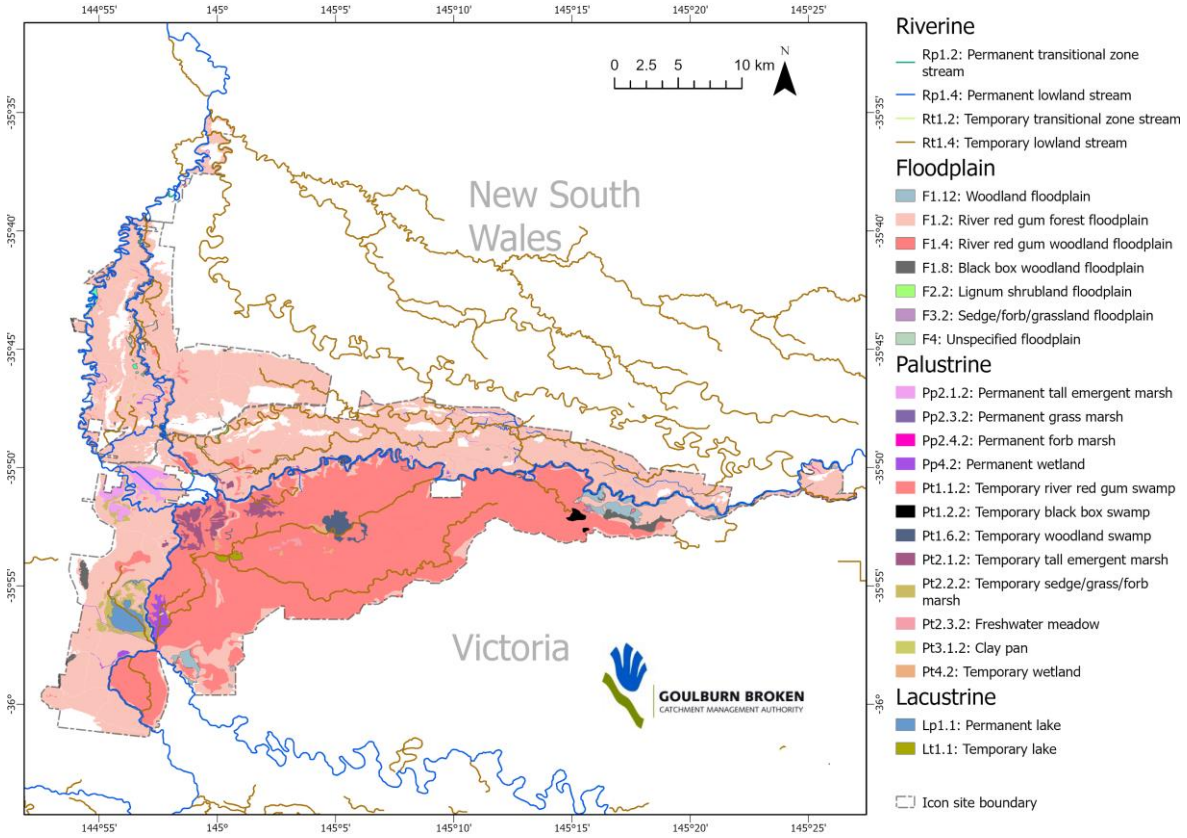


Figure 10. Map of ANAE ecosystem types at Barmah-Millewa Forest. Note: Ecosystem types such as Pt1.1.2 and Pt1.2.2 are assigned as palustrine rather than floodplain ecosystems in Barmah Forest. This is an anomaly of the Victorian mapping included in ANAE, which will be potentially addressed in the next update to the Victorian Wetland Inventory.

5.1.2 Biodiversity – animals and plants

Barmah-Millewa Forest is a known biodiversity hotspot. Records from the Victorian Biodiversity Atlas (VBA)/NatureKit (for Barmah) and NSW's BioNet (for Millewa) provided by the Goulburn Broken CMA (June 2023) listed over 300 animal and over 650 plant species. The high number of species is consistent with previous reports of biodiversity (e.g., Loyn et al. 2002, Hale and Butcher 2011). Of note, the VBA and BioNet records included:

- Over 140 aquatic dependent plant species;
- Over 60 waterbird species;
- Over 25 fish species, including over 20 native species;
- Nine frog species;
- Three decapod species, including Murray spiny crayfish;
- Over 15 reptile species, including three turtle species;
- Over 25 native mammal species, including 15 species of bat.

The broader icon site is known to support a range of threatened species including at least:

- 21 nationally threatened species; and
- 31 state-listed fauna species.

The threatened species and communities found within the site are presented in Table 7 and Table 8. Not all woodland birds are listed here, see Appendix 1 for a complete list.

Table 7. Listed fauna recorded at Barmah-Millewa Forest. ** being assessed under EPBC Act.

Scientific name	Common name	Conservation status		
		EPBC	Vic	NSW
Birds				
Anthochaera phrygia	Regent honeyeater	CR	CR	CR
Aphelocephala leucopsis	Southern whiteface	VU	-	-
Ardea alba modesta	Eastern great egret	-	VU	-
Ardea intermedia	Plumed egret	-	CR	-
Artamus cyanopterus cyanopterus	Dusky woodswallow	-	-	VU
Aythya australis	Hardhead	-	VU	-
Biziura lobata	Musk duck	-	VU	-
Botaurus poiciloptilus	Australasian bittern	EN	CR	EN
Burhinus grallarius	Bush stone-curlew	-	-	VU
Calidris ferruginea	Curlew sandpiper	CR	CR	EN
Circus assimilis	Spotted harrier	-	-	VU
Climacteris picumnus victoriae	Brown treecreeper	VU	-	VU
Egretta garzetta nigripes	Little egret	-	EN	-
Falco subniger	Black falcon	-	CR	VU
Geopelia cuneata	Diamond dove	-	VU	-
Grantiella picta	Painted honeyeater	VU	VU	VU
Grus rubicunda	Brolga	-	EN	VU
Haliaeetus leucogaster	White-bellied sea-eagle	-	EN	VU
Hieraaetus morphnoides	Little eagle	-	VU	VU
Hirundapus caudacutus	White-throated needletail	VU	VU	-
Ixobrychus dubius	Australian little bittern	-	EN	-
Lathamus discolor	Swift parrot	CR	EN	EN
Lophochroa leadbeateri	Major Mitchell's cockatoo	EN	CR	EN
Melanodryas cucullata	South-eastern hooded robin	EN	VU	VU
Neophema chrysostoma	Blue-winged parrot	VU	-	-
Oxyura australis	Blue-billed duck	-	VU	VU
Polytelis swainsonii	Superb parrot	VU	EN	VU
Spatula rhynchotis	Australasian shoveler	-	VU	-
Stagonopleura guttata	Diamond firetail	VU	VU	VU
Stictonetta naevosa	Freckled duck	-	EN	VU
Tringa nebularia	Common greenshank	-	EN	-
Fish				
Bidyanus bidyanus	Silver perch	CR	EN	VU
Galaxias rostratus	Flathead galaxias	CR	VU	CR
Maccullochella macquariensis	Trout cod	EN	EN	EN
Maccullochella peelii	Murray cod	VU	EN	-
Macquaria australasica	Macquarie perch	EN	EN	EN
Melanotaenia fluviatilis	Murray-Darling rainbowfish	-	EN	-
Morgunda adspersa	Purple-spotted gudgeon	-	EN	CR
Nannoperca australis	Southern pygmy perch (MDB lineage)	EN	VU	EN
Tandanus tandanus	Freshwater catfish	-	EN	EN

Scientific name	Common name	Conservation status		
		EPBC	Vic	NSW
Amphibians				
Crinia sloanei	Sloane's froglet	EN	EN	VU
Litoria raniformis	Southern bell frog	VU	VU	EN
Invertebrates				
Euastacus armatus	Murray crayfish	**	VU	VU
Reptiles				
Chelodina expansa	Broad-shelled turtle	-	EN	-
Emydura macquarii	Murray River turtle	-	CR	-
Pogona barbata	Bearded dragon	-	VU	-
Varanus varius	Lace monitor	-	EN	-
Morelia spilota metcalfei	Carpet python	-	EN	-
Mammals				
Ornithorhynchus anatinus	Platypus	-	VU	-
Phascolarctos cinereus	Koala	EN	-	EN
Legend Status: VU = Vulnerable, EN = Endangered, CR = Critically Endangered				

Table 8. Threatened water-dependent flora for Barmah-Millewa Forest.

Species name	Common name	Conservation status		
		EPBC	Vic	NSW
Ammannia multiflora	Jerry-jerry	-	EN	-
Amphibromus fluitans	River swamp wallaby-grass	VU	-	VU
Amyema linophylla subsp. *orientalis*	Buloke mistletoe	-	CR	-
Brachyscome muelleroides	Mueller daisy	VU	EN	VU
Callitriche umbonata	Winged water-starwort	-	EN	-
Cardamine moirensis	Riverina bitter-cress	-	EN	-
Centipeda nidiformis	Cotton sneezeweed	-	EN	-
Centipeda pleiocephala	Tall sneezeweed	-	EN	-
Coronidium gunnianum	Pale swamp everlasting	-	CR	-
Cyperus bifax	Downs nutgrass	-	CR	-
Cyperus flaccidus	Lax flat-sedge	-	EN	-
Cyperus leptocarpus	Button rush	-	EN	-
Eleocharis plana	Flat spike-sedge	-	CR	-
Glossostigma cleistanthum	Small-flower mud-mat	-	EN	-
Gratiola pumilo	Dwarf brooklime	-	VU	-
Lepidium monoplocoides	Winged peppercress	EN	EN	-
Nymphoides crenata	Wavy marshwort	-	EN	-
Nymphoides geminata	Open marshwort	-	EN	-
Rorippa eustylis	Dwarf bitter-cress	-	EN	-
Santalum lanceolatum	Northern sandlewood	-	CR	-
Viola betonicifolia subsp. *novaguineensis*	Floodplain violet	-	EN	-
Legend Status: VU = Vulnerable, EN = Endangered, CR = Critically Endangered.				

The following sections provide an overview of the significant fauna and flora values of the Barmah-Millewa Forest with an emphasis on aquatic and water-dependent species; a full listing of the species recorded is provided in Appendix 1.

Fish

The aquatic environments within the Barmah-Millewa Forest support 29 native fish species (Table 9), although this number is likely to be higher given recent taxonomic advances on groups such as the Carp gudgeon complex (Thacker et al. 2022). Nine species (Table 7) are listed under the *EPBC Act* (1999) and/or the Victorian *Flora and fauna Guarantee Act* (1988) and NSW *Threatened Species Conservation Act* (1995). This includes large-bodied species such as Murray cod (*Maccullochella peelii*) and trout cod (*Maccullochella macquariensis*) and small-bodied species such as southern pygmy perch (*Nannoperca australis*) and Murray-Darling rainbowfish (*Melanotaenia fluviatilis*).

Table 9. Fish species (and Murray spiny crayfish) captured from Barmah-Millewa Forest (from Raymond et al. 2021, VBA/BioNet accessed June 2023).

Species name	Common name
Native species	
Bidyanus bidyanus	Silver perch
Craterocephalus fulvus	Un-specked hardyhead
Craterocephalus stercusmuscarum	Fly-specked hardyhead
Gadopsis marmoratus	River blackfish
Galaxias brevipinnis	Climbing galaxias
Galaxias maculatus	Common galaxias
Galaxias rostratus	Flat-headed galaxias
Hypseleotris spp.	Carp gudgeon
Hypseleotris klunzingeri	Western carp gudgeon
Nematalosa erebi	Bony herring
Maccullochella macquariensis	Trout cod
Maccullochella peelii	Murray cod
Macquaria ambigua ambigua	Golden perch
Macquaria australasica	Macquarie perch
Melanotaenia fluviatilis	Murray-Darling rainbowfish
Morgurnda adspersa	Southern purple-spotted gudgeon
Nannoperca australis	Southern pygmy perch
Philypnodon grandiceps	Flat-headed gudgeon
Philypnodon macrostoma	Dwarf flat-headed gudgeon
Retropinna semoni	Australian smelt
Tandanus tandanus	Freshwater catfish
Euastacus armatus	Murray spiny crayfish
Alien species	
Carassius auratus	Goldfish
Cyprinus Carpio	Common carp
Gambusia holbrooki	Gambusia
Misgurnus anguillicaudatus	Oriental weatherloach
Perca fluviatilis	Redfin perch
Salmo salar	Atlantic salmon
Salmo trutta	Brown trout
Tinca tinca	Tench

Amphibians and reptiles

The habitats across the Barmah-Millewa Forest support native frogs and reptiles, of which 32 species have been recorded in surveys to date. This includes 11 frog species (Table 10), three turtle species, five

snake species and 11 species of lizard (Table 11). Barmah Forest regularly supports six species of frog, with a further three species recorded rarely. High spatial and temporal variability in abundance, with most calling frogs occurring in grassy wetland habitats in spring and in wet years (McGinness et al. 2014 cited in Hale 2022). Breeding of all six common species occurs in Barmah with well vegetated intermittent wetlands the preferred habitat for frog activity and breeding (Ward 2006, Hale 2022).

Two of the three turtle species present are listed under the Victorian FFG Act (Table 7). This includes the broad-shelled turtle (*Chelodina expansa*) and Murray River turtle (*Emydura macquarii*) that are listed as endangered and critically endangered, respectively (DELWP 2021b). In addition, bearded dragon are listed as vulnerable while lace monitor and carpet python are listed as endangered.

Table 10. Frog species recorded from Barmah-Millewa Forest.

Species name	Common name	Victoria (Hale 2022)	NSW (Harrington and Hale 2011)
Litoria peronii	Peron's tree frog	Common	Not recorded
Litoria raniformis	Southern bell frog	Not recorded	Rare
Limnodynastes dumerilii	Eastern banjo frog/pobblebonk	Common	Common
Limnodynastes fletcheri	Marsh frog	Common	Common
Limnodynastes tasmaniensis	Spotted marsh frog	Common	Common
Neobatrachus sudelli	Sudell's frog/Common spadefoot	Rare	Present
Crinia parinsignifera	Eastern sign-bearing froglet/plains froglet	Common	Common
Crinia signifera	Common froglet	Common	Common
Crinia sloanei	Sloane's froglet	Rare	Rare
Pseudophryne bibronii	Brown toadlet	Rare	Not recorded
Uperoleia rugosa	Wrinkled toadlet	Not recorded	Not recorded

Table 11. Reptile species recorded at Barmah-Millewa Forest (from VBA/BioNet accessed June 2023).

Species name	Common name
Snakes	
Anilios proximus	Proximus blind snake
Morelia spilota metcalfei	Carpet python
Notechis scutatus	Tiger snake
Pseudechis porphyriacus	Red-bellied black snake
Pseudonaja textilis	Eastern brown snake
Lizards	
Christinus marmoratus	Marbled gecko
Cryptoblepharus pannosus	Ragged snake-eyed skink
Ctenotus robustus	Robust ctenotus
Eulamprus heatwolei	Yellow-bellied water skink
Eulamprus quoyii	Eastern water-skink
Eulamprus tympanum	Southern water-skink
Lampropholis guichenoti	Pale-flecked garden sunskink
Lerista bougainvillii	South-eastern slider
Morethia boulengeri	Boulenger's snake-eyed skink
Pogona barbata	Common bearded dragon
Varanus varius	Lace monitor
Turtles	
Chelodina longicollis	Snake-necked turtle

Species name	Common name
Chelodina (Macrochelodina) expansa	Broad-shelled turtle
Emydura macquarii	Murray River turtle

Mammals

Barmah-Millewa Forest provides critical floodplain forest habitat for numerous mammals, including 15 bat species and 12 other native mammal species (Table 12). Threatened mammal species include squirrel glider (*Petaurus norfolcensis*) and the yellow-footed antechinus (*Antechinus flavipes*), whose preferential habitat is in decline (Lada & Mac Nally 2008).

Thirteen alien mammal species have also been recorded, many of which are known threats to the environmental values of Barmah-Millewa Forest (see Chapter 6).

Table 12. Mammals recorded from Barmah-Millewa Forest (from VBA/BioNet accessed June 2023).

Species name	Common name
Bats	
Austronomus australis	White-striped freetail-bat
Chalinolobus gouldii	Gould's wattled bat
Chalinolobus morio	Chocolate wattled bat
Chalinolobus picatus	Little pied bat
Myotis macropus	Southern myotis
Nyctophilus geoffroyi	Lesser long-eared bat
Nyctophilus gouldi	Gould's long-eared bat
Ozimops planiceps	South-eastern free-tailed bat
Ozimops ridei	Ride's free-tailed bat
Pteropus scapulatus	Little red flying-fox
Saccolaimus flaviventris	Yellow-bellied sheathtail bat
Scotorepens balstoni	Inland broad-nosed bat
Vespadelus darlingtoni	Large forest bat
Vespadelus regulus	Southern forest bat
Vespadelus vulturnus	Little forest bat
Other mammals	
Acrobates pygmaeus	Feather-tailed glider
Antechinus flavipes	Yellow-footed antechinus
Hydromys chrysogaster	Rakali
Macropus giganteus	Eastern grey kangaroo
Ornithorhynchus anatinus	Platypus
Petaurus breviceps	Sugar glider
Petaurus norfolcensis	Squirrel glider
Phascolarctos cinereus	Koala
Phascogale tapoatafa	Brush-tailed phascogale
Pseudocheirus peregrinus	Common ringtail possum
Tachyglossus aculeatus	Short-beaked echidna
Trichosurus vulpecula	Common brushtail possum
Wallabia bicolor	Swamp wallaby
Alien species	
Bos (Bos) taurus	European cattle
Canis lupus	Dog
Capra hircus	Goat
Dama dama	Fallow deer

Species name	Common name
Rusa unicolor	Sambar deer
Equus (Equus) caballus	Horse
Felis catus	Cat
Lepus capensis	Brown hare
Mus musculus	House mouse
Rattus rattus	Black rat
Oryctolagus cuniculus	Rabbit
Ovis aries	Sheep
Sus scrofa	Pig
Vulpes vulpes	Fox

Birds

The habitats across Barmah-Millewa Forest support numerous water and woodland bird species. Over 100 species of birds have been recorded since surveys began, (e.g., Borrell 2021), of which four are listed as threatened (see Table 7). Numbers of waterbirds vary each year in response to local and regional climatic conditions.

Australasian bittern (*Botaurus poiciloptilus*) and Australian little bittern (*Ixobrychus dubius*) surveys have been undertaken at Barmah-Millewa Forest since 2015 across nine wetlands. Results for 2020 and 2021 reinforce previous findings that the wetlands in the icon site provide critical habitat for Australasian bitterns on an ongoing basis. The number of Australasian bitterns recorded in 2020 represent between 8-20% of the global population, based on the population estimates of 1000 – 2500 and 22% of the Australian population based on the population estimate of 800 adult birds (Birdlife International, 2014). There was a 21% increase in the number of Australian little bitterns recorded compared to 2018 data in 2020 (Belcher and Borrell 2020), and an even larger number of bitterns encountered in 2021 (Znidersic and Towsey 2022).

The Barmah-Millewa Forest is a significant breeding site for colonial nesting waterbirds. Inundating the floodplain habitat will support waterbird breeding events through the provision of productive foraging areas – a critical requirement for breeding success. The main species are cormorants, ibis, spoonbills, night-herons and egrets.

The Barmah-Millewa Forest support species listed under the Japan Australia Migratory Bird Agreement (JAMBA), China Australia Migratory Bird Agreement (CAMBA), Republic of Korea Australia Migratory Bird Agreement (ROKAMBA) and the Bonn Convention. These species do not occur in large numbers at the site as the preferred habitat is not a dominant feature of the icon site.

Many woodland birds are associated with floodplain forests, using them for habitat, foraging and breeding. Barmah-Millewa Forest supports several listed woodland birds of the Victorian temperate woodland bird community, which is a listed ecological community under the Victorian FFG Act (1988).

Woodland bird surveys were undertaken across four broad habitat types including two river red gum forest communities (tallest and wettest forest, moderately tall and slightly drier forest), box woodland (Grey Box, *Eucalyptus microcarpa* and yellow box, *E. melliodora*), and sandhill woodland which is a mix of river red gum, yellow box and white cypress-pine, *Callitris glaucophylla* (Tzaros and Tzaros 2021). The bird communities varied between the four different habitat types surveyed. Assessing habitat types by bird species richness, box woodland supported the most diverse woodland bird assemblage (total

species richness of 60 species), whereas the tall, wetter river red gum was the least diverse (total species richness of 47 species) (Tzaros and Tzaros 2021).

Vegetation communities

The majority of the Barmah-Millewa Forest is dominated by eucalyptus forest and woodlands. Riparian fringes of modern river channels and lower areas of the floodplain support river red gum forest and woodlands, black box woodland occurs on the higher less frequently inundated floodplain. There are small areas of sandy soils on higher ground such as levees, old channels, dunes and lunettes, which support Plains Woodland and Low-rises Woodland (Ecology Australia 2013).

Low-lying portions of the Barmah-Millewa Forest feature a variety of treeless palustrine wetlands, including Moira grass plains, giant rush beds, common reed beds, moist grasslands and aquatic herblands. These wetlands are associated with a variety of geomorphic settings including intermittent drainage lines, flood-runners, oxbow lagoons and floodplain depressions. Two vegetation classifications have been used to describe the vegetation communities present at the site: in Victoria Ecological Vegetation Classes (EVCs, see DSE 2013) are used, and in NSW Plant Community Types (PCT) are used (see Keith 2004). Both classifications describe characteristic native plant species assemblages in relation to environmental conditions, with frequently co-occurring species, including combinations of trees, shrubs and/or ground cover plants forming the descriptions for each type. Ecological Vegetation Classes found within the Barmah-Millewa Forest which are of conservation concern are listed in **Error! Reference source not found.**. The area of each EVC and PCT recorded at the site is presented in Appendix 1.

Table 13. Main Ecological Vegetation Classes of conservation concern in Barmah-Millewa Forest (Ecology Australia 2013).

EVC No.	EVC Name	(Vic) Conservation Status
653	Aquatic Herbland	Depleted
809	Floodplain Grassy Wetland	Endangered
56	Floodplain Riparian Woodland	Depleted
810	Floodway Pond Herbland	Depleted
106	Grassy Riverine Forest	Depleted
66	Low Rises Woodland	Endangered
803	Plains Woodland	Endangered
1088	Riverine Grassland	Endangered
295	Riverine Grassy Woodland	Vulnerable
814	Riverine Swamp Forest	Depleted
815	Riverine Swampy Woodland	Vulnerable
264	Sand Ridge Woodland	Endangered
816	Sedgy Riverine Forest	Depleted
819	Spike-sedge Wetland	Vulnerable
821	Tall Marsh	Least Concern

Flora

Two aquatic grasses Moira grass (*Pseudoraphis spinescens*) and swamp wallaby grass (*Amphibromus fluitans*) are target species for environmental watering and interventions across the icon site. Moira

grass is an iconic species of the area and representative of the floodplain landscape, especially during the flooding season (Hale 2022). Moira grass is well adapted to the wetting and drying regime typical of the floodplain conditions along the mid-Murray. Under wetter conditions it can extend its stems up to 3-4 metres and develops floating leaves, on drying the stems dry along the flow direction and re-root multiple times developing new plants in the next wet period (Cooling et al 2019). Swamp wallaby grass grows mostly in permanent wetlands with fluctuating water levels resulting in exposed mud flats/edges. Flowering occurs in spring to autumn (November to March).

Vivian et al. (2015) estimated that that only 182 hectares of grassy wetlands remained in Barmah Forest in 2015, with only 50 hectares of the monospecific swards that were a historically important part of the floodplain (Vivian 2013, Vivian et al. 2015). This represents only 12 per cent of the extent at the site since its Ramsar-listing and shows a continuing decline (Colloff et al. 2014).

Arial survey of Little Rushy Swamp in Barmah Forest is illustrated in Figure 11. This area of Little Rushy Swamp is managed as an exclusion zone from feral horses (note fence line/straight edge of the mapped area in the left of the image) clearly indicating the impacts of feral grazers on aquatic grasses.

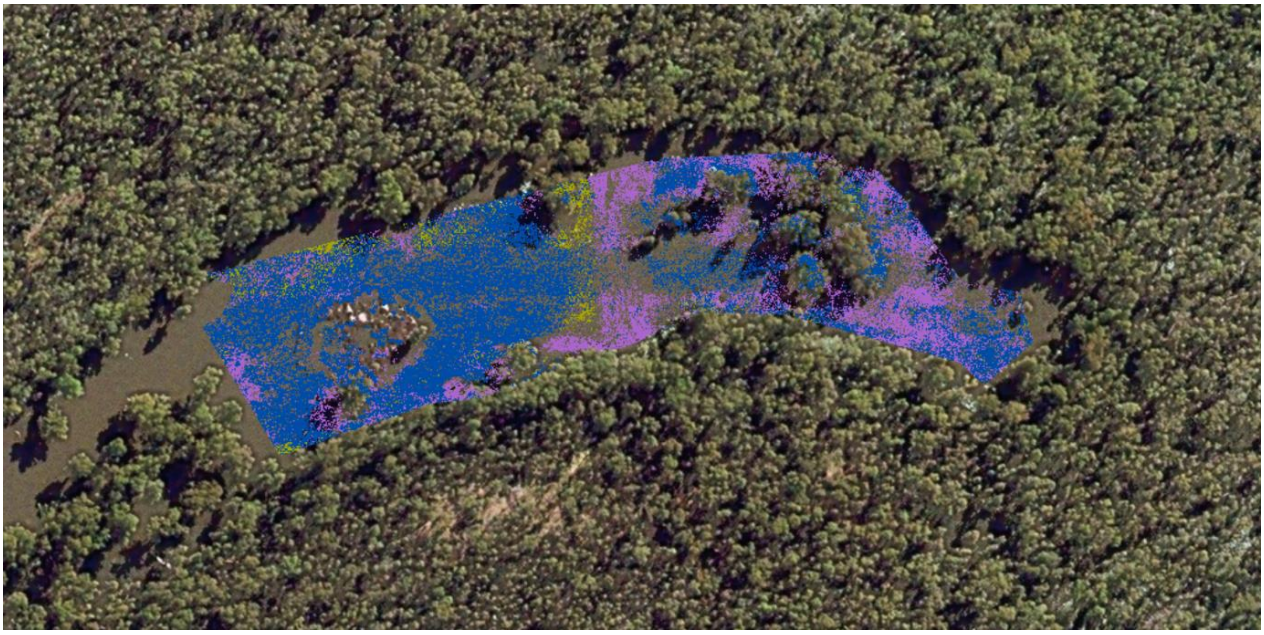


Figure 11. Aquatic grass classification map for Little Rushy Swamp on Google Earth map background. Note: Classes were defined based on a survey carried out in May 2018. Moira grass areas are represented in blue, swamp wallaby grass in dark yellow and other broadleaf species in purple (from Saurez et al. 2018).

5.2 Shared benefits

Barmah-Millewa Forest is an excellent example of a remnant floodplain forest ecosystem. The river red gum floodplain and waterways provide essential habitat and resources that support a diversity of native flora and fauna (e.g., Loyn et al. 2002, Goulburn Broken CMA 2015), including many threatened species. Such habitats are of high conservation value providing important refuges and hotspots for biodiversity.

Barmah-Millewa Forest also provides a range of cultural, social and economic benefits; these benefits are an integral consideration in the annual water delivery and management process.

Table 14. Social, recreational, and economic shared benefits of environmental water in 2023-24 (Goulburn Broken CMA 2023).

Waterway	Shared benefit	Beneficiary	Description
Murray River and distributary channels within Barmah-Millewa Forest	Economic	Consumptive water users – GMW irrigators and diverters	Environmental flows improve water quality, reduces blackwater risk and Blue Green Algal blooms which reduces the treatment costs for downstream urban water authorities and reduces operational risk. Water diversion through Barmah-Millewa Forest (when required for environmental purposes) can alleviate some Choke channel capacity constraints for downstream irrigation and urban water demands.
As above	Recreational Amenity	Broader community, local residents, visitors (day or camping), anglers, bird watchers, photographers, kayakers/canoers.	Environmental water improves vegetation and water quality and consequently provides an attractive area for day visitors and campers with enhanced active (e.g., fishing, boating) and passive (e.g., birdwatching) recreational pursuits. Environmental water improves the local environment and increases species richness in the riparian and floodplain area to retain or enhance natural assets that can be enjoyed by everyone and encourages community conservation and outdoor activities.
As above	Recreational Economic	Broader community Anglers	Using environmental water to provide fish spawning, migration, passage and habitat enhances native fish populations for recreational benefit. The benefits are extended to other waterways in the entire southern connected Murray Darling Basin.

5.2.1 Aboriginal values

The people of the Yorta Yorta and Bangerang Nations have an ongoing connection to Barmah-Millewa Forest. This is recognised in the partnership arrangements established within the Joint Management Plan For Barmah National Park (YYTOLMB 2020), which confirms the high value First Nations people place on restoring the habitat of the forest by reinstating a more natural flooding frequency.

- Sites of significance - burial mounds, scarred trees, artefact scatters, middens and hearths.
- Totemic species and associated story lines – particularly Dhungalla (Murray River) *Bayadherra* the broad-shelled turtle, *Burnanga* the Murray cod, *Borpa* the Murray spiny crayfish, *Nurnamamdatba* the kingfisher and *Gurranyin* the eagle.
- Food and resources – food (plants and animals) and other resources such as reed spears, fibre for nets, and bark for carrying vessels.

- Biodiversity values — the Aboriginal community understands and appreciates indicators of forest and river health, as the forest and waterways are part of Country;
- Ecological values — associated with wetlands, river red gum forest and open box ridges (black box).

The Murray River (*Dhungalla*) and the Barmah–Millewa forest provided year-round food stocks such as fish and yabbies, and the annual floods that spread through the forest allowed fish and turtles to breed, bringing nesting and wading birds in large numbers for months at a time. Kangaroos and emus grazed on the grassy plains that occur throughout the forest. River red gum forest and wetlands provided a rich place to live, with fuel for fires and wood for building shelters and making canoes, weapons and other implements. Water continued to flow in the creeks as the floods receded, gradually drying out as the summer and autumn seasons progressed. Aboriginal people camped throughout the forest and moved across all parts of it, hunting, gathering resources, and managing the vegetation and wildlife. The entire forest continues to be a very important place, not just the sites where cultural heritage artefacts of occupation occur. Water areas are as important as land areas. Most traditional food collecting activities and lifestyle was shaped by the waterways. Survival depended on water resources such as fish, crustaceans, freshwater mussels, turtles, cumbungi and the bird life that gravitates to the waters, particularly ducks and swans. Other resources such as reed spears, fibre for nets and bark for carrying vessels are water-based products (Atkinson 2002).

5.2.2 Recreational values

Barmah-Millewa Forest provides social value to the local community and broader public through recreational activities such as:

- Water-based recreation (such as boating, fishing, kayaking and canoeing)
- Riverside recreation and amenity (such as birdwatching, picnicking, photography, camping and the general physical, mental and social benefits of communing with nature)
- Community events and tourism (such as boat tours).

As an example of recreation value, Dyak et al. (2007) estimated (based on limited data) that recreational visits to Barmah-Millewa Forest had a non-market value of approximately $13 million (in 2007 dollars, assuming a trip value of $529 per adult visitor and 25,000 visits). Dyak et al. (2007) noted that the most important reason for visiting Barmah Forest was (in descending order):

1. Relaxing,
2. Catching up with friends,
3. Fishing,
4. Being close to water,
5. Having quality time with family,
6. Water activities,
7. Getting close to nature,
8. Good for my wellbeing,
9. Enjoying this part of the Murray River,
10. Outdoor activities,
11. Area offers best combination of activities,
12. Visiting special spots.

5.2.3 Economic values

Barmah-Millewa Forest is important economically, both to local communities and Victorians more generally. The surrounding agricultural land, along with tourism, is a major economic resource for the region (e.g., Goulburn Broken CMA 2015) and proximity to Barmah-Millewa Forest can positively affect land values (Tupsuwan et al. 2015). For example, the site is an integral part of the Murray River system that delivers water for consumptive use from Lake Hume to South Australia and sits adjacent to Goulburn-Murray Irrigation District in Victoria, which is often referred to as Victoria's food bowl and generates $5.9 billion worth of production a year (GMW 2016 cited in DELWP 2019).

5.3 Current ecological condition

5.3.1 Trajectory of change

The condition of Barmah-Millewa Forest, along with many other assets in the Murray-Darling Basin, has been in long-term decline in response to regulation of the Murray River and artificial changes to the floodplain (e.g., levees, blockages in waterways), and adverse land-use (cattle grazing, forestry, and pest plant and animals) (Gawne et al. 2011, Bond et al. 2021). There is strong evidence of a decline in ecosystem condition at Barmah-Millewa Forest, ranging from empirical scientific investigations to more broad condition monitoring and inferential studies pre the Millennium Drought (Gawne et al. 2011).

Murray River regulation

Regulation of the Murray River and changes to inflow points (e.g., blockages) has created drier conditions across Barmah-Millewa Forest, causing an overall shift towards more terrestrial vegetation types. Changes in extent to Moira grass plains, one of the most characteristic wetland types in the icon site, indicate a deteriorating trend in condition.

Altered water regimes is one of the potential causes of encroachment into Moira grass plains by giant rush and river red gum (Cooling et al 2019). Analyses of data pre 2000 indicate that incursion of giant rush and river red gum onto Moira grass wetlands/open plains in Barmah Forest were very large (Brown and Tolsma 2021). Results for the period 2003 to 2017 indicate a 7.3% loss (102 hectares across 35 sites) of surveyed wetlands to river red gum encroachment, with large sites sustaining larger changes. Giant rush encroachment was more variable with both increases and decreases observed between 2007 to 2017, with an overall decrease of 3.6% (10 hectares across 13 sites) mostly driven by a single wetland - Barmah Lake. Excluding Barmah Lake indicated a 6.8% increase in encroachment across the remaining wetlands (Brown and Tolsma 2021).

Current conditions

Wetland and tree canopy response following the extensive natural flooding and above average rainfall conditions are excellent and have supported very good waterbird breeding outcomes. Flooding in 2022 into 2023 prevented on ground field assessments, however aerial assessments and anecdotal information indicated the following (GBCMA 2023):

- Australasian bitterns were reported to delay nesting in response to the depth and duration of the recent floods (Znidersic and Towsey 2023).
- A significant hypoxic blackwater event occurred following the large-scale 2022 spring flood events with associated reports of fish deaths. Relatively large numbers of terrestrial fauna

(especially kangaroos and feral horses in Barmah) became stranded on unflooded islands are known to have perished during the floods.

- Approximately 2000 nests of Australian white Ibis and straw-necked ibis (and possibly royal spoonbill) occurred in several sub-colonies spread throughout Boals Deadwoods wetland in Barmah Forest, and approximately 1000 nests of the species in Reed Beds Swamp in Millewa Forest.
- A substantial size heron colony occurred on both sides of the river adjoining Picnic Point with numbers estimated to be similar to 2022.
- A reasonable size cormorant colony also developed at Harbours Lake in Barmah Forest, with numbers estimated to be similar to 2022, possibly larger.
- A strong response in Moira grass growth and flowering in flooded wetlands was observed where the species retains its presence. In Barmah Forest the best outcome for this species was in the six grazing-exclusion fenced sites. Feral horse grazing exclusion fencing erected by the Goulburn Broken CMA boosted the environmental gains achieved by the environmental watering on selected floodplain marshes by protecting the vegetation from extreme grazing impacts.
- Sampling turtle subpopulations in Barmah-Millewa Forest began in 2018-19, with early results from monitoring indicating sub-optimal health with average body condition, little evidence of recruitment, and a decline in most relative abundance metrics for two of the three species. The increase in relative abundance of eastern long-necked turtles indicates continued recovery for this species following the mass mortality event associated with the Millennium drought (Howard et al. 2021).
- Frog monitoring in 2020-21 revealed that breeding was 'fair', returning a score between 0.4-0.6 out of 1, but was highly variable across sites. Species richness across the entire icon site was classified as 'good'. The status of adult frogs for this survey season remains unclear as neural net analysis of frog recordings was a complex and lengthy process that generated a vast quantity of data. Preliminary interrogation of these data indicated that further consideration is required about how best to summarise the data and which calling metrics are useful.

Although the results from flooding events are in part encouraging, Barmah-Millewa Forest requires a more long-term reinstatement of a natural flooding regime, including relaxation of constraints, if its condition is to improve further. Complementary management interventions focusing on control of feral grazers and invasive species are required to ensure gains.

Continued encroachment of giant rush and river red gum into grassy wetlands

Altered water regimes at Barmah-Millewa Forest (see Section 4) have strongly influenced water-dependent vegetation across the site. Colloff et al. (2014) report that giant rush, *Juncus ingens*, was limited to around 1 hectare in 1945, expanding significantly post 1985 (Figure 12). Brown and Tolsma (2021) reported that in 2007 the total area of infestation across sampled wetlands was 285 ha, equivalent to 32% of the total wetland area in Barmah Forest. Various approaches to control have been undertaken with variable results dependent on the local conditions at each managed wetland. There has since been a significant decrease in giant rush at Barmah Lake (initially caused by an extreme flooding event in 2010), but other sites have increased in cover Brown and Tolsma 2021).

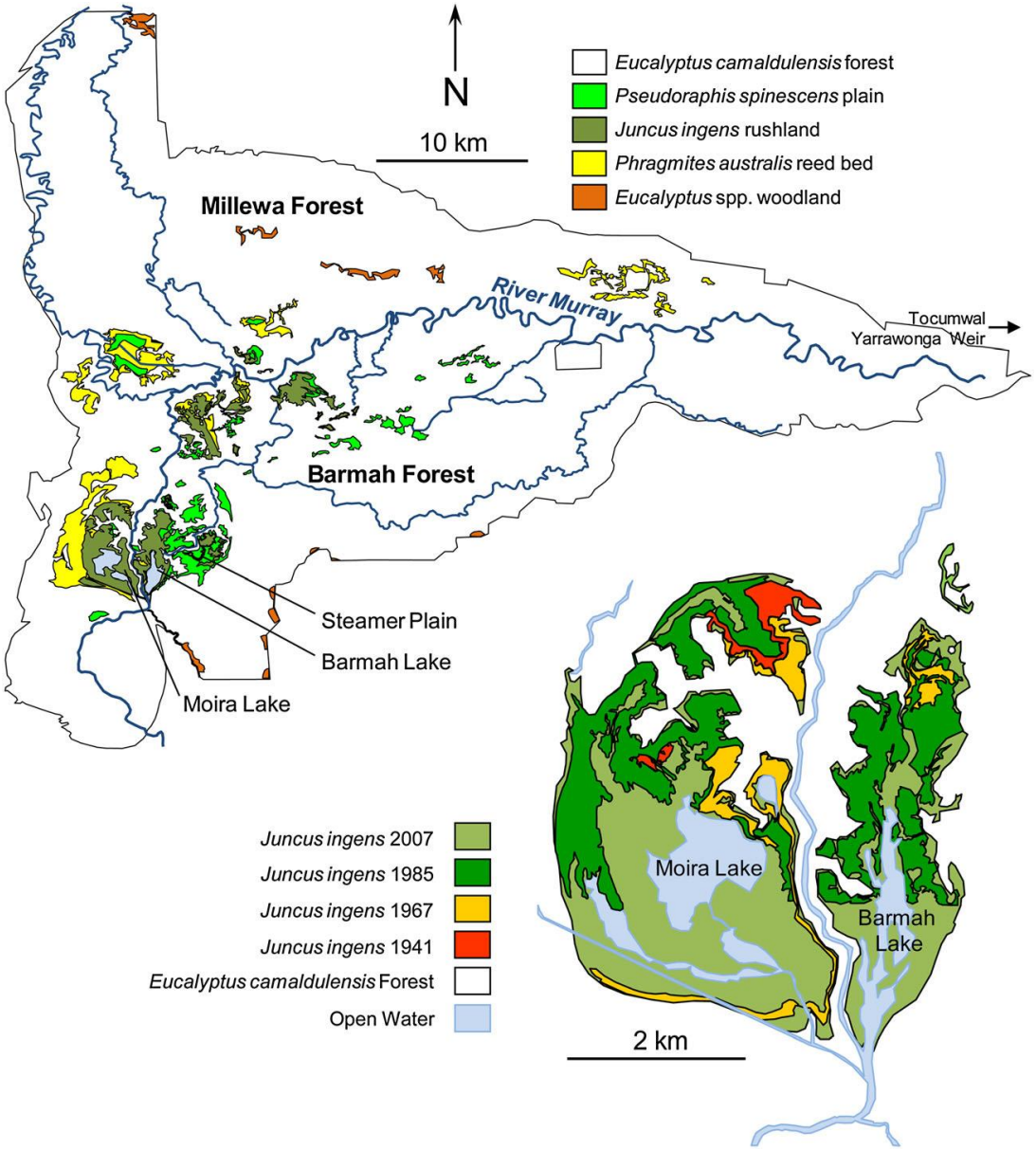


Figure 12. The distribution of dominant vegetation at Barmah–Millewa Forest. From Chesterfield (1986); Bowen (2005) and DPI (2009). Areas of vegetation in Barmah Forest: Moira grass *Pseudoraphis spinescens* plains 947 hectares (3.2%), giant rush *Juncus ingens* that was previously Moira grass 1106 hectares (3.7%), common reed Phragmites australis 131 hectares (0.4%). Percentages based on area estimate of 29 515 hectares (DSE, 2008). Inset: detail of Barmah and Moira Lakes, showing chrono sequence of infilling of Moira grass plains with *Juncus ingens*. From Colloff et al. (2014).

Saintilan et al. (2021) undertook time-series mapping of Barmah-Millewa Forest using detailed photogrammetry, supported by extensive ground survey to investigate response of non-woody aquatic vegetation to tree encroachment over multiple wet and dry periods. The results indicate that Moira grasslands have been declining since 1945 (when air photos first became available) with concurrent expansion of river red gum. River red gum extent did not decline with the Millennium Drought, with an 11% increase in river red gum extent in the western half of the Barmah-Millewa Forest and a 78%

decline in Moira grass in the period 1945-2010. There was no overall change in extent of river red gum as a result of the Millennium Drought, with both giant rush and *Typha* being more resistant to river red gum encroachment than the grass species.

Potential climate change impacts

As part of the 2020 Basin Plan Evaluation and the Victorian Floodplain Restoration Project, the MDBA assessed the vulnerability of ecosystem objectives to climate change (MDBA 2020c, MDBA 2022b). These assessments indicated that the likelihood of natural floodplain inundation is likely to further decrease as a result of plausible climate change outcomes. Example ecological consequences due to reduced flood frequency are presented below and summarised in Figure 13.

Changes in rainfall are likely to decrease the frequency of overbank and flood events and the magnitude, duration and seasonal timing of large flow events. Reduced lateral connectivity will have implications for floodplain species and change ecosystems functions such as food web productivity and nutrient, sediment and carbon cycling (including increases in blackwater events).

Reduced floodplain inundation may contribute to water quality issues as there is less capacity to flush salt and other pollutants from waterways. Reduced flows may also lead to low dissolved oxygen in thermally stratified waterbodies, increase the occurrence of blackwater events, and lead to more frequent algal blooms due to increases in temperature. More intensive rainfall events would increase erosion and surface runoff resulting in other water quality issues.

Vegetation communities adapted to a wetting and drying regime will be vulnerable to reduced rainfall and floodplain inundation. Reduced flooding may facilitate the encroachment of drought tolerant plant species (including mass germination of river red gums) into channels and open water areas. Saintilan et al. (2021) predict that further loss of grassy wetlands, such as the Moira grass and swamp wallaby grass systems in Barmah-Millewa.

Loss or changes to plant species and communities will affect the availability of habitat for water-dependent fauna and in turn food web structure.

Reduced floodplain inundation frequency and duration can also affect key life cycle components such as movement and migration, spawning and recruitment, and habitat quality and quantity. For example, there may be a loss of freshes that provide breeding and migration cues for native fish.

The ecological changes described above emphasise the need for managed inundation events to meet environmental objectives for Barmah-Millewa Forest.

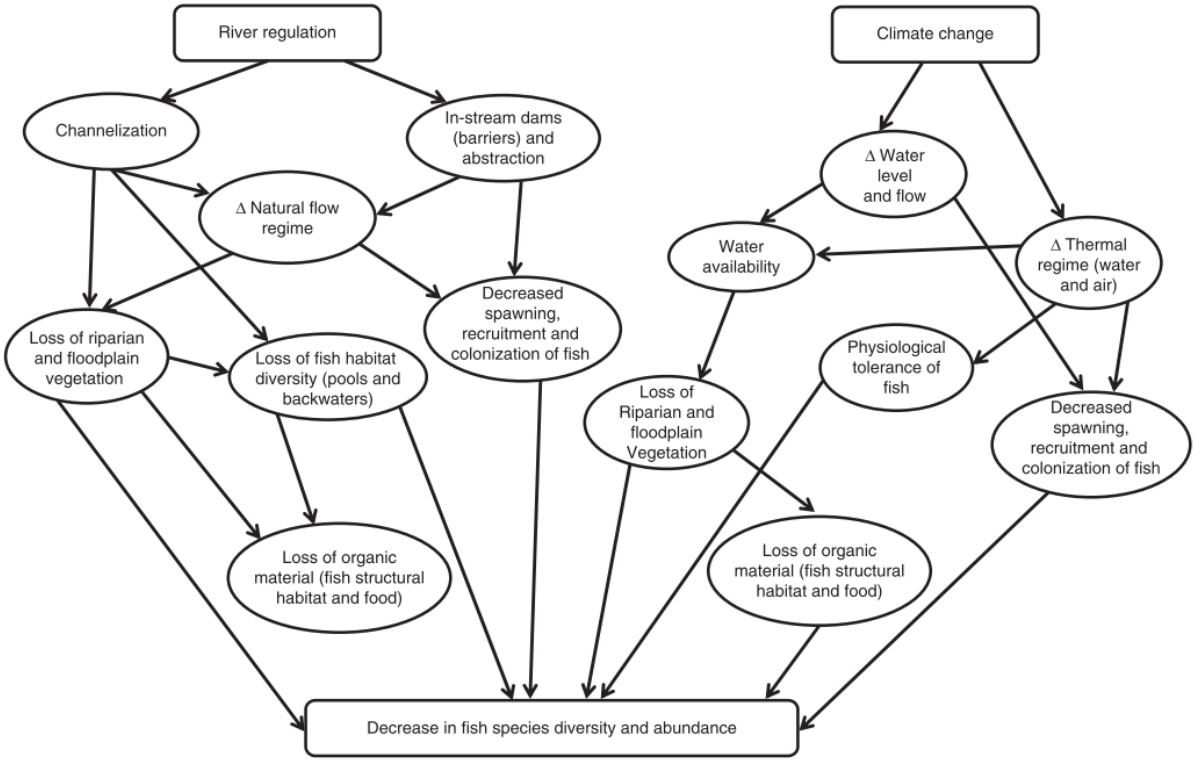


Figure 13: Conceptual model of possible impacts of river regulation and climate change on the abundance and diversity of native fish communities in the MDB (from Balcombe et al. 2011).

Indirect impacts from climate change are also likely to compound environmental changes in aquatic ecosystems. Indirect impacts include increased interception by farm dams, increased fire intensity and frequency, non-stationary dominant hydrological processes, land use changes in response to climate conditions, water quality issues such as algal blooms and hypoxic black water events, and pest animals and plants (Robertson et al. 2021).

6 Managing water related threats

Detailed ecological risk assessments have been undertaken for Barmah-Millewa Forest as part of Ramsar site ecological character descriptions and plans of management (e.g., Hale and Dickson 2020, Harrington and Hale 2011), and as part of the joint management plans (YYTOLMB 2020) and strategic action plans (Parks Victoria 2020).

6.1 High priority threats

Threats assessed as being extreme or high risk to environmental values (Appendix 2) include:

- Dams and water management/use (water resource use) resulting in altered water regimes:
    - reduced frequency and duration of floodplain inundation due to reduced Murray River inflows caused by increased frequency and severity of drought and climate change across the southern Murray-Darling Basin.
    - reduced frequency and duration of floodplain inundation due to reduced Murray River inflows caused by river regulation and consumptive water extraction.
- Invasive species that increase disturbance, predation or competition including:
    - grazing, foraging and damage caused by feral herbivores as well as incursions by invasive plants, that adversely affect ecologically important floodplain marshes and threatened vegetation species (e.g., Moira grass and swamp wallaby grass).
    - predation by foxes and cats on native animal species.
    - competition from alien fish species (e.g., carp, gambusia) that affect fish abundance and diversity, including threatened native fish such as Murray cod and silver perch.
- Modification of key vegetation communities:
    - Degradation of key vegetation communities, including reed bed wetlands, cypress pine sandhills, river red gum forests and black box woodlands, from the combined effects of river regulation, river flow constraints, drought/climate change, forestry operations and timber extraction, land clearing, wildfire, and high total grazing pressure.
- Climate change impacts leading to altered water regimes adversely affects:
    - floodplain marshes and threatened vegetation species.
    - wetland bird breeding and threatened waterbird species (Australasian bittern).
- Large-scale riverbank erosion along the Murray and Edward rivers:
    - Degradation of the natural levees and of Aboriginal sites and other cultural values.
    - Degradation of in-stream habitats and the aquatic foodweb.
    - Sedimentation across large areas of river red gum forest.
    - Adverse impacts to the ecological character of the Ramsar sites.
    - Adverse impacts to the hydrological function and ecological character of waterways and wetlands.

Of the threats listed above, grazing, foraging and predation by feral animals was considered an extreme risk to environmental values at Barmah-Millewa Forest, while inappropriate water regimes (due to water management/use and climate change), competition from alien fish species and incursions by invasive plant species were considered high risk.

Climate change is an emerging issue that can exacerbate other threats to environmental values, such as those listed above. In particular, shifting rainfall and runoff patterns in tributary catchments (e.g., Kiewa and Ovens) has led to reduced inflows to the Murray River (HARC 2021). This, along with increased air temperature, can increase consumptive water demand and reduce the amount of water available for the environment. As mentioned in Section 5.3.1, reduced floodplain inundation frequency and duration predicted to occur with climate change (MDBA 2021) has the potential to exacerbate the impact of the threats listed above.

6.2 Management actions

The various Ramsar site and other management plans relevant to Barmah-Millewa Forest (Hale and Dickson 2020, YYTOLMB 2020, Parks Victoria 2020) include a suite of activities to address the high priority threats, including by:

- Managing water regimes;
- Protecting flora and fauna;
- Improving our understanding and knowledge base;
- Programs of communication, education, participation and awareness (CEPA).

For example, the Barmah Ramsar site management plan (Hale and Dickson 2020) includes a series of management activities linked to implementation responsibilities and complementary programs to address high priority threats (Table 15). It is expected that the implementation of existing programs will continue to manage priority threats in both Barmah and Millewa Forests.

Table 15. Management activities to address threatening processes occurring at the Barmah Forest Ramsar site (Hale and Dickson 2020).

Management activity	Responsibility (lead agency indicated in bold)	Linkages to existing programs/activities
1. Managing water regimes		
1.1 Continue to develop and implement watering proposals for environmental watering to maintain the ecological character of the Ramsar site.	**Goulburn Broken CMA,** VEWH, Parks Victoria	Barmah Seasonal Watering Proposals, Barmah-Millewa Environmental Watering Plan
1.2 Work with partner agencies to remove barriers to the passage of native fish, turtles and other aquatic species in waterways of the Ramsar site	Yorta Yorta, Parks Victoria, Goulburn–Murray Water, **MDBA, Goulburn Broken CMA**	Joint Management Plan
1.3 Work with partner agencies to identify opportunities and options for managing environmental water in a changing climate.	**MDBA**, VEWH, Goulburn Broken CMA, Parks Victoria	Barmah Seasonal Watering Proposals, Barmah-Millewa Environmental Watering Plan
2. Protecting flora and fauna		

Management activity	Responsibility (lead agency indicated in bold)	Linkages to existing programs/activities
2.1 Implement actions in the Parks Victoria Strategic Action Plan: Protection of Floodplain Marshes in Barmah National Park and Barmah Forest Ramsar Site aimed at reducing the population of feral horses from the Ramsar Site.	**Parks Victoria**, Yorta Yorta, Goulburn Broken CMA	Parks Victoria Strategic Action Plan: Protection of Floodplain Marshes in Barmah National Park and Barmah Forest Ramsar Site
2.2 Implement actions in the Parks Victoria Strategic Action Plan: Protection of Floodplain Marshes in Barmah National Park and Barmah Forest Ramsar Site aimed at controlling other pest grazing species (feral deer, goats, pigs, sheep, rabbits)	**Parks Victoria**, Yorta Yorta, Goulburn Broken CMA	Parks Victoria Strategic Action Plan: Protection of Floodplain Marshes in Barmah National Park and Barmah Forest Ramsar Site
2.3 Continue to protect remaining areas of floodplain marsh vegetation and trial methods to re-establish Moira grass in suitable habitats.	**Goulburn Broken CMA**, Parks Victoria, Yorta Yorta, DEECA	Parks Victoria Strategic Action Plan: Protection of Floodplain Marshes in Barmah National Park and Barmah Forest Ramsar Site
2.4 Continue pig and fox control programs and trial feral cat control in the Ramsar site particularly at sites where waterbirds are vulnerable.	**Parks Victoria**, Yorta Yorta, Goulburn Broken CMA	Parks Victoria Strategic Action Plan: Protection of Floodplain Marshes in Barmah National Park and Barmah Forest Ramsar Site
2.5 Identify options to reduce exotic fish populations within the Ramsar Site.	**DEECA**, Goulburn Broken CMA	
2.6 Implement actions in the Parks Victoria Strategic Action Plan: Protection of Floodplain Marshes in Barmah National Park and Barmah Forest Ramsar Site aimed at controlling invasive native plant species (giant rush and river red gum) and exotic wetland weeds.	**Parks Victoria**, Yorta Yorta, Goulburn Broken CMA	Parks Victoria Strategic Action Plan: Protection of Floodplain Marshes in Barmah National Park and Barmah Forest Ramsar Site
2.7 Implement measures identified in the Draft Joint Management Plan for Barmah National Park aimed at protecting potential nest trees for superb parrot are protected from damage and disturbance.	**Yorta Yorta**, Parks Victoria, **Goulburn Broken CMA**	Draft Joint Management Plan for Barmah National Park
2.8 Implement Barmah NP Ramsar Site PPA Strategy	**Parks Victoria, Goulburn Broken CMA, Yorta Yorta**	PPA Strategy
3. Improving our understanding		
3.1 Investigate options to minimise or mitigate the effects of future blackwater events.	**MDBA**, VEWH, Goulburn Broken CMA	
3.2 Investigate options to increase the extent and condition of Moira grass.	Parks Victoria, **Goulburn Broken CMA**, DEECA	Threatened species recovery plans

Management activity	Responsibility (lead agency indicated in bold)	Linkages to existing programs/activities
3.3 Investigate options to increase populations of threatened plant species, including establishing ex-situ seed orchards. 3.4 Continue research into relationships between flood regimes, vegetation dynamics and fauna responses.	Parks Victoria, **Goulburn Broken CMA**, DEECA	Threatened species recovery plans
4. Communication, Education, Participation and Awareness (CEPA)		
4.1 Work closely with Yorta Yorta to protect Country and sites of cultural significance.	Goulburn Broken CMA, Parks Victoria, **Yorta Yorta**, DEECA	Joint Management Plan for Barmah National Park
4.2 Develop and implement a Barmah Forest Ramsar site wetland information and interpretation program.	Goulburn Broken CMA, Parks Victoria, **Yorta Yorta**, DEECA	
4.3 Build capacity and collaboration with community and industry groups by supporting citizen science and on-ground community action in Ramsar site management.	Goulburn Broken CMA, Parks Victoria, **Yorta Yorta**, DEECA	Joint Management Plan for Barmah National Park
4.4 Manage Park use and visitor access to minimise damage to vegetation, particularly floodplain marshes and reduce disturbance to waterbirds.	Parks Victoria**, Yorta Yorta**	Joint Management Plan for Barmah National Park

7 Management goals, objectives, and targets

7.1 Management goal

In 2001, the Murray Darling Ministerial Council established the Living Murray program (including Barmah-Millewa Forest) to maintain:

A healthy River Murray system, sustaining communities and preserving unique values.

A series of ecological objectives and targets have since been developed for Barmah-Millewa Forest that represent the desired ecological outcomes of an improved environmental watering regime. These are presented in the following sections.

Key documents which reference environmental objectives and flow recommendations for Barmah-Millewa Forest include (Goulburn Broken CMA 2022):

- Barmah-Millewa Environmental Water Management Plan (MDBA 2012),
- Barmah-Millewa Ecological Operating Strategy (Goulburn Broken CMA 2015),
- Barmah Forest Strategic Action Plan (Parks Victoria 2018) and Extension (Parks Victoria 2023),
- Joint Management Plan for Barmah National Park (YYTOLMB 2020).

The Victorian Murray LTWP management goals are specified as (DEWLP 2021c):

- Maintain or improve populations of threatened species and communities that are dependent upon waterways and wetlands in the region.
- Improve lateral connectivity and enhance floodplain productivity.
- Restore and maintain a mosaic of healthy floodplain communities across the region which will ensure that indigenous plant and animal species and communities survive and flourish throughout the site.
- Create and maintain a range of wetland types, with water regimes that vary from permanently inundated through to occasionally inundated.

The NSW Murray-Lower Darling LTWP has specified objectives for the following themes, consistent with the BWS (DPIE 2020a):

- Native vegetation,
- Waterbirds,
- Native fish,
- Ecosystem functions, and
- Other species.

7.2 Regional significance

The values and importance of the Barmah-Millewa Forest icon site at a Murray-Darling Basin and regional landscape scale are detailed in previous sections, in particular Section 3 and Section 5. The Murray River, with its floodplain, wetland and forest systems, forms a unique environment with outstanding ecological values. The floodplain is home to many rare and endangered species and

internationally significant wetlands, is a biodiversity hotspot for a diverse range of animals and provides vital refuge during extreme drought.

7.3 Environmental objectives and targets

A hierarchical approach that aligns objectives and targets of the Barmah-Millewa Forest icon site to the Environmental Watering Plan (Chapter 8, Commonwealth of Australia 2012) of the Basin Plan has been adopted (Butcher 2022). Detailed objectives and associated targets have been aligned to the Basin-wide Environmental Watering Strategy and Victorian Murray Long Term Watering Plan where appropriate, and support achievement of the outcome specified in the overarching objective (Appendix 3). SMART criteria were also applied, as well as terminology consistent with the Basin Plan. This has increased the line of sight of objectives and targets for Barmah-Millewa Forest to the Basin Plan and associated reporting requirements. Targets are not presented for the overarching objectives as the detailed objectives and associated targets should be designed to achieve the general outcome specified in the overarching objectives[7]. The overall logic for formulating objectives and targets is summarised in Figure 14.

The overarching objectives for the icon site are (MDBA 2012):

- Restore the extent and distribution of healthy wetland and floodplain vegetation communities.
- Provide suitable feeding and breeding habitat for a range of waterbirds, including colonial nesting species.
- Support successful breeding and recruitment of native fish species.
- Provide high quality feeding, breeding and nursery habitat for native frogs, turtles and crayfish.

The detailed objectives and targets (Table 17 to Table 24) specify an achievement by 2033, reflecting the 10 year cycle of review for EWMPS (DEWLP 2022).

[7] Noting that the overarching objectives were not written to be quantitatively measured.

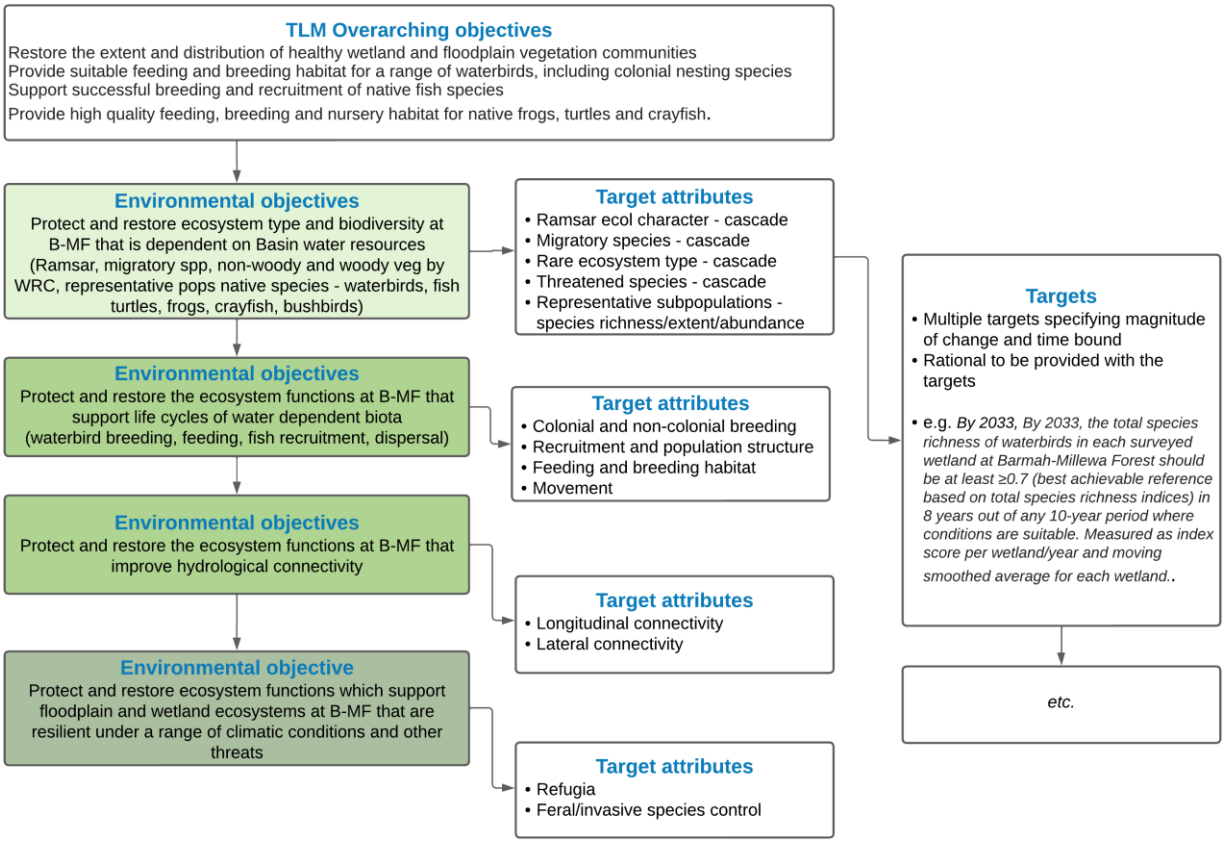


Figure 14. Objective logic adopted for the Barmah-Millewa Forest EWMP.

7.3.1 Ecosystem and biodiversity objectives and targets

The majority of the ecosystem and biodiversity objectives relate to the condition of the icon site. These objectives relate to priority environmental asset criteria for the maintenance of the ecological character of the Ramsar sites, supporting migratory species and representative ecosystem types and supporting representative subpopulations of water-dependent biota (see Table 16 to Table 18). Cascading outcomes are those which will be achieved by meeting the objectives and targets for other values. Cascading outcomes are not directly monitored. Where multiple targets are set for an objective, they are either required to all be met (indicated with an AND) or only one is needed to be met (indicated with an OR).

Table 16: Objectives and associated targets for biodiversity outcomes.

Mapping element	Description
BMF1_2023 environmental objective	Contribute to the maintenance of the ecological character of the Barmah Forest and Central Murray Ramsar sites.
BMF1_2023 target	No target as cascading outcome achieved by other objectives for ecosystem type and biodiversity. Relevant objectives which will contribute to the maintenance of the ecological character of the Ramsar site include BMF5_2023, BMF6_2023, BMF7_2023, BMF8_2023 and BMF10_2023.
BMF2_2023 environmental objective	Continue to support key life cycle stages for migratory waterbirds listed under international treaties.
BMF2_2023 target	No target as cascading outcome achieved by other objectives for ecosystem type and biodiversity – see BMF5_2023 which will support habitat outcomes for migratory species.
BMF3_2023 environmental objective	A positive trajectory in the condition of representative ecosystem types (i.e., Water Regime Classes/ANAE) at Barmah-Millewa Forest by 2033.
BMF3_2023 target	No target specified – cascading outcome achieved by meeting objectives BMF5_2023, BMF6_2023.
BMF4_2023 environmental objective	By 2033, maintain the presence of threatened water-dependent species that are recorded on a regular basis at Barmah-Millewa Forest icon site.
BMF4_2023 target	No target as cascading outcome achieved by other objectives for ecosystem type and biodiversity. Relevant objectives which will contribute to supporting threatened species include BMF5_2023, BMF6_2023, and BMF7_2023. See Table 7 and Table 8 for listed threatened species that occur at Barmah-Millewa Forest icon site.

Table 17: Objective and associated targets for water-dependent native vegetation outcomes.

Mapping element	Description
BMF5_2023 environmental objective	By 2033, a positive trajectory in the condition of native non-woody aquatic vegetation in permanent river and creek, temporary river and creek, temporary marsh and permanent lake WRCs at Barmah-Millewa Forest.
BMF5_2023 targets	**Condition** By 2033, improve the condition of non-woody wetland vegetation at Barmah-Millewa Forest measured as increased number of sites within each WRC (>20%) in compliance with all indices as detailed in Robinson (2018a, b) including: • Native species richness. • Total cover. • Native cover. Permanent creeks include Gulpa Creek and Budgee Creek in Barmah, Gulpa Creek in Millewa. Temporary creeks include Toupna Creek and Towrong Creek in Millewa. Temporary marshes include Harbours Lake and Steamer Plain in Barmah, Duck Hole Plain and Algabohnyah Plain in Millewa. Permanent lakes include Barmah Lake and Millewa Lake. **Extent** By 2033, increase the extent of open water and non-woody wetland vegetation in Millewa Forest measured as increased area of Phragmites by 15% compared to 2020 baseline. • Relevant areas for monitoring include: Moira Forest, including the Moira-Sheldrakes area, and remnants of Algabonhya and Porters plains, Millewa Forest west from James Swamp to the Edward River, and along the Towrong Creek from where the creek re-enters the forest from Dudley's and becomes a braided system to the Edward River, and including the area of forest along the Edward River where the Geraphna Creek and Winter creeks return flows from the Cornalla to the Edward River.
BMF6_2023 environmental objective	A positive trajectory in condition of native woody vegetation associated with river red gum forest and woodlands and box woodlands WRCs at Barmah-Millewa Forest by 2033.

Mapping element	Description
BMF6_2023 targets	**River red gum tree condition and recruitment** By 2033 a positive trajectory in condition of 20% in woody vegetation at 80% of sites assessed. OR By 2033 a positive trajectory of >35% over any 5-year rolling period in condition status (as per Cunningham et al. 2009) of closely fringing river channels. AND By 2033 at least two recruitment events where germination and seedling establishment are sustained in Millewa Forest. AND **River red gum understorey condition** By 2033, a positive trajectory in condition in understory vegetation in floodplain river red gum forest, floodplain river red gum woodland and temporary swamp Water Resource Class sites measured as compliance with indices as detailed Robinson 2018. • Characteristic Plant Functional Group species richness for each WRC. • Characteristic Plant Functional Group species cover for each WRC. Condition of plant functional groups at 70% of the monitored sites measured by: • native species richness. • native species cover/abundance. Understorey condition is measured at 11 sites including (Arcadis 2021): Barmah Forest: Boal's Deadwoods, Top Island (Burnt), Top Island (Original), Little Rushy Swamp, Top Lake, Steamer Plain. Millewa Forest: Walthours Lagoon, Reed Beds Swamp, Black Gate Lagoon, Duck Lagoon, Algeboia Plain.

Table 18: Objective and associated targets for restoration of representative subpopulations of water-dependent biota.

Mapping element	Description
BMF7_2023 environmental objective	Restore representative subpopulations of native water dependent biota at Barmah-Millewa Forest, by 2033.
BMF7_2023 targets	**Plants:** By 2033 increase the extent (cover) of Category 1 Moira grass swards at six key wetland sites in Barmah-Millewa Forest by 30% compared to 2014 (approximately 28ha). Sites to be assessed as per Vivian et al. (2015). • Category 1 is defined as a distinct patch, or sward, of *P. spinescens*, with a relatively clear boundary. *P. spinescens* is the dominant (often only) species in the patch (Vivian et al. 2015). • Extent in 2014 of all Moira grass assessed at 31 lakes and treeless plains was approximately 1460 ha using 2012 aerial imagery. • Extent of Category 1 Moira grass at six sites was approximately 28ha, with most found at Steamer Plain. • Six key wetlands included: Steamer Plain, Bucks Lake, Harbours Lake, Hut Lake, Top Lake and Little Rushy Swamp. **Waterbirds:** By 2033, the total species richness of waterbirds in each surveyed wetland at Barmah-Millewa Forest should be at least ≥0.7 (best achievable reference based on total species richness indices to be developed as per Robinson 2018) in 8 years out of any 10-year period where conditions are suitable. Measured as index score per wetland/year and moving smoothed average for each wetland. AND By 2030, average total species richness for waterbirds at Barmah-Millewa Forest ≥0.8 in 8 years out of any 10-year period. Measured as moving smoothed average across all seasons by wetland (see Robinson 2018c). OR By 2033, maintain a 5-year rolling average of 23 or more waterbird species across all sites assessed within Barmah-Millewa Forest with all functional groups represented. **Fish:** By 2033, fish populations in permanent and temporary river and creek WRCs at Barmah-Millewa Forest will be composed predominantly of native fish as measured by abundance, biomass and species (see Robinson 2015, Raymond et al. 2020). *Population indices*

Mapping element	Description
	• The proportion of fish abundance that is native. • The proportion of fish biomass that is native (average of site scores). • The proportion of fish species that is native. AND By 2033, positive trajectory in native fish communities of permanent and temporary river WRC across the whole Barmah-Millewa Forest measured as number of native species, large bodied fish and extent of occurrence (see Robinson 2015, Raymond 2020). *Community indices* • The expected number of historic native species collected. • The number of large-bodied native fish above or below length at maturity. • Extent, the number of sites each native species is detected in. **Turtles:** By 2033, maintain the condition of broad-shelled turtle (*Chelodina expansa*), snake-necked turtle (*Chelodina longicollis*) and Murray River turtle (*Emydura macquarii*) subpopulations at Barmah-Millewa Forest measured by the following (from Howard et al. 2021): *Recruitment metrics* • Proportion of inhabited sites with juvenile turtle detections. • Proportion of sub-adult turtles compared to historical levels (species-specific). *Relative abundance metrics* • Mean CPUE (catch-per-unit-effort) per site. • Mean CPUE per site per species. • Mean CPUE per species per habitat type and water permanence. *Distribution metrics* • Species occurrence at sites over time. *Body condition metric* • Mean body condition per species per year.

Mapping element	Description
	Note that post 2023-24 sampling undertake a refinement of metrics and update targets to specify a magnitude of change. **Frogs:** By 2033, maintain presence of common native frog species at Barmah-Millewa Forest in 50-75% of survey sites annually. Species include Peron's tree frog (*Litoria peroni*), Eastern banjo frog (*Limnodynastes dumerilii*), barking marsh frog (*L. fletcheri*), spotted marsh frog (*L. tasmaniensis*), plains froglet (*Crinia parinsignifera*) and the common froglet (*C. signifera*). Sampling design for monitoring to be refined to account for different life history traits. OR By 2033, maintain subpopulations of common native frog species at Barmah-Millewa Forest measured as per Howard et al. 2021). Species include Peron's tree frog (*Litoria peroni*), Eastern banjo frog (*Limnodynastes dumerilii*), barking marsh frog (*L. fletcheri*), spotted marsh frog (*L. tasmaniensis*), plains froglet (*Crinia parinsignifera*) and the common froglet (*C. signifera*). Sampling design for monitoring to be refined to account for different life history traits. Metrics are (from Howard et al. 2021): *Community composition* • Community composition, overall. *Community composition, pooled site average* • Relative abundance. • Calling activity over time, all sites (not reported this year). • Calling activity, per site (not reported this year). Recruitment metrics are used to assess breeding objective – see BMF11_2023 **Crayfish:** By 2033, positive trajectory in condition of the subpopulation of Murray spiny crayfish in riverine WRC at Barmah-Millewa Forest measured as per Raymond et al. (2017, 2020) including: • yield an Index of Abundance (IOA). • subpopulation sex-ratios. • subpopulation size structure. **Woodland birds:**

Mapping element	Description
	Maintain species richness of woodland birds at Barmah-Millewa icon site to average more than 75% of best achievable point of reference assessed every 3-5 years (see Tzaros and Tzaros 2022): • Total species richness – seasonal and annual. • Victorian Woodland Bird Community species richness. • Tree hollow using species. • Dietary guilds. Monitoring to occur at 20 sites across four habitat types as described in Tzaros and Tzaros (2022). Woodland bird species as per Tzaros and Tzaros (2022).

7.3.2 Ecosystem function

In previous versions of the objectives for condition monitoring in TLM icon sites the objectives were listed in themes relating to groups of biota (i.e., vegetation, waterbirds, fish, other fauna). To improve line of sight to the Basin Plan the objectives and associated targets in this updated EWMP are grouped according to the functions that are supported by environmental watering and include supporting breeding, feeding and connectivity.

Table 19: Objective and target for ecosystem functions that support populations - waterbird breeding and feeding.

Mapping element	Description
BMF8_2023 environmental objective	By 2033, regularly support waterfowl breeding and small-scale colonial breeding events at Barmah-Millewa Forest icon site.
BMF8_2023 targets	By 2033, maintain successful waterfowl breeding in 9 out of 10 years. AND By 2033, support small scale colonial breeding events in 3 out of 10 years when suitable conditions are present. • Key sites for Millewa are (Borrell 2018): ○ St Helena Swamp, Reed Beds wetland complex (North and South), Picnic Point (not on park), War Plain and Boals

Mapping element	Description
	Deadwood. • Colonial nesting species may include (from Borrell 2018): ○ Australian white ibis *Threskiornis molucca*; ○ Royal spoonbill *Platalea regia*; ○ Eastern great egret *Ardea modesta*; ○ Intermediate egret *Ardea intermedia*; ○ Nankeen night heron *Nycticorax caledonicus*; ○ Little black cormorant *Phalacrocorax sulcirostris*; ○ Little pied cormorant *Microcarbo melanoleucos*; ○ Australasian darter *Anhinga novaehollandiae*.
BMF9_2023 environmental objective	By 2033, maintain or increase representative species richness of shallow-water and deep-water feeding guilds of waterbird (F2 and F3, respectively, after Jaensch 2002) at Barmah-Millewa Forest.
BMF9_2023 targets	By 2033, functional guild richness at individual wetlands (F2 and F3 feeding guilds, Jaensch 2002) of waterbirds at Barmah-Millewa Forest ≥0.5 in 8 years out of any 10-year period (where conditions are suitable). Measured as index score per wetland/year and moving smoothed average for each wetland. • Representative F2 species include Pacific black duck (*Anas superciliosa*), white-faced heron (E*gretta novaehollandiae)*, yellow-billed spoonbill (*Platalea flavipes*), Australasian shoveler (*Anas rhynchotis*), black swan (*Cygnus atratus*), Australasian grebe (*Tachybaptus novaehollandiae*), • Representative F3 species include Australian pelican (*Pelecanus conspicillatus*), great cormorant (*Phalacrocorax carbo*), little black cormorant (*Phalacrocorax sulcirostris*), white-bellied sea eagle (*Haliaeetus leucogaster*), black swan (*Cygnus atratus*), Pacific black duck (*Anas superciliosa*), Australasian grebe (*Tachybaptus novaehollandiae*). AND By 2030, average function guild species richness (F2 and F3 feeding guilds, Jaensch 2002) of waterbirds at Barmah-Millewa Forest ≥0.7 in 8 years out of any 10-year period where conditions are suitable. Measured as moving smoothed average across all wetlands. Monitoring sites are (NSW National Parks and Wildlife Service 2021): Barmah Forest: Pig Hole, Steamer Plain, Barmah Lake, Goose Swamp, Bunyip Hole, Top Island, Boals Deadwood. Murray Valley National Park (precinct): Horseshoe Lagoon (Gulpa Is), Reed Beds Nort (Moira), Reed Beds South (Moira), Duck Lagoon (Moira), Moira Lake (Moira) and St Helena Swamp (Millewa).

Table 20: Objective and associated targets for ecosystem functions that support populations – fish recruitment.

Mapping element	Description
BMF10_2023 environmental objective	By 2033 support successful breeding and recruitment of native fish across the whole Barmah-Millewa Forest in permanent and temporary riverine WRCs.
BMF10_2023 targets	By 2033, support recruitment in permanent and temporary river WRC at Barmah-Millewa Forest (see Robinson 2015, Raymond et al. 2020) including: • Large bodied species: Murray cod, trout cod, golden perch, and silver perch to facilitate subpopulation expansion. • Small bodied species: Murray rainbowfish, flat-headed gudgeon, un-specked hardyhead, Australian smelt and carp gudgeons. *Recruitment as per Robinson 2015, Raymond et al. 2020)* • The number of sites with recruits. • The number of species with recruits. • The number of recruits as a proportion of subpopulation.

Table 21: Objective and associated targets for ecosystem functions that support populations – other fauna recruitment/breeding.

Mapping element	Description
BMF11_2023 environmental objective	By 2033 support successful breeding and recruitment of frogs at Barmah-Millewa Forest.
BMF11_2023 targets	By 2033, maintain subpopulations of common native frog species at Barmah-Millewa Forest measured as per Howard et al. (2021). Target species include Peron's tree frog (*Litoria peroni*), Eastern banjo frog (*Limnodynastes dumerilii*), barking marsh frog (*L. fletcheri*), spotted marsh frog (*L. tasmaniensis*), plains froglet (*Crinia parinsignifera*) and the common froglet (*C. signifera*). Sampling design for monitoring to be refined to account for different life history traits. Metrics are (from Howard et al. 2021): *Recruitment metrics* • Evidence of breeding, overall.

	• Evidence of breeding, species per habitat type. • Relative abundance of recruits – CPUE, all sites pooled. • Relative abundance of recruits – CPUE, per site.

Table 22: Objective and associated targets for ecosystem functions that support populations – connectivity/dispersal

Mapping element	Description
BMF12_2023 environmental objective	By 2033, support access to habitat for small bodied fish and movement of large bodied riverine native fish by ensuring that flow sequences, and inundation and recession events, meet ecological requirements of key species in Barmah-Millewa Forest.
BMF12_2023 targets	**Small bodied fish – off channel species**: No target as cascading outcome achieved by other objectives for ecosystem type and biodiversity, and ecosystem function. Relevant objectives which will contribute to cascading outcome include BMF7_2023, BMF5_2023, BMF6_2023, BMF10_2023. **Large bodied fish movement:** No target as cascading outcome achieved by other objectives for ecosystem type and biodiversity, and ecosystem function. Relevant objectives which will contribute to cascading outcome include BMF7_2023, BMF5_2023, BMF6_2023, BMF10_2023.

7.3.3 Ecosystem resilience under climate change and other threats

Table 23: Objective and associated targets for resilience against climate change and extreme dry periods – provision of refugia

Mapping element	Description
BMF13_2023 environmental objective	By 2033, regularly provide refugia to support the long-term survival of water-dependent biota on the managed floodplain of the Barmah-Millewa Forest icon site and Gulpa Creek during drought.
BMF13_2023 targets	By 2033, maintain permanent water refugia in Gulpa Creek, Moira Lake, Reed Beds Swamp and Duck Lagoon during periods of regional drought (i.e., serious rainfall deficiency).

Table 24: Objective and associated targets for resilience and mitigation of human induced threats – invasive and feral species control

Mapping element	Description
BMF14_2023 environmental objective	By 2033, mitigate the impact of invasive species and feral animals on floodplain and wetland ecosystems and native water-dependent species at Barmah-Millewa Forest icon site.
BMF14_2023 targets	**Feral Horses:** Cascading outcome reliant of current Pest Plant and Animal management activities as per Parks Victoria (2020) and YYTOLMB (2020) **Pigs and other feral herbivores:** Cascading outcome reliant of current Pest Plant and Animal management activities as per Parks Victoria (2020). **Invasive natives:** By 2033, reduce encroachment of invasive native flora species (giant rush and river red gum) by 20% at nominated sites to support Moira grass recovery. AND Control arrowhead invasion at nominated sites by 80% to support Moira grass recovery (Parks Victoria 2020).

8 Environmental water requirements and intended water regime

8.1 Watering requirements and intended watering regimes

The environmental watering regimes presented in Table 25 and Table 26 have been derived from the environmental objectives identified in Chapter 7 and WRCs identified in Section 3.3.5. To allow for adaptive and integrated management, the watering regimes have been framed using the seasonally adaptive approach used for water planning by the VEWH (e.g., VEWH 2021), which identifies the watering that will likely occur under a given set of climatic conditions (dry through to wet). This approach has been linked to the WRCs included in Table 25, which are those likely to receive water depending on water availability (i.e., there is likely to be less water available during droughts than during wet periods).

Due to the inter-annual variability of these estimates (particularly the climatic conditions), determination of the predicted volume requirements in any given year will need to be undertaken by the environmental water manager when watering is planned.

Table 25: Target water regime class in response to climatic conditions. Note: there may be variation in the WRCs actually watered in given year, depending on factors such as sharing arrangements for the Barmah-Millewa EWA.

Dry/drought	Median	Wet
Permanent rivers and creeks	Permanent rivers and creeks	Permanent rivers and creeks
Temporary rivers and creeks	Temporary rivers and creeks	Temporary rivers and creeks
Sedge/forb/grass floodplain	Sedge/forb/grass floodplain	Sedge/forb/grass floodplain
Permanent marsh	River red gum floodplain forest	River red gum floodplain forest
Permanent lakes	River red gum floodplain woodland	River red gum floodplain woodland
	Permanent marsh	Box floodplain woodlands
	Temporary swamps	Permanent marsh
	Temporary marshes	Temporary swamps
	Permanent lakes	Temporary marshes
	Temporary lakes	Permanent lakes
		Temporary lakes

Table 26: Barmah-Millewa Forest watering regimes (adapted from MDBA 2012 and Goulburn Broken CMA 2015 and Cooling et al. 2019).

Objective	WRC	Events per 10 years	Maximum interval between events	Duration of events (months)	Timing	Depth	Equivalent Murray River flow threshold (ML/d)
BMF1_2023 (maintain ecological character)	Cascading outcome: see watering requirements for BMF5_2023, BMF6_2023, BMF7_2023, BMF8_2023 and BMF10_2023.						
BMF2_2023 (support key life cycle stages for migratory waterbirds)	Cascading outcome: see watering requirements for BMF5_2023.						
BMF3_2023 (improve condition of representative ecosystem types)	Cascading outcome: see watering requirements for BMF5_2023 and BMF6_2023.						
BMF4_2023 (maintain threatened water-dependent species)	Cascading outcome: see watering requirements for BMF5_2023, BMF6_2023 and BMF7_2023.						
BMF5_2023 (improve condition of native non-woody aquatic vegetation)	**Permanent rivers and creeks**	9 in 10	1 year	9-12	Winter-spring	Not critical	Up to 10,400 ML/d
	Temporary marshes	6-10 in 10	3 years	5-9	Winter-mid summer	Min 0.5 metres Optimal 1.5-2.0 metres (based on Moira grass)	12,000-25,000 ML/d for Moira grass
BMF6_2023 (improve condition of native woody vegetation)	**River red gum forest**	4-9 in 10	4 years	3-5 months	Winter-spring	Not critical	15,000-35,000 ML/d
	River red gum woodland	3-5 in 10	5 years	1-4 months	Winter-spring	Not critical	35,000-55,000 ML/d
	Box floodplain woodland	1-2 in 10	12 years	1-3 months	Spring	Not critical	55,000-65,000 ML/d
BMF7_2023 (restore representative subpopulations of native water dependent biota)	**For plants and waterbirds: Sedge/forb/grass floodplain**	6-10 in 10	3 years	5-9	Winter-spring	Min 0.5 metres Optimal 1.5-2.0 metres	4,000-25,000 ML/d overall 12,000-25,000 ML/d for Moira grass

Objective	WRC	Events per 10 years	Maximum interval between events	Duration of events (months)	Timing	Depth	Equivalent Murray River flow threshold (ML/d)
	Temporary marshes Temporary lakes					(based on Moira grass)	
	For fish[8], turtles, frogs and crayfish: Permanent rivers and creeks	9 in 10	1 year	12	Late winter-spring	Varies with fish species	Up to 10,400 ML/d
	For fish and frogs: Temporary rivers and creeks	3-10 in 10	1 year	9-12	Late winter-spring	Varies with fish species	4,500-12,000 ML/d
	For woodland birds: River red gum woodland	3-5 in 10	5 years	1-4 months	Winter-spring	Not critical	35,000-55,000 ML/d
	For woodland birds: Box woodland	1-2 in 10	12 years	1-3 months	Spring	Not critical	55,000-65,000 ML/d
BMF8_2023 (support waterfowl breeding and small-scale colonial breeding)	**Permanent marshes**	4 in 10	2 years	10-12 months	Spring-summer	Maintain relatively stable water levels	18,000-30,000 ML/d
	Temporary marshes	6-10 in 10	3 years	5-9	Spring-summer	Maintain relatively stable water levels	18,000-30,000 ML/d
	River red gum forest	4 in 10	2 years	10-12 months	Spring-summer	Maintain relatively stable water levels	18,000-30,000 ML/d
BMF9_2023 (maintain or increase representative species	See watering requirements for BMF7_2023 and BMF8_2023.						

[8] See also Figure 14 in Goulburn Broken CMA (2015) for the preferred hydrograph for large-bodied fish.

Objective	WRC	Events per 10 years	Maximum interval between events	Duration of events (months)	Timing	Depth	Equivalent Murray River flow threshold (ML/d)
richness of shallow-water and deep-water feeding guilds of waterbird)							
BMF10_2023 (support successful breeding and recruitment of native fish)	**Permanent rivers and creeks**[9]	9 in 10	1 year	12 months	Late winter-spring	Not critical	4,500-12.000 ML/d
	Temporary rivers and creeks	3-10 in 10	1 year	9-12	Late winter-spring	Varies with fish species	4,500-12,000 ML/d
BMF11_2023 (support successful breeding and recruitment of frogs)	See watering requirements for BMF7_2023 and BMF8_2023.						
BMF12_2023 (support small bodied fish and movement of large bodied riverine native fish)	**Permanent rivers and creeks**[10]	9 in 10	1 year	12 months	Late winter-spring	Not critical	4,500-12.000 ML/d
	Temporary rivers and creeks	3-10 in 10	1 year	9-12	Late winter-spring	Varies with fish species	4,500-12,000 ML/d
BMF13_2023 (provide refugia to support the long-term survival of water-dependent biota)	**Permanent rivers and creeks**	9 in 10	1 year	12 months	Late winter-spring	Greatest depth practicable	4,500-12.000 ML/d
	Permanent marshes	4 in 10	2 years	10-12 months	Spring-summer	Greatest depth practicable	18,000-30,000 ML/d
	Permanent lakes	9 in 10	1 year	12 months	Late winter-spring	Greatest depth practicable	>3,000 ML/d
BMF14_2023 (mitigate the impact of invasive species and feral animals)	Cascading outcome: see complementary activities (Parks Victoria 2020) and BMF5_2023.						

[9] See also Figure 14 in Goulburn Broken CMA (2015) for the preferred hydrograph for large-bodied fish.
[10] See also Figure 14 in Goulburn Broken CMA (2015) for the preferred hydrograph for large-bodied fish.

8.2 Expected watering effects

Environmental water delivery to Barmah-Millewa Forest is expected to generate a range of environmental benefits related to filling hydrological gaps on the floodplain as a result of river regulation and supply of water for consumptive uses. Environmental water delivery and management will benefit flow-ecology relationships and processes through improved:

- Aquatic biodiversity,
- Floodplain vegetation,
- Hydrological variation,
- Habitat connectivity,
- Fish passage,
- Ecosystem function.

A summary of expected watering effects is presented in Table 27. Further details on the benefits expected with environmental water management can be found in the annual seasonal water proposals provided to Commonwealth and State water delivery partners (e.g., Goulburn Broken CMA 2022 and 2023).

Table 27: Expected environmental watering outcomes at Barmah-Millewa Forest. The watering regimes to meet environmental objectives is presented in Table 26.

Environmental objective code and intent	Watering outcomes
BMF1_2023 (maintain ecological character)	The ecological character of Barmah-Millewa Forest will be maintained by providing watering regimes that supports a mosaic of ecosystem types, as well as ecosystem components, processes and services (CPS) as identified in the ECD for Barmah Forest (Hale and Butcher 2011) and Millewa Forest (Harrington and Hale 2011). This includes the aquatic ecosystem (ANAE) types, EVCs and PCTs identified across the site. This will be achieved by watering for other outcomes, most notably for vegetation, waterbird and fish outcomes.
BMF2_2023 (support key life cycle stages for migratory waterbirds)	Environmental watering will maintain a mosaic of habitats that will support foraging by migratory waterbirds. This will be achieved by watering for other outcomes, most notably for vegetation and fish outcomes.
BMF3_2023 (improve condition of representative ecosystem types)	Outcomes as for BMF1_2023, above.
BMF4_2023 (maintain threatened water-dependent species)	Environmental watering will maintain foraging and breeding habitat for threatened waterbird, fish, crayfish and turtle species.
BMF5_2023 (improve condition of native non-woody aquatic vegetation)	Environmental watering will provide floodplain inundation and maintain soil moisture to improve or maintain the condition of ecologically important aquatic and amphibious plants (e.g., Moira grass). Maintaining an appropriate watering regime will also help control the incursion of river red gum seedlings and giant rush that occurs at the expense of Moira grass extent (e.g., Cooling et al. 2019, Ecological Associates and Roberts 2019).
BMF6_2023 (improve condition of native woody vegetation)	Environmental watering will provide floodplain inundation and maintain soil moisture to improve or maintain the condition of

Environmental objective code and intent	Watering outcomes
	ecologically important river red gum, yellow box and black box communities and their understorey vegetation.
BMF7_2023 (restore representative subpopulations of native water dependent biota)	Environmental watering of the various WRCs will maintain a mosaic of ecosystem types that in turn support water-dependent biota such as: • Moira grass extent • Waterbirds species richness • Native fish species richness, including threatened species such as silver perch (*Bidyanus 69idyanus*) and southern pygmy perch (*Nannoperca australis*) • Turtle species, including threatened species such as broad-shelled turtle (*Chelodina expansa*) and Murray River turtle (*Emydura macquarii*) • Frog species richness and Murray spiny crayfish • Woodland bird species richness.
BMF8_2023 (support waterfowl breeding and small-scale colonial breeding)	Environmental water delivery to marsh and river red gum forest WRCs will continue to support waterfowl and colonial-nesting waterbird breeding habitat.
BMF9_2023 (maintain or increase representative species richness of shallow-water and deep-water feeding guilds of waterbird)	Outcomes as for BMF7_2023, above.
BMF10_2023 (support successful breeding and recruitment of native fish)	Delivery of the preferred hydrograph for native fish (Goulburn Broken CMA 2015) will provide flow cues for migration and spawning by large and small-bodied native fish.
BMF11_2023 (support successful breeding and recruitment of frogs)	Outcomes as for BMF7_2023, above.
BMF12_2023 (support small bodied fish and movement of large bodied riverine native fish)	Delivery of the preferred hydrograph for native fish (Goulburn Broken CMA 2015) will provide water depth for movement through permanent rivers and creeks by large and small-bodied native fish, as well as access to temporary rivers and creeks in order to access feeding and breeding habitat.
BMF13_2023 (provide refugia to support the long-term survival of water-dependent biota)	Maintenance of permanent rivers, creeks and lakes will help ensure the survival of water-dependent biota during times of drought, or during other disturbances such as times of poor water quality (e.g., blackwater events).
BMF14_2023 (mitigate the impact of invasive species and feral animals)	Delivery of environmental water in combination with complementary management activities will mitigate the threat of invasive species.

8.3 Do nothing scenario

Under a do nothing scenario, the current trajectory of values and condition described in Section 5.3 is likely to continue. If no active management intervention is implemented to restore a more natural flooding regime and alleviate water stress, the ecological values and condition of Barmah-Millewa Forest and its floodplain ecosystems are likely to decline due to (e.g., Goulburn Broken CMA 2022 and 2023, Gawne et al. 2011, Bond et al. 2021):

- Simplification of ecosystem types (e.g., via replacement of Moira grass floodplain with giant rush and river red gum);
- Reduced extent of wetland areas and the habitats they support (e.g., foraging habitat for waterbirds, habitat for threatened species);
- Decline in river red gum and black box tree health in woodland areas;
- Encroachment of terrestrial species into wetlands and areas of river red gum and black box woodland.

Changes such as those listed above would also be exacerbated by the effects of climate change (e.g., MDBA 2021, 2020c). The provision of a more natural flooding regime is expected to assist in managing a number of these threats and improve the condition and resilience of ecological values.

9 Environmental water delivery infrastructure

9.1 Overview of water delivery infrastructure

Flows in the Barmah-Millewa Forest are principally governed by releases from Yarrawonga Weir on the Murray River. Once water arrives at the site, a series of regulators can be used to control water flow into the forest or retain it within the Murray River, depending upon volume.

There are more than 50 existing water management structures across Barmah-Millewa Forest (Goulburn Broken CMA 2015, Appendix 4). Most of the larger structures were built in the late 1930s following regulation of the Murray River to prevent water loss from the regulated river into forest areas. More recently, many smaller structures have been constructed to re-permit flow into previously blocked creeks or into areas where improved water management for the wetland system ecology had been identified. Structures are managed as joint ventures with the MDBA (Jacobs 2018), or by NSW or Victorian management agencies. Examples of some of the main regulators are listed in Table 28.

Table 28. Example regulators and their capacity (Ecological Associates and SKM 2011).

Regulator name	Wetland/creek system	State	Murray River commence to flow (ML/d)	Capacity at low Murray River flows (ML/d)
Mary Ada	Toupna Creek	NSW	3,500	2,800
House Creek	House Creek	NSW	6,000	630
Pinchgut Creek	Pinchgut Creek	NSW	4,500	375
Nestrons	Douglas Swamp	NSW	4,500	240
Walthours	Walthours Wetland	NSW	4,500	90
n/a	Duck Lagoon	NSW	~4,700 to provide Gulpa Ck flow of 400	unknown
n/a	Reed Bed North Wetland	NSW	~4500 to provide Gulpa Ck flow of 370	unknown
n/a	Reed Bed South Wetland	NSW	~4500 to provide Gulpa Ck flow of 370	unknown
Horse-shoe Lagoon	Horse-shoe Lagoon	NSW	unknown	unknown
Crumps	St Helena	NSW	unknown	unknown
Black Swamp	Black Swamp	NSW	unknown	unknown
Sandspit Regulator	Smiths Creek	VIC	9,000	340
Gulf Regulators	Gulf Creek	VIC	3,000	2,400
Stewarts Kitchen	unknown	VIC	9,000	20
Bull Paddock	unknown	VIC	9,000	40
Punt Paddock	unknown	VIC	8,000	90
Big Woodcutter	unknown	VIC	7,500	90
Boals Creek	Boals Creek	VIC	5,000	90
Sapling Creek	Sapling Creek	VIC	7,500	40
Island Creek	Island Creek	VIC	7,500	40

As described in Section 3.3.3, water management structures such as regulators are used to deliver water to individual water management areas across Barmah-Millewa Forest. Despite the flexibility provided by the regulators, options to use infrastructure to create large-scale flooding are limited. The shedding nature of the floodplain means that once river flows drop, water runs off the floodplain, with few wetland basins that will retain water for longer periods. Achieving the ecological objectives for the forest will, therefore, generally require sustained high river flows, often achieved by combining natural river freshes and environmental water allocations. This work will be assisted by new regulating structures such as those proposed under the NSW SDLAM project and at Kynmer Creek.

9.2 Constraints

There are two delivery constraints that influence the delivery of environmental water to the Barmah-Millewa Forest (Table 29) (Goulburn Broken CMA 2023). For example, imposed flow constraint on the Murray River downstream of Yarrawonga currently limits releases to a maximum of 18,000 ML/d until the end of September (pending stakeholder approval) and to 15,000 ML/d for the remainder of the year to prevent flooding of private access points across the Bullatale Creek system in NSW. In recognition of this constraint, annual watering proposals accept that both Barmah Forest and Millewa Forest cannot achieve Floodplain Marsh flood inundation (a key objective) to the required minimum depths if both forests were to be flooded during the same managed e-water event, and hence instead accept a continuation of the local "seasonal annual alternating management" (time-share) agreement only one of Barmah or Millewa Forest can be flooded at the minimum depth target in any given event.

Table 29. Environmental water delivery constraints (Goulburn Broken CMA 2023)

Priority environmental site	Potential constraint	Impact on priority watering action
Barmah-Millewa Forest	Bullatale Creek flooding of access to private land issue unresolved	Limited to releases of 18,000 ML/d until the end of September (pendingstakeholder approval) and 15,000 ML/d thereafter.
Barmah Forest	At present MDBA River Operations may need to supply bulk water delivery through Barmah Forest during August to December, thereby using full Murray River channel capacity and thus rendering inability to deliver environmental water to Millewa Forest given preference to pass water through Barmah Forest. This may change in the future.	Cannot deliver to Millewa Floodplain Marsh plains if this situation arises, hence will capitalise on Barmah Forest flooding to ensure developing environmental gains are achieved (e.g., maintain flows to complete waterbird nesting outcomes if one initiates during Murray River Operations delivery).

10 Demonstrating outcomes – monitoring and assessment

10.1 Monitoring against EWMP objectives

The detailed objectives for Barmah-Millewa Forest EWMP are presented in Table 30 and relate to the scale at which water will be managed and outcomes monitored.

Demonstrating outcomes from environmental watering is important for the ongoing adaptive management of Barmah-Millewa Forest, and for reporting against the Basin Plan; thus, Basin Plan language and themes are adopted to improve line of sight to the various Basin Plan instruments (e.g., Basin-wide Environmental Watering Strategy, Long Term Watering Plans).

Much of the monitoring outlined in Table 30 is already being undertaken as part of TLM program and therefore not repeated here.

Table 30: Monitoring required for the Barmah-Millewa EWMP detailed objectives.

EWMP objective	Theme	Key monitoring component
BMF1_2023 (maintain ecological character)	All themes	See monitoring proposed for BMF5_2023, BMF6_2023, BMF7_2023, BMF8_2023 and BMF10_2023.
BMF2_2023 (support key life cycle stages for migratory waterbirds)	Ecosystem type and Biodiversity	Number of migratory waterbird species.
BMF3_2023 (improve condition of representative ecosystem types)	Ecosystem type and Biodiversity	ANAE ecosystem type.
BMF4_2023 (maintain threatened water-dependent species)	Ecosystem type and Biodiversity	Presence of threatened plant species. Presence of threatened bird species. Presence of threatened fish species.
BMF5_2023 (improve condition of native non-woody aquatic vegetation)	Ecosystem type and Biodiversity	Cover and number of species.
BMF6_2023 (improve condition of native woody vegetation)	Ecosystem type and Biodiversity	Stand condition, stand structure of river red gum and box woodland, understorey condition.
BMF7_2023 (restore representative subpopulations of native water dependent biota)	Ecosystem type and Biodiversity	Vegetation: Moira grass extent. Waterbirds: species richness (individual wetlands and whole site). Fish: native fish species, abundance and biomass Turtles: CPUE for each species; species occurrence and body condition per species. Frogs: presence of six common species. Crayfish: population condition. Woodland birds: species richness.
BMF8_2023 (support waterfowl breeding and small-scale colonial breeding)	Ecosystem function	Number of waterfowl species breeding.

EWMP objective	Theme	Key monitoring component
BMF9_2023 (maintain or increase representative species richness of shallow-water and deep-water feeding guilds of waterbird)	Ecosystem function	Waterbird feeding guilds: species richness.
BMF10_2023 (support successful breeding and recruitment of native fish)	Ecosystem function	Number of large and small-bodied fish species with recruits.
BMF11_2023 (support successful breeding and recruitment of frogs)	Ecosystem function	Number of species breeding; relative abundance of recruits for each species breeding.
BMF12_2023 (support access to habitat for small bodied fish and movement of large bodied riverine native fish)	Ecosystem function	See monitoring for BMF7_2023, BMF5_2023, BMF6_2023, BMF10_2023.
BMF13_2023 (provide refugia to support the long-term survival of water-dependent biota)	Ecosystem resilience, climate change and other risks and threats	Capacity of Gulpa Creek during drought.
BMF14_2023 (mitigate the impact of invasive species and feral animals)	Ecosystem resilience, other risks and threats	Number and extent of invasive species, impacts of invasive species predation of turtles nests, cover of high threat weeds.

11 Knowledge gaps and recommendations

The partners involved in managing water delivery at Barmah-Millewa Forest can gain additional insights to inform future adaptive management by addressing knowledge gaps, particularly those related to optimizing the volume and delivery of water across the Icon site and the response of target flora and fauna to water delivery.

Knowledge gaps related to optimising water delivery across Barmah-Millewa Forest (see also Goulburn Broken CMA 2023) include:

- Confirming groundwater levels under Barmah-Millewa forest, particularly in response to recent years of flooding and the role of groundwater recharge in maintaining the health of River Red Gum forest.
- Confirming volumes to water individual WRCs. WRCs have been applied as a means to ensure watering of EVCs and PCTs with common watering requirements. Further work is required to determine the volume of water that would be required to inundate each WRC under different climatic conditions. Filling this knowledge gap will assist the joint-partners in decision-making, such as when there is limited environmental water available, and it is not possible to inundate all WRCs.
- Modelling – the areas of forest influenced by individual regulators rather than operating them as a collective open or shut scenario.
- Watercourses – the hydrological requirements of each individual watercourse depending on the specific values present e.g., instream vegetation which is not currently documented or monitored.
- Vegetation units – how the different approaches to defining management zones in Barmah-Millewa Forest relate to each other (e.g., what landscape components and WRCs are present in each of the Water Management Areas, what EVCs and PCTs and plant functional groups are found in which landscape components, what important species occur within each EVC and PCT?).

Knowledge gaps related to ecosystem response to water delivery (see also Goulburn Broken CMA 2023) include:

- Bird movements – particularly for colonial nesting species. This includes migration (when and where) and what cues stimulate nesting in Barmah-Millewa Forest and broader regions where birds have been captured and tagged. The waterbird tracking project[11] commenced as an EWKR-funded project between 2015-19 and has since continued as a CEWO-funded project. The project has already greatly assisted with answering many basic movement questions whilst continuing to discover much more and providing useful considerations for water management. Further opportunity remains to capture additional birds for tagging.
- Large-bodied fish movements, spawning and recruitment – cues responsible for accessing the main river, creeks and wetlands, breeding, larvae drift, recruitment migration and movement response to water quality, as well as cues responsible for inducing spawning and recruitment outcomes. This is being investigated through Barmah-Millewa Intervention Monitoring (Ward 2022) in addition to other research projects along the Murray River.

[11] https://flow-mer.org.au/satellite-tracking-waterbird-movements-what-can-it-tell-us-and-how-does-it-work/

- Small-bodied wetland dependent fish – identify sites within Barmah-Millewa Forest where flows and physical habitats could be maintained/restored to help restore populations of small-bodied fish species such as the southern pygmy perch. ARI is currently investigating potential re-introduction sites in Barmah Forest for southern pygmy perch and possibly also purple-spotted gudgeon.
- Frogs – species, numbers, breeding locations and cues, and recruitment outcomes. Currently being investigated by Barmah-Millewa Condition Monitoring project (Howard et al. 2021).
- Murray crayfish – population, movement and the impacts of blackwater events. Currently being investigated by Barmah-Millewa Condition Monitoring project (e.g., Raymond et al. 2018).
- Swamp yabby habitat preference – currently forms a trial intervention monitoring project with ARI (Ward 2022) that is intended to be refined based on preliminary results achieved.
- Turtle movements – continue GPS transmitter tracking of a sample of turtles (Howard et al. 2021) of all three species to determine movements in relation to water management and nesting locations (which also has ramifications for pest animal control programs and potential drought refuge management).
- Macro invertebrates – very little is known of their significance or water requirements in Barmah-Millewa Forest.
- Causes and significance of filamentous algae coating wetland plants at Barmah-Millewa wetlands in occasional years.
- Carbon cycling – importance of floodplain-riverine interaction to support riverine food-webs (thereby potentially increasing the importance of return flow management).
- Rare or threatened species – undertake targeted surveys to determine location for potential water management.
- Erosion and sedimentation rates (main river channel and other waterways) – value would be obtained from re-surveying existing erosion monitoring transect sites in Barmah Forest that have previously survey data from 1998, 1999, 2002 and 2006, in addition to MDBA's sand slug and erosion studies.
- Exploring the best method (particularly timing) to restore wetlands with Moira grass propagules. Currently subject to a Ramsar-funded project managed by Goulburn Broken CMA (Ecological Associates and Jane Roberts 2019).
- Further refine remote mapping of the distribution of Moira grass (and other targeted species). Recent Ramsar-funded project managed by the Goulburn Broken CMA showed some encouraging results (White et al. 2021), but this needs to be refined.

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13 Abbreviations and acronyms

13.1 Abbreviations and acronyms

CAMBA	China-Australia Migratory Bird Agreement
CMA	Catchment Management Authority
DEECA	Department of Energy, Environment and Climate Action
DELWP	Department of Environment, Land, Water and Planning
DEPI	Department of Environment and Primary Industries (now DEWLP)
DSE	Department of Sustainability and Environment (now DELWP)
EVC	Ecological Vegetation Class
EPBC	Environment Protection and Biodiversity Conservation Act
EWMP	Environmental Water Management Plan
EWH	Environmental Water Holder
EWR	Environmental Water Reserve
FFG	Flora and Fauna Guarantee Act
FSL	Full Supply Level
WMU	Floodplain Management Unit
IWC	Index of Wetland Condition
JAMBA	Japan-Australia Migratory Bird Agreement
MCMA	Mallee Catchment Management Authority
MDBA	Murray-Darling Basin Authority (formally Murray-Darling Basin Commission, MDBC)
Ramsar	The Convention on Wetlands is an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. The treaty was first signed in the Iranian city of Ramsar in 1971, and the convention entered into force in Australia on 21 December 1975.
ROKAMBA	Republic of Korea-Australia Migratory Bird Agreement
RRG	River red gum (*Eucalyptus camaldulensis*)
SDL	Sustainable Diversion Limit
TLM	The Living Murray Initiative
TSL	Targeted Supply Level
VEWH	Victorian Environmental Water Holder
VWMS	Victorian Waterway management Strategy
WMU	Waterway Management Unit

WRC Ecological Water Regime Class

13.2 Glossary

Table 31: Glossary of terms.

Term	Definition
Adaptive management	Adaptive management is a procedure for implementing management while learning about which management actions are most effective at achieving specified objectives. Adaptive management incorporates planning, management, monitoring and evaluation mechanisms to allow waterway managers to adjust their approach in response to current climatic conditions, new information and local knowledge when planning for the future. Adaptive management would be implemented during operation to ensure changes in management actions are most effective at achieving the identified benefits of the projects.
Anabranch	An anabranch is a section of a river or stream that diverts from the main channel or stem of the watercourse and re-joins the main stem downstream. Local anabranches can be the result of small islands in the watercourse.
Containment bank	Containment banks are a raised embankment, and predominantly earth fill. Their primary objective is to provide water containment for the purpose of containing environmental water on the floodplain and avoiding or / controlling the breakout of water to prevent unintended flooding. Containment banks may include a road or track, especially where constructed along an existing road or track.
Culverts	A tunnel carrying a stream or open drain under a road, access track or similar obstruction from one site to the other. Typically embedded to be surrounded by soil, a culvert may be made from reinforced concrete or other material. Culverts (pipe and box) will allow water to move within the site, whilst also maintaining access for operational staff and the public.
Drop structure	Drop structures are rock chutes constructed from large rocks and small boulders that cover the surface of descending channels to control the erosion associated with discharge of managed releases from the floodplain to the river. Drop structures and rock chutes are constructed near rivers to control the erosion associated with discharge of managed releases from the floodplain to the river.
Environmental Water Management Plan	The Environmental Water Management Plan details the operational management of the projects and their water regime. This document would provide a framework for water planning, delivery, monitoring and consultation processes and would be responsive to changing water resource conditions, opportunities, and environmental priorities.
Fishway	Fishways would be included in selected regulators where the movement of fish into and/or out of the inundated floodplain areas is critical for sustaining fish populations. The fishways will typically be vertical slot fishways, which provide a

Term	Definition
	channel around the regulator structure with baffles forming a vertical opening that controls head drop and velocity through the fishway. A cone fishway refers to a cone shaped baffle that forms a series of ridges through which fish pass. The fishway at low discharge volumes allow small-bodied fish to pass while at higher flows the physical dimensions of the gaps between the cones increases allowing larger fish to pass.
Flood runner	A flood runner is a natural depression. Water gravitates into the flood runner to form a small channel.
Infrastructure	General term to collectively describe all works, including physical structures, to be delivered as part of VMFRP.
Inundation	Inundation is the deliberate flooding of land. Also used to indicate presence of water within a wetland/system.
Managed Inundation	The delivery of environmental water to a specific location to achieve pre-determined environmental objectives. Delivery of environmental water may occur before or in addition to natural a natural flood, taking advantage of the naturally wetted conditions to extend the duration of inundation.
Maximum Inundation Area	The Maximum Inundation Area is the maximum area able to be watered by the proposed works based on the design, including private land that would only be subject to managed inundation if private flood agreements are established.
Monitoring, Evaluation and Reporting Plan	The Monitoring, Evaluation and Reporting Plans will provide the framework, variables and triggers for monitoring and evaluating the delivery of environmental water across the VMFRP sites.
Natural Flood	A scenario where high rainfall results in the passage of water that is no longer confined within the banks of a defined waterway (e.g., river, steam, drain) and begins to fill wetlands, the floodplain and, in extreme events, higher ground.
Operation	Operation, also known as the operational phase, is the 'use' phase in a project's lifecycle. This project phase is the longest stage of the project lifecycle and includes the maintenance of infrastructure.
Regulator	A structure of varying sizes used to deliver, move or retain water on the floodplain to meet the environmental watering regime (e.g., volume and duration of flood water). The various regulator sizes include: *Very large* – major regulator structures on large waterways that will require individual design. They typically are multi-bay structures with more than 3-4m head height with bridge crossings for access and will be designed as cast in situ concrete structures with sheet pile cut offs for seepage control. Some will require piled foundations for structural support and some have fishways *Large* – intermediate sized regulator structures nominally 2-3m in height with some degree of individual design of the structure required. They will typically have box culverts for the road crossing but the remainder will be cast in situ concrete, typically with sheet pile cut offs for seepage control.

Term	Definition
	Small – control regulators that retain water less than 2m deep. The small regulators generally comprise box culvert style regulators with box culvert units up to 1.8m high, and variations of these. Non-standard small regulators consist of small irrigation type flow control structures. Some regulators will be operated so that fish passage (targeting small-bodied fish) can occur both in managed release and natural flood scenarios and flow velocities are also appropriate for fish passage.
River floodplain	An area of low-lying ground adjacent to a river, which is subject to flooding during periods of high river flow.
Road (see also track)	Roads refer to existing Council or State managed public roads, comprised of formalised sealed or unsealed pavement structures consisting of a prepared subgrade with base and / or subbase layers.
Spillway	Spillways are hydraulic structures built to divert or control the release of flood waters. Spillways have been incorporated into some containment banks or integrated with regulator structures to control overflow during a natural or managed flood.
Threshold	For water – A water height, or flow that defines a critical transition in operational conditions. For ecology – A time or ecological health condition that defines a critical transition in ecological conditions.
The Living Murray (TLM) program	The Living Murray program was established in 2002 in response to concerns about the environmental health of the Murray River. The initiative aims to improve the environmental health of six icon sites that were chosen for their significant values. The six icon sites include the Barmah–Millewa Forest, Gunbower–Koondrook–Pericoota Forests, Hattah Lakes, Chowilla Floodplains and Lindsay–Wallpolla–Mulcra Islands, Lower Lakes, Coorong and Murray Mouth and Murray River Channel. The program has recovered 500 GL of environmental water and has constructed water management structures to enable the efficient and effective use of environmental water.
Track	Tracks refer to public access tracks in National Parks or State Forests or National Parks and range from formalised pavements to unformed tracks established by clearing vegetation, re-grading and re-profiling utilising existing materials. There are also some tracks located on private land.
Water-dependent	An ecosystem or species that depends on periodic or sustained inundation, waterlogging or significant inputs of water (in addition to water held in the soil profile) for natural functioning and survival.
Water Management Area	A Water Management Area is defined as a subset of the Maximum Inundation Area, used to manage surface water. Each Water Management Area has a different target inundation water level, and several areas are designed to cascade water to extend the inundation benefits by reusing water.

14 Appendix 1: Plant Community Types (PCTs) and Ecological Vegetation Types (EVCs) recorded in Barmah-Millewa Forest.

14.1 Plant Community Types (New South Wales)

PCT description	Area of each PCT (hectares)
River red gum herbaceous-grassy very tall open forest	21386.7
River red gum-sedge dominated very tall open forest in frequently flooded forest	8752.5
Riverine western grey box grassy woodland	2017.8
Shallow marsh wetland of regularly flooded depressions on floodplains	1551.8
River red gum - Warrego grass - herbaceous riparian tall open forest	867.5
Yellow box - river red gum tall grassy riverine woodland	731.0
Cypress pine woodland of source-bordering dunes	704.3
Non Native	643.2
River red gum - black box woodland wetland	501.4
Western grey box tall grassy woodland	371.8
Derived corkscrew grass grassland/forbland on sandplains and plains	237.8
Forb-rich speargrass - Windmill grass - White Top grassland	218.2
Black box - Lignum woodland wetland	133.7
Common reed - bushy groundsel aquatic tall reedland grassland	48.5
River red gum-sedge dominated very tall open forest in frequently flooded forest	41.7
Derived mixed shrubland on loamy-clay soils in the Cobar Peneplain bioregion	19.9
River red gum herbaceous-grassy very tall open forest wetland on inner floodplains	1.2
Plains grass grassland on alluvial mainly clay soils	1.2
River red gum - Warrego grass - couch grass riparian tall woodland	0.3
River red gum - lignum very tall open forest or woodland wetland on floodplains	0.2
Cumbungi rushland	0.2
Nitre goosefoot shrubland	0.2

14.2 Ecological Vegetation Types (Victoria)

EVC description	Area of each EVC (hectares)
Sedgy Riverine Forest	5,741.0
Sedgy Riverine Forest/Riverine Swamp Forest Complex	3,735.5
Riverine Swamp Forest	3,638.0
Grassy Riverine Forest/Riverine Swamp Forest Complex	2,760.5
Riverine Grassy Woodland	2,670.3
Grassy Riverine Forest	1,508.9
Riverine Swampy Woodland	1,002.7
Mosaic of Riverine Swamp Forest/Floodway Pond Herbland-Riverine Swamp Forest Complex	898.1
Riverine Swamp Forest/Sedgy Riverine Forest-Riverine Swamp Forest Complex	862.2

EVC description	Area of each EVC (hectares)
Tall Marsh	689.1
Plains Woodland	667.2
Riverine Swamp Forest/Tall Marsh Mosaic	572.3
Floodway Pond Herbland/Riverine Swamp Forest Complex	519.4
Floodplain Grassy Wetland	470.4
Drainage-line Aggregate	410.2
Floodplain Riparian Woodland	371.8
Mosaic of Floodway Pond Herbland/Grassy Riverine Forest-Riverine Swamp Forest Complex	367.8
Mosaic of Sedgy Riverine Forest/Sedgy Riverine Forest-Riverine Swamp Forest Complex	270.1
Grassy Riverine Forest/Sedgy Riverine Forest Mosaic	268.4
Low Rises Woodland	257.1
Riverine Grassy Woodland/Riverine Swampy Woodland Mosaic	247.7
Water Body - Fresh	197.7
Mosaic of Grassy Riverine Forest-Riverine Swamp Forest Complex/Riverine Swamp Forest	191.0
Mosaic of Drainage-line Aggregate/Grassy Riverine Forest-Riverine Swamp Forest Complex	147.4
Aquatic Herbland	144.8
Riverine Grassy Woodland/Sedgy Riverine Forest Mosaic	141.3
Spike-sedge Wetland	107.1
Floodway Pond Herbland	104.1
Floodplain Grassy Wetland/Riverine Swamp Forest Mosaic	98.9
Mosaic of Tall Marsh/Floodway Pond Herbland-Riverine Swamp Forest Complex	83.5
Mosaic of Sedgy Riverine Forest-Riverine Swamp Forest Complex/Floodway Pond Herbland-Riverine Swamp Forest Complex	77.0
Aquatic Herbland/Tall Marsh Mosaic	68.1
Grassy Riverine Forest/Riverine Swamp Forest Mosaic	66.6
Riverine Grassland	62.5
Aquatic Herbland/Floodplain Grassy Wetland Mosaic	58.3
Mosaic of Grassy Riverine Forest/Sedgy Riverine Forest-Riverine Swamp Forest Complex	57.6
Riverine Swamp Forest/Sedgy Riverine Forest Mosaic	41.0
Rushy Riverine Swamp	40.2
Drainage-line Aggregate/Riverine Swamp Forest Mosaic	35.3
Mosaic of Riverine Swampy Woodland/Sedgy Riverine Forest-Riverine Swamp Forest Complex	32.9
Riverine Swamp Forest/Riverine Swampy Woodland Mosaic	29.9
Mosaic of Sedgy Riverine Forest/Floodway Pond Herbland-Riverine Swamp Forest Complex	29.8
Grassy Riverine Forest/Riverine Grassy Woodland Mosaic	23.5
Drainage-line Aggregate/Sedgy Riverine Forest Mosaic	23.2
Mosaic of Grassy Riverine Forest/Floodway Pond Herbland-Riverine Swamp Forest Complex	22.5
Floodplain Grassy Wetland/Spike-sedge Wetland Mosaic	22.0

EVC description	Area of each EVC (hectares)
Mosaic of Floodplain Grassy Wetland/Grassy Riverine Forest-Riverine Swamp Forest Complex	21.9
Floodplain Grassy Wetland/Tall Marsh Mosaic	20.5
Tall Marsh/Non-Vegetation Mosaic	15.8
Sand Ridge Woodland	14.7
Riverine Swampy Woodland/Sedgy Riverine Forest Mosaic	14.7
Riverine Grassy Woodland/Riverine Swamp Forest Mosaic	13.7
Mosaic of Drainage-line Aggregate/Sedgy Riverine Forest-Riverine Swamp Forest Complex	9.7
Spike-sedge Wetland/Tall Marsh Mosaic	8.9
Mosaic of Floodway Pond Herbland/Sedgy Riverine Forest-Riverine Swamp Forest Complex	8.5
Mosaic of Sedgy Riverine Forest-Riverine Swamp Forest Complex/Tall Marsh	6.9
Riverine Swamp Forest/Spike-sedge Wetland Mosaic	6.2
Floodway Pond Herbland/Tall Marsh Mosaic	6.1
Floodplain Grassy Wetland/Floodway Pond Herbland Mosaic	5.8
Floodplain Riparian Woodland/Riverine Grassy Woodland Mosaic	5.0
Grassy Riverine Forest/Floodway Pond Herbland Mosaic	4.7
Tall Marsh/Riverine Swamp Forest Mosaic	2.8
Grassy Riverine Forest/Drainage-line Aggregate Mosaic	2.7
Drainage-line Aggregate/Tall Marsh Mosaic	2.7
Riverine Grassy Woodland/Grassy Riverine Forest-Riverine Swamp Forest Complex	2.7
Floodplain Riparian Woodland/Floodway Pond Herbland Mosaic	2.4
Grassy Riverine Forest/Tall Marsh Mosaic	2.0
Sedgy Riverine Forest/Tall Marsh Mosaic	1.8
Mosaic of Floodplain Grassy Wetland/Sedgy Riverine Forest-Riverine Swamp Forest Complex	1.8
Floodplain Riparian Woodland/Sedgy Riverine Forest Mosaic	1.8
Sandy Beach	1.7
Billabong Wetland Aggregate	1.7
Mosaic of Aquatic Herbland/Floodway Pond Herbland-Riverine Swamp Forest Complex	1.6
Floodplain Grassy Wetland/Riverine Swampy Woodland Mosaic	1.6
Low Rises Woodland/Riverine Swampy Woodland Mosaic	1.5
Aquatic Herbland/Riverine Swamp Forest Mosaic	1.2
Mosaic of Riverine Grassy Woodland/Floodway Pond Herbland-Riverine Swamp Forest Complex	1.2
Grassy Riverine Forest/Riverine Swampy Woodland Mosaic	1.0
Riverine Ephemeral Wetland	0.9
Mosaic of Floodplain Grassy Wetland/Floodway Pond Herbland-Riverine Swamp Forest Complex	0.8
Aquatic Herbland/Floodway Pond Herbland Mosaic	0.7
Floodplain Riparian Woodland/Tall Marsh Mosaic	0.7
Floodplain Riparian Woodland/Riverine Swamp Forest Mosaic	0.7
Floodway Pond Herbland/Riverine Swamp Forest Mosaic	0.6

EVC description	Area of each EVC (hectares)
Mosaic of Drainage-line Aggregate/Floodway Pond Herbland-Riverine Swamp Forest Complex	0.6
Sedgy Riverine Forest/Spike-sedge Wetland Mosaic	0.4
Mosaic of Aquatic Herbland/Sedgy Riverine Forest-Riverine Swamp Forest Complex	0.3
Grassy Riverine Forest/Plains Grassy Woodland/Grassy Woodland Mosaic	0.2
Riverine Grassy Woodland/Plains Woodland/Riverine Chenopod Woodland Complex	0.1
Floodplain Riparian Woodland/Grassy Riverine Forest Mosaic	0.0

14.3 Fauna species

The following list of fauna was compiled by the Goulburn Broken CMA. The list presented below includes water-dependent species – defined as those that spend a substantial part of their life-cycle in or around water and/or wetland ecosystems (incl mudflats) (T. Barlow, GBCMA, pers. comm. June 2023) as well as terrestrial species.

NB: This species list has been compiled from reports generated by the Victorian Biodiversity Atlas (for Barmah NP) and NSW BioNet (for Murray Valley NP) on 08/06/2023. No assurances can be made regarding the accuracy of the data, and therefore any liability for consequences of use.

List of fauna species for Barmah-Millewa Forest. CR: Critically Endangered, EN: Endangered, VU: Vulnerable, C: CAMB, J: JAMBA, RoK: ROKAMBA

Family	Species	Common name	Vic	NSW	EPBC
Waterbirds					
Accipitridae	*Circus approximans*	Swamp harrier			
Accipitridae	*Haliaeetus leucogaster*	White-bellied sea-eagle	EN	VU	
Acrocephalidae	*Acrocephalus australis*	Australian reed-warbler			
Alcedinidae	*Ceyx azureus*	Azure kingfisher			
Anatidae	*Anas castanea*	Chestnut teal			
Anatidae	*Anas gracilis*	Grey teal			
Anatidae	*Anas rhynchotis*	Australasian shoveler			
Anatidae	*Anas superciliosa*	Pacific black duck			
Anatidae	*Aythya australis*	Hardhead	VU		
Anatidae	*Biziura lobata*	Musk duck	VU		
Anatidae	*Chenonetta jubata*	Australian wood duck			
Anatidae	*Cygnus atratus*	Black swan			
Anatidae	*Dendrocygna eytoni*	Plumed whistling-duck			
Anatidae	*Malacorhynchus membranaceus*	Pink-eared duck			
Anatidae	*Oxyura australis*	Blue-billed duck	VU	VU	
Anatidae	*Spatula rhynchotis*	Australasian shoveler	VU		
Anatidae	*Stictonetta naevosa*	Freckled duck	EN	VU	
Anatidae	*Tadorna tadornoides*	Australian shelduck			
Anhingidae	*Anhinga novaehollandiae*	Australasian darter			
Ardeidae	*Ardea alba*	Great egret			
Ardeidae	*Ardea intermedia*	Intermediate (plumed) egret	CE		
Ardeidae	*Ardea pacifica*	White-necked heron			
Ardeidae	*Botaurus poiciloptilus*	Australasian bittern	CE	EN	EN
Ardeidae	*Casmerodius modesta*	Eastern great egret	VU		
Ardeidae	*Egretta garzetta*	Little egret	EN		
Ardeidae	*Egretta novaehollandiae*	White-faced heron			
Ardeidae	*Ixobrychus dubius*	Australian little bittern	EN		
Ardeidae	*Nycticorax caledonicus*	Nankeen night heron			
Charadriidae	*Elseyornis melanops*	Black-fronted dotterel			
Charadriidae	*Erythrogonys cinctus*	Red-kneed dotterel			
Charadriidae	*Vanellus tricolor*	Banded lapwing			
Cisticolidae	*Cisticola exilis*	Golden-headed cisticola			
Gruidae	*Grus rubicunda*	Brolga	EN	VU	
Laridae	*Chlidonias hybrida*	Whiskered tern			
Laridae	*Chroicocephalus novaehollandiae*	Silver gull			
Locustellidae	*Poodytes gramineus*	Little grassbird			
Pelecanidae	*Pelecanus conspicillatus*	Australian pelican			
Percidae	*Perca fluviatilis*	Redfin perch	*	*	

Family	Species	Common name	Vic	NSW	EPBC
Phalacrocoracidae	*Microcarbo melanoleucos*	Little pied cormorant			
Phalacrocoracidae	*Phalacrocorax carbo*	Great cormorant			
Phalacrocoracidae	*Phalacrocorax sulcirostris*	Little black cormorant			
Phalacrocoracidae	*Phalacrocorax varius*	Pied cormorant			
Podicipedidae	*Podiceps cristatus*	Great crested grebe			
Podicipedidae	*Poliocephalus poliocephalus*	Hoary-headed grebe			
Podicipedidae	*Tachybaptus novaehollandiae*	Australasian grebe			
Rallidae	*Fulica atra*	Eurasian coot			
Rallidae	*Gallinula tenebrosa*	Dusky moorhen			
Rallidae	*Porphyrio porphyrio*	Purple swamphen			
Rallidae	*Porzana fluminea*	Australian spotted crake			
Rallidae	*Porzana tabuensis*	Spotless crake			
Rallidae	*Tribonyx ventralis*	Black-tailed native-hen			
Recurvirostridae	*Himantopus himantopus*	Black-winged stilt			
Recurvirostridae	*Himantopus leucocephalus*	Pied stilt			
Recurvirostridae	*Recurvirostra novaehollandiae*	Red-necked avocet			
Scolopacidae	*Calidris ferruginea*	Curlew sandpiper	CR	EN	CR, C, J, RoK
Scolopacidae	*Calidris ruficollis*	Red-necked stint			
Scolopacidae	*Gallinago hardwickii*	Latham's snipe			
Scolopacidae	*Tringa nebularia*	Common greenshank	EN		
Threskiornithidae	*Platalea flavipes*	Yellow-billed spoonbill			
Threskiornithidae	*Platalea regia*	Royal spoonbill			
Threskiornithidae	*Plegadis falcinellus*	Glossy ibis			
Threskiornithidae	*Threskiornis moluccus*	Australian white ibis			
Threskiornithidae	*Threskiornis spinicollis*	Straw-necked ibis			
Fish					
Atherinidae	*Craterocephalus stercusmuscarum fulvus*	Unspecked hardyhead			
Cobitidae	*Misgurnus anguillicaudatus*	Oriental weatherloach	*	*	
Cyprinidae	*Carassius auratus*	Goldfish	*	*	
Cyprinidae	*Cyprinus carpio*	European carp	*	*	
Cyprinidae	*Tinca tinca*	Tench	*	*	
Eleotridae	*Hypseleotris klunzingeri*	Western carp gudgeon			
Eleotridae	*Philypnodon grandiceps*	Flatheaded gudgeon			
Galaxiinae	*Galaxias brevipinnis*	Climbing galaxias			
Galaxiinae	*Galaxias rostratus*	Flat-headed galaxias	CR		CR
Galaxiinae	*Galaxias* spp.	Galaxias			
Melanotaeniidae	*Melanotaenia fluviatilis*	Murray-Darling rainbowfish	EN		
Percichthyidae	*Gadopsis marmoratus*	River blackfish			
Percichthyidae	*Maccullochella macquariensis*	Trout cod	EN	EN	EN
Percichthyidae	*Maccullochella peelii*	Murray cod	EN	VU	VU
Percichthyidae	*Macquaria ambigua*	Golden perch			
Percichthyidae	*Macquaria australasica*	Macquarie perch	EN	EN	EN
Percichthyidae	*Nannoperca australis*	Southern pygmy perch (Murray-Darling)	VU		VU
Plotosidae	*Tandanus tandanus*	Freshwater catfish	EN		
Poeciliidae	*Gambusia holbrooki*	Mosquito fish	*	*	
Retropinnidae	*Retropinna semoni*	Australian smelt			
Terapontidae	*Bidyanus bidyanus*	Silver perch	CR		CR
Amphibians					

Family	Species	Common name	Vic	NSW	EPBC
Hylidae	*Litoria peronii*	Peron's tree frog			
Hylidae	*Litoria raniformis*	Southern bell frog		EN	VU
Limnodynastidae	*Limnodynastes dumerilii*	Eastern banjo frog			
Limnodynastidae	*Limnodynastes fletcheri*	Long-thumbed frog			
Limnodynastidae	*Limnodynastes tasmaniensis*	Spotted grass frog			
Myobatrachidae	*Crinia parinsignifera*	Eastern sign-bearing froglet			
Myobatrachidae	*Crinia signifera*	Common eastern froglet			
Myobatrachidae	*Crinia sloanei*	Sloane's froglet	EN	VU	EN
Myobatrachidae	*Uperoleia rugosa*	Wrinkled toadlet			
Reptiles					
Chelidae	*Chelodina expansa*	Broad-shelled turtle	EN		
Chelidae	*Chelodina longicollis*	Snake-necked turtle			
Chelidae	*Emydura macquarii*	Murray River turtle	CR		
Elapidae	*Pseudechis porphyriacus*	Red-bellied black snake			
Scincidae	*Eulamprus heatwolei*	Yellow-bellied water skink			
Scincidae	*Eulamprus tympanum*	Southern water-skink			
Crustacea					
Parastacidae	*Cherax destructor destructor*	Common yabby			
Parastacidae	*Cherax latimanus*	Barmah Swamp yabby			
Mammals					
Muridae	*Hydromys chrysogaster*	Rakali			
Ornithorhynchidae	*Ornithorhynchus anatinus*	Platypus	VU		
Vespertilionidae	*Myotis macropus*	Southern myotis		VU	

14.4 Flora species

The following plant species list was compiled by the Goulburn Broken CMA. The list presented below only includes aquatic dependent species – defined as those that spend a substantial part of their life-cycle in or around water and/or wetland ecosystems (incl mudflats) (T. Barlow, GBCMA, pers. comm. June 2023).

NB: This species list has been compiled from reports generated by the Victorian Biodiversity Atlas (for Barmah NP) and NSW BioNet (for Murray Valley NP) on 08/06/2023. No assurances can be made regarding the accuracy of the data, and therefore any liability for consequences of use.

List of water-dependent flora for Barmah-Millewa Forest. CR: Critically Endangered, EN: Endangered, VU: Vulnerable, K: Poorly known, #: Unclear origin, * introduced species

Species name	Common name	Vic	NSW	EPBC
Acaena novae-zelandiae	Bidgee-widgee			
Alisma plantago-aquatica	Water plantain			
Alopecurus aequalis	Orange fox-tail	*	*	
Alopecurus geniculatus	Marsh fox-tail	*	*	
Alternanthera denticulata s.l.	Lesser joyweed			
Ammannia multiflora	Jerry-jerry	EN		
Amphibromus fluitans	River swamp wallaby-grass	VU	VU	VU
Amphibromus macrorhinus	Long-nosed swamp wallaby-grass			
Amphibromus neesii	Southern swamp wallaby-grass			
Amphibromus nervosus	Common swamp wallaby-grass			
Amyema linophylla subsp. *orientalis*	Buloke mistletoe	CR		
Amyema miquelii	Box mistletoe			
Amyema pendula	Drooping mistletoe			
Aphanes arvensis	Parsley piert	*	*	
Aphanes australiana	Australian piert			
Asperula subsimplex	Water woodruff			
Azolla pinnata	Ferny azolla			
Azolla rubra	Pacific azolla			
Bellardia latifolia	Red bartsia	*	*	
Bolboschoenus medianus	Marsh club-sedge			
Brachyscome muelleroides	Mueller daisy	EN	VU	VU
Brachyscome paludicola	Woodland swamp-daisy			
Callitriche brutia subsp. *brutia*	Thread water-starwort	*	*	
Callitriche sonderi	Matted water-starwort			
Callitriche stagnalis	Common water-starwort	*	*	
Callitriche umbonata	Winged water-starwort	EN		
Calystegia sepium subsp. *roseata*	Large bindweed			
Cardamine moirensis	Riverina bitter-cress	EN		
Carex appressa	Tall sedge			
Carex bichenoviana	Plains sedge			
Carex gaudichaudiana	Fen sedge			
Carex inversa	Knob sedge	#	#	
Carex inversa (dwarf matted form)	Knob sedge (dwarf matted form)			
Carex tereticaulis	Poong'ort			
Centipeda cunninghamii	Common sneezeweed			
Centipeda elatinoides	Elatine sneezeweed			
Centipeda minima s.l.	Spreading sneezeweed			
Centipeda nidiformis	Cotton sneezeweed	EN		
Centipeda pleiocephala	Tall sneezeweed	EN		

Species name	Common name	Vic	NSW	EPBC
Convolvulus erubescens s.l.	Pink bindweed			
Coronidium gunnianum	Pale swamp everlasting	CR		
Cotoneaster glaucophyllus	Large-leaf cotoneaster	*	*	
Cotula coronopifolia	Water-buttons	*	*	
Craspedia glauca s.l.	Common billy-buttons			
Craspedia paludicola	Swamp billy-buttons			
Craspedia variabilis	Variable billy-buttons			
Crassula colorata	Dense crassula			
Crassula decumbens var. *decumbens*	Spreading crassula			
Crassula helmsii	Swamp crassula			
Crassula peduncularis	Purple crassula			
Crassula sieberiana s.l.	Sieber crassula			
Crassula tetragona subsp. *robusta*	Shrubby crassula	*	*	
Cuscuta australis	Australian dodder			
Cycnogeton multifructum	Northern water-ribbons	#	#	
Cycnogeton procerum s.s.	Common water-ribbons			
Cyperus bifax	Downs nutgrass	CR		
Cyperus difformis	Variable flat-sedge	#	#	
Cyperus eragrostis	Drain flat-sedge	*	*	
Cyperus exaltatus	Tall flat-sedge			
Cyperus flaccidus	Lax flat-sedge	EN		
Cyperus gunnii subsp. *gunnii*	Flecked flat-sedge			
Cyperus gymnocaulos	Spiny flat-sedge			
Cyperus leptocarpus	Button rush	EN		
Cyperus victoriensis	Yelka			
Damasonium minus	Star fruit			
Datura stramonium	Common thornapple	*	*	
Deyeuxia quadriseta	Reed bent-grass			
Dichondra repens	Kidney-weed			
Dodonaea viscosa subsp. *cuneata*	Wedge-leaf hop-bush			
Duma florulenta	Tangled lignum			
Elatine gratioloides	Waterwort			
Eleocharis acuta	Common spike-sedge			
Eleocharis pallens	Pale spike-sedge	K		
Eleocharis plana	Flat spike-sedge	CR		
Eleocharis pusilla	Small spike-sedge			
Elodea canadensis	Canadian pondweed	*	*	
Eragrostis infecunda	Southern cane-grass			
Eucalyptus camaldulensis	River red gum			
Eucalyptus camaldulensis subsp. *camaldulensis*	River red gum			
Eucalyptus largiflorens	Black box			
Eulalia aurea	Silky browntop			
Exocarpos cupressiformis	Cherry Ballart			
Exocarpos strictus	Pale-fruit Ballart			
Fimbristylis aestivalis	Summer fringe-sedge			
Fumaria bastardii	Bastard's fumitory	*	*	
Fumaria muralis subsp. muralis	Wall fumitory	*	*	
Glinus lotoides	Hairy carpet-weed			
Glinus oppositifolius	Slender carpet-weed			
Glossostigma cleistanthum	Small-flower mud-mat	EN		
Glossostigma drummondii	Desert mud-mat	K		
Glossostigma elatinoides	Small mud-mat			

Species name	Common name	Vic	NSW	EPBC
Goodenia fascicularis	Silky goodenia			
Goodenia glauca	Pale goodenia			
Goodenia gracilis	Slender goodenia			
Goodenia humilis	Swamp goodenia			
Gratiola peruviana	Austral brooklime			
Gratiola pubescens	Glandular brooklime			
Gratiola pumilo	Dwarf brooklime	VU		
Grevillea robusta	Silky oak	*	*	
Hakea tephrosperma	Hooked needlewood			
Haloragis aspera	Rough raspwort			
Haloragis glauca f. glauca	Bluish raspwort			
Haloragis heterophylla	Varied raspwort			
Hemarthria uncinata var. *uncinata*	Mat grass			
Hypsela tridens	Hypsela			
Isoetes muelleri	Rock quillwort			
Isolepis hookeriana	Grassy club-sedge			
Isotoma fluviatilis subsp. *australis*	Swamp isotome			
Juncus amabilis	Hollow rush			
Juncus aridicola	Tussock rush			
Juncus australis	Austral rush			
Juncus bufonius	Toad rush	#	#	
Juncus flavidus	Gold rush			
Juncus holoschoenus	Joint-leaf rush			
Juncus ingens	Giant rush			
Juncus radula	Hoary rush			
Juncus remotiflorus	Diffuse rush			
Juncus semisolidus	Plains rush			
Juncus subglaucus	Rush			
Lemna disperma	Common duckweed			
Limosella australis	Austral mudwort			
Limosella curdieana	Large mudwort			
Lobelia concolor	Poison pratia			
Lobelia pratioides	Poison lobelia			
Ludwigia palustris	Marsh ludwigia	*	*	
Ludwigia peploides subsp. *montevidensis*	Clove-strip	#	#	
Lycium ferocissimum	African box-thorn	*	*	
Lythrum salicaria	Purple loosestrife			
Maclura pomifera	Osage orange	*	*	
Malus pumila	Apple	*	*	
Marsilea costulifera	Narrow-leaf nardoo			
Marsilea drummondii	Common nardoo			
Marsilea hirsuta	Short-fruit nardoo			
Melaleuca parvistaminea	Rough-barked honey-myrtle			
Melia azedarach	White cedar	*	*	
Mentha australis	River mint			
Mentha satureioides	Creeping mint			
Mimulus gracilis	Slender monkey-flower			
Muellerina eucalyptoides	Creeping mistletoe			
Myosurus australis	Mousetail			
Myriophyllum caput-medusae	Coarse water-milfoil			
Myriophyllum crispatum	Upright water-milfoil			
Myriophyllum papillosum	Robust water-milfoil			

Species name	Common name	Vic	NSW	EPBC
Myriophyllum simulans	Amphibious water-milfoil			
Myriophyllum variifolium	Varied Water-milfoil			
Myriophyllum verrucosum	Red water-milfoil			
Nymphoides crenata	Wavy marshwort	EN		
Nymphoides geminata	Open marshwort	EN		
Ornduffia reniformis	Running marsh-flower			
Ottelia ovalifolia subsp. *ovalifolia*	Swamp lily			
Parietaria debilis s.s.	Shade pellitory			
Paspalidium jubiflorum	Warrego summer-grass	#	#	
Paspalum distichum	Water couch	*	*	
Persicaria decipiens	Slender knotweed			
Persicaria hydropiper	Water pepper	#	#	
Persicaria lapathifolia	Pale knotweed	#	#	
Persicaria praetermissa	Spotted knotweed			
Persicaria prostrata	Creeping knotweed			
Phragmites australis	Common reed			
Phyla nodiflora var. *minor*	Fog-fruit	*	*	
Poa labillardierei	Common tussock-grass			
Polygonum plebeium	Small knotweed			
Polypogon monspeliensis	Annual beard-grass	*	*	
Potamogeton australiensis	Thin pondweed			
Potamogeton cheesemanii	Red pondweed			
Potamogeton sulcatus	Furrowed pondweed			
Potamogeton tricarinatus s.l.	Floating pondweed			
Pseudocrossidium crinitum	Dusky beard-moss			
Pseudoraphis spinescens	Moira grass			
Pteridium esculentum subsp. *esculentum*	Austral bracken			
Pycnosorus globosus	Drumsticks	#	#	
Ranunculus inundatus	River buttercup			
Ranunculus lappaceus	Australian buttercup			
Ranunculus muricatus	Sharp buttercup	*	*	
Ranunculus pentandrus var. *platycarpus*	Inland buttercup			
Ranunculus pumilio var. *politus*	Ferny small-flower buttercup	K		
Ranunculus pumilio var. *pumilio*	Ferny small-flower buttercup			
Ranunculus sceleratus subsp. *sceleratus*	Celery buttercup	*	*	
Ranunculus sessiliflorus	Annual buttercup			
Ranunculus sessiliflorus var. *sessiliflorus*	Annual buttercup			
Ranunculus trilobus	Large annual buttercup	*	*	
Ricciocarpos natans	Fringed heartwort			
Rorippa eustylis	Dwarf bitter-cress	EN		
Rorippa laciniata	Jagged bitter-cress			
Rorippa palustris	Marsh yellow-cress	*	*	
Rosa canina	Dog rose	*	*	
Rosa rubiginosa	Sweet biar	*	*	
Rubus anglocandicans	Common blackberry	*	*	
Rubus fruticosus spp. agg.	Blackberry	*	*	
Rubus ulmifolius var. *ulmifolius*	Elm-leaf blackberry	*	*	
Rumex brownii	Slender dock			
Rumex conglomeratus	Clustered dock	*	*	
Rumex crystallinus s.l.	Glistening dock			
Rumex tenax	Narrow-leaf dock			
Rytidosperma duttonianum	Brown-back wallaby-grass			

Species name	Common name	Vic	NSW	EPBC
Sagittaria platyphylla	Sagittaria	*	*	
Salix babylonica s.l.	Weeping willow	*	*	
Salix X rubens	Basket willow	*	*	
Santalum lanceolatum	Northern sandlewood	CR		
Schinus molle	Pepper tree	*	*	
Solanum aviculare	Kangaroo apple			
Solanum esuriale	Quena			
Solanum laciniatum	Large kangaroo apple			
Solanum nigrum s.l.	Black nightshade	*	*	
Solanum pseudocapsicum	Madeira winter-cherry	*	*	
Spirodela punctata	Thin duckweed			
Stellaria angustifolia subsp. *angustifolia*	Swamp starwort			
Stellaria angustifolia subsp. *tenella*	Matted starwort			
Swainsona procumbens	Broughton pea			
Syntrichia papillosa	Screw moss			
Tribulus terrestris	Caltrop	#	#	
Triquetrella papillata	Common twine-moss			
Typha domingensis	Narrow-leaf cumbungi			
Typha orientalis	Broad-leaf cumbungi			
Urtica incisa	Stinging nettle	*	*	
Urtica urens	Small nettle	*	*	
Utricularia australis	Yellow bladderwort			
Vallisneria americana var. *americana*	Eel grass			
Viola betonicifolia subsp. *novaguineensis*	Floodplain violet	EN		
Wahlenbergia fluminalis	River bluebell			

15 Appendix 2: Risk assessment

Semi-quantitative risk analysis is often used analyse risks associated with infrastructure projects. The approach is compliant with the AS/NZS ISO 31000:2009 Risk management - Principles and Guidelines. This risk assessment process is based upon an Ecological Risk Assessment process developed by Victoria EPA (EPA 2004), and has seven steps:

- Clearly define the management context for the risk assessment;
- Identify the values associated with the ecosystems to have TLM operations undertaken and any connected waterways;
- Identify the threats posed to the values associated with the TLM operations;
- Develop an explicit statement of investigation and associated conceptual model (completing problem formulation) for the risk assessment;
- Undertake a preliminary risk analysis with existing information and local knowledge;
- Document and incorporate gaps identified and assumptions made during the process to characterise the risk; and,
- Report recommendations for appropriate risk mitigation actions to protect values and reduce threats to these values.

Semi-quantitative risk assessments use a categorical approach to describe the **consequences** and **likelihood** (or probability) of threats having impacts on the values at the site:

- Risk = Consequence x Likelihood
- Risk Attribute Definitions

Risk tables provide a consistent way of allocating the level of consequence and likelihood for each threat on the values of each site. The risk scores are calculated as the product of consequence (Table 32) and likelihood (Table 33) under conditions likely to be experienced during operational phase of the project works for TLM project. Table 34 details the definitions of the levels of risk and the management response required.

Table 32: Definitions for assigning levels of the consequences of threats.

	Level	Description
Consequences	Minor (1)	The effects are limited in extent or duration and do not significantly impact on the asset values
	Moderate (2)	The effects are moderate in extent or duration and are in conflict with asset values or will have minor impacts on offsite values
	Severe (3)	The event significantly undermines asset values or moderately impacts on offsite values
	Catastrophic (4)	The event is in significant conflict with asset values or has severely impacts offsite values and will result in a serious deterioration of the system

Table 33: Definitions for assigning levels of the likelihood of threats.

	Level	Description
Likelihood	Remote (1)	An event which is not expected to occur but may occur under rare, exceptional circumstances
	Unlikely (2)	An event which is not expected to occur as a result of normal activities but may occur
	Possible (3)	An event which is possible and will occasionally occur as a result of normal activities
	Likely (4)	An event which is expected to occur as part of normal activities
	Certain (5)	An event which is certain to occur as a result of normal activities

Table 34: Risk is calculated as the product of consequence and likelihood scores.

		Consequence			
		Minor (1)	Moderate (2)	Severe (3)	Catastrophic (4)
Likelihood	Remote (1)	1	2	3	4
	Unlikely (2)	2	4	6	8
	Possible (3)	3	6	9	12
	Likely (4)	4	8	12	16
	Certain (5)	5	10	15	20

Table 35: Definitions of the levels of risk.

	Scores	Risk	Definitions
Risk	1-2	Negligible	There is no reasonable prospect that the environmental objectives will be affected by the event.
	3-4	Low	The event is a low priority for management but risk management measures should be considered.
	5-8	Moderate	The risk is a moderate priority for management. Risk management measures should be undertaken.
	9-12	High	The risk is a high priority for management. There is a reasonable likelihood it will occur and will have harmful consequences in terms of achieving environmental objectives. Risk management is essential.
	15-20	Extreme	The risk is a very high priority for management. It is likely to occur and will have very harmful consequences in terms of environmental objectives. Risk management is essential

15.1 Barmah-Millewa Ramsar site risk assessment and mitigation

A detailed risk assessment was undertaken as part of the Ramsar site management plans for Barmah and the NSW Central Murray forests (DELWP 2018), as well as the Barmah Forest joint plan of management (YYTOLMB and YYNAC 2020). High priority threats are presented in Table 36.

Table 36. Key threats and levels of risk to conservation assets and values (adapted from YYTOLMB and YYNAC 2020).

Threat	River red gum forest and woodlands condition and extent	Floodplain marshes Moira grass extent	Wetland birds Colonial nesting waterbirds	Native fish	Other water dependent species (e.g., Murray spiny crayfish, frogs, turtles)	First Nation cultural heritage values	Recreational values	Mitigation measures
Inappropriate (altered) water regimes	Low	**High**	Medium	Low	Medium	Medium	Low	Provision for environmental water deliveries to maintain ecological character. Diverting irrigation rejection.
Inappropriate (altered) fire regimes	Medium	Low	Negligible	Negligible	Low	Medium	Medium	Maintaining tolerable fire intervals through the exclusion of fire, plus preparedness and effective response,
Predation by foxes and cats	Negligible	Negligible	Medium	Negligible	**High**	**High**	Low	Fox control (baiting) of the park boundary and turtle nest sites.
Grazing, browsing and trampling (foraging) pressure on wetlands and cultural sites from feral horses, feral pigs and goats, feral deer, rabbits, kangaroos	Medium	**Extreme**	Low	Negligible	Medium	**Extreme**	Medium	Feral pig trapping and shooting. Horse exclusion fence trial (one wetland). Rabbit baiting and night-shooting. Site protection.
Competition from alien fish (e.g., carp)	Negligible	Low	Negligible	**High**	Medium	Medium	**High**	No current mitigation measures.

Threat	River red gum forest and woodlands condition and extent	Floodplain marshes Moira grass extent	Wetland birds Colonial nesting waterbirds	Native fish	Other water dependent species (e.g., Murray spiny crayfish, frogs, turtles)	First Nation cultural heritage values	Recreational values	Mitigation measures
Incursion by invasive plants (e.g., arrowhead, incursion by giant rush and River red gum saplings)	Low	**High**	Medium	Low	Low	Medium	Medium	Environmental watering. Herbicides registered for use in aquatic situations. Cutting/burning for rush/saplings.
Illegal recreation activity (off road, damage to vegetation)	Medium	Low	Low	Low	Low	Medium	Medium	Enforced compliance on illegal activities, education.
Legal recreation activity (generating erosion, sedimentation, disturbance)	Medium	Medium	Medium	Medium	Low	Medium	Low	Maintenance activities e.g., roads, boat ramps.

Table 37. Extreme and high risk threats to environmental values (adapted from Hale and Dickson 2020).

Pressures	Stressors	Effect	Likelihood of impact	Consequence of impact	Risk	Evidence / comments
Water resource use	Altered water regimes	Adversely affects floodplain marshes	Almost certain	Moderate	High	There is a large body of evidence that indicates that unseasonal and insufficient inundation is contributing to the demise of Moira grass (Ward 2019).

Pressures	Stressors	Effect	Likelihood of impact	Consequence of impact	Risk	Evidence / comments
Water resource use	Altered water regimes	Adversely affects threatened vegetation species	Almost certain	Moderate	High	There is some evidence of river red gum encroachment into swamp wallaby-grass wetlands as a result of insufficient duration of inundation (Raymond et al. 2019). Mueller daisy recorded in Barmah meadows in August 2019 (Tim Barlow pers. comm.).
Water resource use	Altered water regimes	Impacts fish abundance and diversity	Almost certain	Moderate	High	While overall condition scores for fish with respect to population and recruitment have been fair to good in recent years, there are a number of species that were previously common in the site that are now absent (e.g., freshwater catfish (*Tandanus tandanus*), river blackfish (*Gadopsis marmoratus*), Murray hardyhead (*Craterocephalus fluviatilis*), southern pygmy perch (*Nannoperca australis*), and olive perchlet (*Ambassis agassizii*). In addition, the fish condition scores were better in permanent rivers and streams than in the temporary wetland environments. Both of these findings were attributed to insufficient wetland inundation (Raymond et al. 2019).
Invasive species	Foxes and cats	Impacts wetland bird threatened species (Australasian bittern)	Likely	Major	High	Recent bittern monitoring at Barmah Forest has suggested that foxes and cats may be predating on Australasian bittern (Vivian 2013, Colloff et al. 2014b, Ward 2017).
Invasive species	Foxes and cats	Impacts wetland bird threatened species (superb parrot)	Likely	Major	High	As identified in the superb parrot recovery plan.

Pressures	Stressors	Effect	Likelihood of impact	Consequence of impact	Risk	Evidence / comments
Invasive species	Feral horses	Adversely affects river red gum forests and woodlands	Likely	Major	High	Horses can affect both the understory of forest communities as well as limit recruitment of seedlings through grazing & trampling. In addition, grazing can remove grass competition, allowing tree seedlings to establish en masse
Invasive species	Feral horses	Adversely affects floodplain marshes	Almost certain	Extreme	Extreme	There is a large body of evidence of feral horses, impacting on floodplain marshes (Ward 2019). The extent of Moira grass has declined significantly, and the LAC has been exceeded, largely due to feral horse trampling and grazing. Fencing that excludes horses (but not native grazers such as kangaroos) have highlighted that impact of feral horses on wetland flora.
Invasive species	Feral horses	Adversely affects threatened vegetation species	Almost certain	Major	Extreme	Swamp wallaby-grass has been threatened by feral horses grazing and trampling at Little Rushy Swamp.
Invasive species	Feral horses	Impacts wetland bird threatened species (Australasian bittern)	Likely	Major	High	Wetland areas in Barmah Forest that support bitterns and colonial nesting birds are being impacted by feral horses, impacting habitat and potentially breeding success.
Invasive species	Feral horses	Impacts wetland bird threatened species (superb parrot)	Likely	Major	High	Grazing unlikely to affect hollow bearing trees.

Pressures	Stressors	Effect	Likelihood of impact	Consequence of impact	Risk	Evidence / comments
Invasive species	Pigs	Adversely affects floodplain marshes	Almost certain	Extreme	Extreme	As per Pest Plant and Animal Strategy (Ecology Australia 2013)
Invasive species	Pigs	Adversely affects threatened vegetation species	Likely	Major	High	As per Pest Plant and Animal Strategy (Ecology Australia 2013)
Invasive species	Pigs	Impacts wetland bird abundance and diversity	Almost certain	Major	High	Wetland areas in Barmah Forest that support bitterns and colonial nesting birds are being impacted by feral pigs, impacting habitat and potentially breeding success
Invasive species	Pigs	Impacts wetland bird breeding	Almost certain	Major	Extreme	Evidence of waterbird nesting being impacted by pigs trampling and predation.
Invasive species	Pigs	Impacts wetland bird threatened species (Australasian bittern)	Likely	Major	High	Based on impact to habitat
Invasive species	Deer Rabbits, goats, other grazers	Adversely affects river red gum forests and woodlands	Almost certain	Moderate	High	As per Pest Plant and Animal Strategy (Ecology Australia 2013) – noting that risk from rabbits was considered higher than that for goats and deer.

Pressures	Stressors	Effect	Likelihood of impact	Consequence of impact	Risk	Evidence / comments
Invasive species	Rabbits, goats, other grazers	Adversely affects threatened vegetation species	Almost certain	Major	Extreme	As per Pest Plant and Animal Strategy (Ecology Australia 2013)
Invasive species	Rabbits, goats, other grazers	Impacts wetland bird threatened species (Australasian bittern)	Likely	Major	High	Wetland areas that support bitterns at Barmah Forest are being impacted by feral horses, impacting habitat and potentially breeding success.
Invasive species	Exotic fish (carp, gambusia, goldfish)	Adversely affects floodplain marshes	Likely	Major	High	Carp can have an effect on vegetation in wetland systems through disturbance of sediments and uprooting plants. Risk based on Pest Plant and animal strategy (Ecology Australia 2013)
Invasive species	Exotic fish (carp, gambusia, goldfish)	Impacts fish abundance and diversity including threatened species	Likely	Major	High	In wetland habitats, the abundance of exotic fish species has remained consistently greater than native fish numbers over the past decade, with high numbers of gambusia since 2010 (Raymond et al. 2019). There has however, been studies suggesting that removal of gambusia from wetland habitats did not improve native fish condition (Tonkin et al. 2013)
Climate change	Altered water regimes	Adversely affects floodplain marshes	Possible	Major	High	Floodplain marshes are already affected by reduced frequency and duration of inundation and this is likely to continue (or be exacerbated) into the future.

Pressures	Stressors	Effect	Likelihood of impact	Consequence of impact	Risk	Evidence / comments
Climate change	Altered water regimes	Adversely affects threatened vegetation species	Possible	Major	High	Floodplain marshes are already affected by reduced frequency and duration of inundation and this is likely to continue (or be exacerbated) into the future.
Climate change	Altered water regimes	Impacts wetland bird breeding	Likely	Major	High	Waterbird breeding is vulnerable to climate change (Garnett et al. 2013). Providing adequate duration of inundation for completion of breeding cycles by waterbirds is likely to become increasingly difficult in a future with less water availability.
Climate change	Altered water regimes	Impacts wetland bird threatened species (Australasian bittern)	Likely	Major	High	Bitterns have been identified as bring highly vulnerable to climate change impacts (Timbal et al. 2016). In addition, the floodplain marsh habitat for this species is also highly vulnerable.

16 Appendix 3: Objective mapping to Basin Plan

Environmental objectives represent the desired environmental outcomes based on the management goal in Section 7.1, as well as the key values outlined in the Environmental Values section (Section 5.4).

Environmental watering objectives for Barmah-Millewa Forest icon site were first prepared in 2012 (MDBA 2012) and have subsequently undergone a number of refinements. The various iterations of objectives for the icon site are listed in Table 38.

The update of the objectives takes into consideration the values in each of the Water Regime Classes (see Section 3.3.5 and 5.1). The EWMP objectives and associated targets have been aligned to the Basin-side Environmental Watering Strategy and the Victorian Murray LTWP (DELWP 2021a). Overall, this will increase line of sight to the Basin Plan and its reporting requirements. The objectives have adopted the language/terminology of the Basin Plan and written using the SMART[12] concept as per the Victorian EWMP Guidelines (DELWP 2022).

The primary environmental outcome of the Basin Plan is the protection and restoration of water-dependent ecosystems and ecosystem functions in the Murray-Darling Basin, with strengthened resilience to a changing climate (Basin Plan themes). The MDBA is required to measure progress towards achieving the objectives of the Environmental Watering Plan (EWP) (Chapter 8 of the Basin Plan) by using the targets in Schedule 7 and having regard to the long-term average sustainable diversion limits, environmental objectives, and targets. These are set out in LTWPs for the asset scale, the Basin-wide Environmental Watering Strategy (BWS) and annual Basin environmental watering priorities for the Basin scale.

When updating existing EWMP objectives all changes are required to be documented including a rationale or justification of why changes have been made. Where alignment to the Environmental Management Framework of the Basin Plan is applicable line of sight to the following is required (DELWP 2022):

- The Chapter 8 Environmental Watering Plan objectives and expected environmental outcomes as specified in the Basin-wide Environmental Watering Strategy,
- Long Term Watering Plan objectives and targets, and
- Schedules 7-9 targets and criteria.

The mapping has been presented according to the objective logic of the Basin Plan: Ecosystem type and biodiversity, ecosystem function and ecosystem resilience and climate change (Figure 15).

[12] SMART – Specific, Measurable, Achievable, Relevant and Timebound

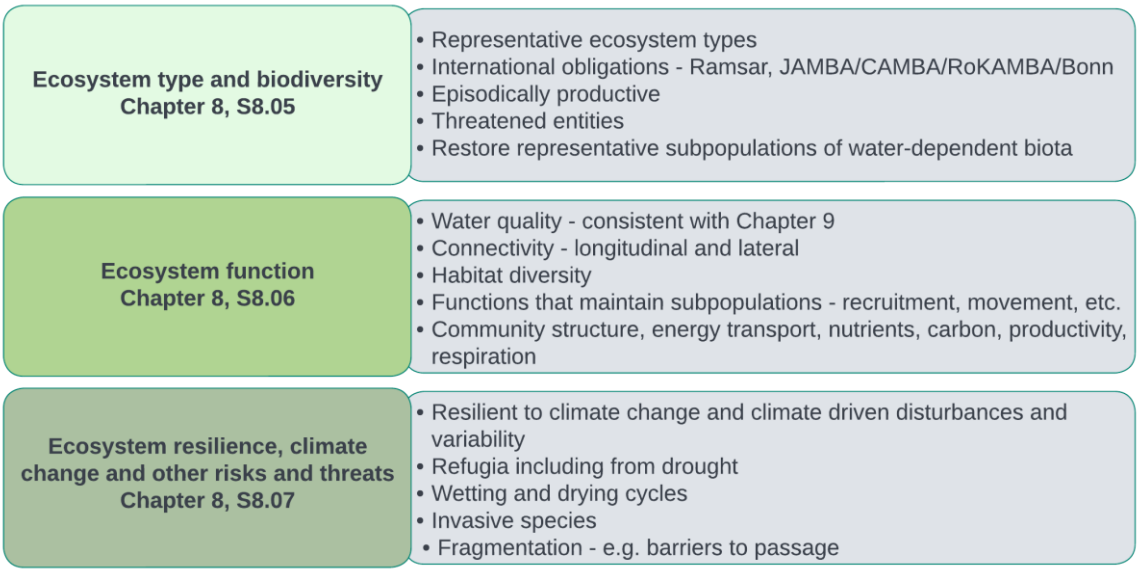

Figure 15. Basin Plan Environmental Watering Plan objective logic adopted.

Objectives and where detailed, targets, have been extracted from the following documents:

- Barmah-Millewa Forest Environmental Water Management Plan (MDBA 2012).
- Barmah Forest ecological watering guide, A practical guide for managing environmental water on the Barmah Forest floodplain, version 1.1. (Ward 2015).
- Reports from the TLM refinement project (Robinson 2014, 2018a).
- Victorian Murray LTWP (DELWP 2021c).
- Murray-Lower Darling LTWP (DPIE 2020a, b).

Table 38 Objectives from key documents for Barmah-Millewa Forest Icon site.

Objective type	Asset	Mapping code		Comment	Source
Overarching TLM objectives for Barmah-Millewa Forest	BMF	O1	Restore the extent and distribution of healthy wetland and floodplain vegetation communities	Retain with no change. Targets are not set for overarching objectives	MDBA (2012), Butcher (2018),
	BMF	O2	Provide suitable feeding and breeding habitat for a range of waterbirds, including colonial nesting species		
	BMF	03	Support successful breeding and recruitment of native fish species		
	BMF	04	Provide high quality feeding, breeding and nursery habitat for native frogs, turtles and crayfish		
Detailed TLM objectives – vegetation	BMF	D1	Promote healthy and diverse vegetation communities, with an emphasis on restoring natural extent and distribution of giant rush, Moira grass, river red gum forest and river red gum woodland in at least 55% of the Barmah–Millewa icon site.		D1a, b - MDBA (2012)
	BMF	D2	Facilitate healthy and diverse vegetation to provide suitable, breeding and foraging habitat for a diverse range of waterbirds and bush birds.		
	BMF	D3	Promote vegetation with an appropriate abundance and richness of native species in wetlands and ephemeral creeks.	Need to specify which creeks this refers to.	Ward (2015)
	BMF	D4	Maintain and restore the abundance of legislatively threatened water dependent flora species.	Doesn't map to any other objective – not captured in LTWP despite Schedule 8 criteria being met. Threatened frogs have objectives in the NSW LTWP, but no flora.	
	BMF	D5	Restrict the abundance, spread and incursion of invasive aquatic species.		

Objective type	Asset	Mapping code		Comment	Source
	BMF	D6	Successful growth and flowering of Moira grass plants.		
	BMF	D7	Promote populations of healthy trees in forests and woodlands with appropriate density, recruitment and habitat trees.		
	BMF	D8	An appropriate diversity and abundance of native understorey species in forests and woodlands.	Understorey is not captured in the LTWP objectives – can it be assumed to be implicit?	
		D9	Promote the open character of the Moira grass plains and restore the total area dominated by Moira grass plants.		
Detailed TLM objectives - birds	BMF	D10	Promote and/or sustain successful breeding events for thousands of colonial and migratory waterbirds at least once every five years by inundating selected floodplain and wetland areas to provide suitable nesting and feeding habitat.		Tranter and Ward (2014) cited in Ward (2015)
	BMF	D11	Healthy waterbird assemblages as defined by high species richness and relative abundance present in Barmah-Millewa Forest each year.		
		D12	The overall health or condition of the floodplain and non-floodplain habitat types present in Barmah-Millewa Forest will be reflected in woodland bird populations.	Need to unpack this further to determine point of reference and update the objective language	
Detailed TLM objectives - fish	BMF	D13	Promote sustainable native fish communities across the whole Barmah-Millewa Icon Site waterways and wetlands and the adjacent River Murray channel.		Tranter and Ward (2014) cited in Ward (2015)
	BMF	D14	Facilitate the recovery of rare native fish species.	Maps to B28 refined objective; no other objective specific to threatened fish. Retain as PEA criteria met.	

Objective type	Asset	Mapping code		Comment	Source
	BMF	D15	Allow (for bi-directional movement to provide) access to a diversity of feeding and breeding areas for native fish within and between river and (B-MF) floodplain habitats.		
	BMF	D16	Fish populations at B-MF will be composed predominantly of native fish.		
	BMF	D17	Provide enhanced breeding opportunities for native riverine fish species in the main river channel adjacent to the Icon Site.		
Detailed TLM objective - crayfish	BMF	D18	Promote sustainable Murray Crayfish populations in Barmah-Millewa Forest waterways and the adjacent River Murray channel.	Abundance of subpopulation, not about habitat as per D23	MDBA (2012), Ward (2015)
Detailed TLM objective - frogs	BMF	D19	Facilitate successful breeding and feeding opportunities for native frog species by seasonal inundation of selected floodplain and wetland areas for appropriate season and duration as required for each species.	Breeding of frogs, not about habitat as per D23	
Detailed TLM objective - turtles	BMF	D20	Facilitate successful breeding of native turtle species by inundation of selected floodplains and wetland areas to provide suitable breeding and nursery habitat.	Breeding, not about habitat as per D23	
Specific objectives for Barmah-Millewa Forest TLM condition monitoring	BMF	D21	Promote healthy and diverse vegetation communities, with an emphasis on restoring natural extent and distribution of giant rush (*Juncus ingens*), Moira grass (*Pseudoraphis spinescens*), river red gum (*Eucalyptus camaldulensis*) forest and river red gum woodland in at least 55% of the Barmah–Millewa icon site.	Split into major veg types in the LTWP see DEWLP 2021a. The magnitude of change is more specific in this version – needs to be aligned with the objectives and targets in the LTWPs.	Butcher (2018) – updated objectives were provided by MDBA
	BMF	D22	Facilitate healthy and diverse vegetation to provide suitable, breeding and foraging habitat for a diverse range of waterbirds and bush birds.		
	BMF	D23	Promote and/or sustain successful breeding events for thousands of colonial and migratory waterbirds in at least 3		

Objective type	Asset	Mapping code		Comment	Source
			years in 10 by inundating selected floodplain and wetland areas to provide suitable nesting and feeding habitat.		
	BMF	D24	Promote successful recruitment of native fish species by improving flow variability in spring and early summer to replicate natural cues, and by inundation of floodplain and wetland areas to provide breeding and nursery habitat.	Hydraulics, recruitment, habitat – split.	
	BMF	D25	Provide high quality feeding, breeding and nursery habitat for native frogs, turtles and crayfish.	About habitat for fauna	
Refined condition objectives - vegetation	BMF	D26	Promote vegetation with an appropriate abundance and richness of native species in wetlands and ephemeral creeks.	Maps to D1	Robinson (2018a), Arcadis (2022)
	BMF	D27	An appropriate diversity and abundance of native understorey species in forest and woodlands.	Maps to D5. Understorey not captured in LTWP objectives	
Refined condition objectives - birds	BMF	D28	Healthy colonial water bird assemblages as defined by high species richness and relative abundance present in Barmah-Millewa Forest each year		Robinson (2018b)
Additional fish objectives	BMF	D29	Promote sustainable native fish communities across the whole Barmah-Millewa Icon Site waterways and wetlands and the adjacent River Murray channel	Maps to D14	Robinson (2015)
	BMF	D30	(Facilitate) the recovery of rare native fish species (Southern pygmy perch, dwarf flathead gudgeon, trout cod, lamprey and catfish)		
	BMF	D31	Fish populations at Barmah-Millewa Forest will be composed predominantly of native fish	Maps to	
Barmah Forest, including Tullah Creek – LTWP (2021a)	Barmah	VIC1	Va. Promote healthy and diverse vegetation communities, with an emphasis on restoring natural extent and distribution of giant rush in at least 55% of the Barmah–Millewa icon site.	TLM objective split into 5 objectives (see Vb - Ve) but same magnitude of change kept for all vegetation groups. This may need to be updated.	DEWLP (2021a)

Objective type	Asset	Mapping code		Comment	Source
	Barmah	VIC2	Vb. Promote healthy and diverse vegetation communities, with an emphasis on restoring natural extent and distribution of Moira grass in at least 55% of the Barmah–Millewa icon site.	Maps to D1, D2, D3, D19 (in part), D24 (in part), NSW2a	
	Barmah	VIC3	Vc. Promote healthy and diverse vegetation communities, with an emphasis on restoring natural extent and distribution of river red gum forest in at least 55% of the Barmah–Millewa icon site.	Maps to D4 (in part), D19 (in part), NSW5, NSW6	
	Barmah	VIC4	Vd. Promote healthy and diverse vegetation communities, with an emphasis on restoring natural extent and distribution of river red gum woodland in at least 55% of the Barmah–Millewa icon site.	Maps to D4 (in part), D19 (in part), NSW5, NSW7	
	Barmah	VIC5	Ve. Promote healthy and diverse vegetation communities, with an emphasis on restoring natural extent and distribution of blackbox woodland in at least 55% of the Barmah–Millewa icon site.	Maps to D4 (?), D5 (?), NSW8. Black box not overtly mentioned in original objectives for the Barmah section of the icon site.	
	Barmah	VIC6	Wba. Promote and/or sustain successful breeding events for thousands of colonial and migratory waterbirds in at least 3 years in 10 by inundating selected floodplain and wetland areas to provide suitable nesting and feeding habitat.		
	Barmah	VIC7	Fa: Promote successful recruitment of native fish species by improving flow variability in spring and early summer to replicate natural cues, and by inundation of floodplain and wetland areas to provide breeding and nursery habitat.	Maps to D22, in part to D11, D13, D15	
	Barmah	VIC8	OFN: Provide high quality feeding, breeding and nursery habitat for native frogs, turtles and crayfish by: Facilitate successful breeding and feeding opportunities for native	Editing issue in the LTWP – not sure what the remainder of the objective relates to. Maps to D16-18	

Objective type	Asset	Mapping code		Comment	Source
			frog species by seasonal inundation of selected floodplain and wetland areas for		
Overarching objective – Lower Murray LTWP (DPIE 2020a)	Millewa	ONSW1	Maintain and improve the viability and extent of river red gum, black box and coolabah communities, lignum shrublands and non-woody wetland and in-channel vegetation		DPIE (2020a, b)
		NSW2	NV1: Maintain the extent and viability of non-woody vegetation communities occurring with or closely fringing river channels	Maps in part to D1, and possibly VIC1, VIC2. Specifics to river channels is distinct to Barmah objectives for non-woody vegetation outcomes which is about wetlands and ephemeral creeks.	
		NSW3	NV2a: Maintain the extent and viability of non-woody vegetation communities occurring in wetlands and on floodplains (semi-permanent, intermittent, temporal and ephemeral wetlands)	Maps in part to D1, VIC1, VIC2.	
		NSW4	NV2b: Maintain the extent and viability of non-woody vegetation communities occurring in wetlands and on floodplains (ephemeral understorey vegetation within forests, woodlands and open floodplain areas)	Maps to D5 – refers to understorey	
		NSW5	NV3: Maintain the extent and maintain or improve the condition of river red gum communities closely fringing river channels.	Maps to D4 but Barmah doesn't have reference to river channels.	
		NSW6	NV4a: Maintain the extent and maintain or improve the condition of river red gum forest	Maps to D4 (in part)	
		NSW7	NV4b: Maintain the extent and maintain or improve the condition of river red gum woodland	Maps to D4 (in part)	

Objective type	Asset	Mapping code		Comment	Source
		NSW8	NV4c: Maintain the extent and maintain or improve the condition of black box woodland	Doesn't map to Barmah objectives, black box not mentioned explicitly in Barmah	
		NSW9	WB1: Maintain the number and type of waterbird present		
		NSW10	WB2: Increase total waterbird abundance		
		NSW11	WB3: Increase breeding activity in non-colonial nesting waterbirds		
		NSW12	WB4: Increase opportunities for colonial waterbird breeding events		
		NSW13	WB5: Maintain the extent and improve condition of waterbird habitats		
		NSW14	NF1: No loss of native fish species	Doesn't map specifically to Barmah objectives, but intent of B29 may overlap to some degree. Will need to decide on the language adopted – if the focus is on biomass/ abundance as per D28 or loss of species.	
		NSW15	NF2: Increase the distribution and abundance of short to moderate lived generalist native fish species	Reference to life span doesn't map to Barmah fish objectives. Need decision on if include this level of specificity – does have greater alignment to BEWS.	
		NSW16	NF3: Increase the distribution and abundance of short to moderate-lived floodplain specialist native fish species		

Objective type	Asset	Mapping code		Comment	Source
		NSW17	NF4: Improve native fish population structure for moderate to long-lived flow pulse specialist native fish species	Population structure could refer to recruitment – need to specify the species involved	
		NSW18	NF5: Improve native fish population structure for moderate to long-lived riverine specialist native fish species	Population structure could refer to recruitment – need to specify the species involved.	
		NSW19	NF6: A 25% increase in abundance of mature (harvestable sized) golden perch & Murray cod	Doesn't map to Barmah fish objectives	
		NSW20	NF7: Increase the prevalence and/or expand the population of key short to moderate-lived floodplain specialist native fish species into new areas (within historical range)	May in part map to D28 if translocation is involved.	
		NSW21	NF8: Increase the prevalence and/or expand the population of key moderate to long-lived riverine specialist native fish species into new areas (within historical range)		
		NSW22	NF9: Increase the prevalence and/or expand the population of key moderate to long-lived flow pulse specialists native fish species into new areas (within historical range)		
		NSW23	NF10: Increase the prevalence and/or expand the population of key moderate to long-lived diadromous native fish species into new areas		
		NSW24	OS1: Maintain species richness of flow-dependent frog communities		
		NSW25	OS2: Maintain successful breeding opportunities for flow-dependent frog species		
		NSW26	OS3a: Maintain & increase number of wetland sites occupied by the threatened southern bell frog		

Objective type	Asset	Mapping code		Comment	Source
		NSW27	OS3b: Maintain & increase number of wetland sites occupied by the threatened Sloane's froglet		
		NSW28	OS4: Maintain water-dependant species richness	Needs further clarification – this is too open ended.	
		NSW29	EF1: Provide & protect a diversity of refugia across the landscape		
		NSW30	EF2: Create quality instream, floodplain and wetland habitat		
		NSW31	EF3a: Provide movement & dispersal opportunities within catchments for water-dependent biota to complete lifecycles		
		NSW32	EF4: Support instream & floodplain productivity		
		NSW33	EF5: Support nutrient, carbon & sediment transport along channels, & exchange between channels & floodplains/wetlands		
		NSW34	EF6: Support groundwater conditions to sustain groundwater dependent biota		
		NSW35	EF7: Increase NSW Murray-Lower Darling contributions to the South Australian Murray		

16.1 Mapping to Basin Plan

The process for identifying priority ecosystem assets differs in NSW and Victoria, Millewa Forest contains 43 separate assets whereas Barmah is treated as a single asset. For the purposes of this report Millewa is assessed against the Schedule 8 and 9 criteria as a single asset, reference to assets identified in DPIE (2020) will be made in the targets for the Icon site. The main issue this creates is that in NSW priority ecosystem functions are identified, but they have not been identified for Barmah.

The Victorian Murray River LTWP and Murray–Lower Darling LTWP contain high-level assessments against the Basin Plan Schedule 8 and 9 criteria (DPIE 2020, DELWP 2021c). The set of Schedule 8 and 9 criteria specified as being met by Barmah-Millewa Forest are shown in Table 39. An updated assessment based on the current values of the site, refines this understanding of which criteria are met by the site. The updated assessment reflects the values listed in the EWMP and the objectives as they currently stand.

Table 39. Basin Plan Schedule 8 and 9 criteria relevant to Barmah-Millewa Forest. Those criteria shaded in the updated assessment require objectives to be developed.

Schedule 8 criteria met		Schedule 9 criteria met	
From DELWP (2021c)	**From DPIE (2020a)**	**From DELWP (2021c)**	**From DPIE (2020a)**
Note: Barmah Forest is considered a single Priority Environmental Asset **1:** Ramsar, JAMBA, CAMBA, ROKAMBA, Bonn Convention **3:** Important breeding, nursery and feeding habitat – waterbirds and fish **4:** EPBC Act, FFG Act **5:** Supports significant numbers of water dependent species	**Note: Millewa Forest supports 22 creeks, a section of the Murray and 21 forest lakes and wetlands listed as separate Priority Environmental Assets (DPIE 2020b).** **1:** The water-dependent ecosystem is formally recognised in international agreements or with environmental watering is capable of supporting species listed in these agreements **2:** The water-dependent ecosystem is natural or near natural, rare or unique **3:** the water-dependent ecosystem provides vital habitat **4:** water-dependent ecosystem that support Commonwealth, State or territory species or communities **5:** The water-dependent ecosystem support, or with environmental watering is capable of supporting significant biodiversity	None identified for Barmah Forest – the LTWP notes PEF criteria met in the WRPA but Barmah is not listed as an asset at which the PEFs are identified as relevant.	Doesn't actually list the criteria, rather paraphrases into 7 ecological functions. • Drought refuge • Quality instream habitat • Movement and dispersal opportunities for animals • Instream and floodplain productivity • Groundwater dependent biota • Sediment, carbon and nutrient exchange
Barmah updated assessment	**Millewa updated assessment**	**Barmah updated assessment**	**Millewa updated assessment**
1(a): a declared Ramsar site **1(b):** supports migratory species listed under JAMBA, CAMBA, RoKAMBA or Bonn **2(c):** represents a rare example of a particular type of water-dependent ecosystem in the Murray-Darling Basin **3(a)(i):** provides vital habitat, including: a refugium for native water-dependent biota during dry spells and drought **3(a)(ii):** provides vital habitat, including: pathways for the dispersal, migration	**1(a):** a declared Ramsar site **1(b):** supports migratory species listed under JAMBA, CAMBA, RoKAMBA or Bonn **2(c):** represents a rare example of a particular type of water-dependent ecosystem in the Murray-Darling Basin **3(a)(i):** provides vital habitat, including: a refugium for native water-dependent biota during dry spells and drought **3(a)(ii):** provides vital habitat, including: pathways for the dispersal, migration and movements of native water-dependent biota	**1(a):** a refugium for native water-dependent biota during dry periods and drought **1(b):** pathways for the dispersal, migration and movement of native water-dependent biota **1(c):** a diversity of important feeding, breeding and nursery sites for native water-dependent biota **1(e):** a vital habitat that is essential for preventing the decline of native water-dependent biota	**1(a):** a refugium for native water-dependent biota during dry periods and drought **1(b):** pathways for the dispersal, migration and movement of native water-dependent biota **1(c):** a diversity of important feeding, breeding and nursery sites for native water-dependent biota **1(e):** a vital habitat that is essential for preventing the decline of native water-dependent biota*

and movements of native water-dependent biota **3(a)(iii):** provides vital habitat, including: important feeding, breeding and nursery sites for native water-dependent biota **3(b):** is essential for maintaining, and preventing declines of, native water-dependent biota. **4(a):** supports a listed threatened ecological community or listed threatened species **4(c)**: supports one or more native water-dependent species treated as threatened or endangered (however described) under State or Territory law. **5(a):** Supports significant numbers of individuals of native water dependent species	**3(a)(iii):** provides vital habitat, including: important feeding, breeding and nursery sites for native water-dependent biota **3(b):** is essential for maintaining, and preventing declines of, native water-dependent biota **4(a):** supports a listed threatened ecological community or listed threatened species **4(c)**: supports one or more native water-dependent species treated as threatened or endangered (however described) under State or Territory law **5(a):** Supports significant numbers of individuals of native water dependent species	**3(a):** longitudinal connections for dispersal and re-colonisation **4(a):** lateral connections for foraging, migration and re-colonisation of native water-dependent species and communities	**2(b):** the dilution of carbon and nutrients from the floodplain to the river systems **3(a):** longitudinal connections for dispersal and re-colonisation **4(a):** lateral connections for foraging, migration and re-colonisation of native water-dependent species and communities

*GDE vegetation communities

16.2 Updated objectives and alignment to Basin Plan instruments

Updated objectives are presented in the logic of the Basin Plan EWP as per Figure 14.

16.2.1 Ecosystem type and biodiversity

Objective 1– Supports Ramsar wetlands of international importance

Mapping element	Description
BMF1_2023 environmental objective	Maintain the ecological character of the Barmah Forest and Central Murray Ramsar sites by 2034

BMF1_2023 targets	No target as cascading outcome achieved by other objectives for ecosystem type and biodiversity. Relevant objectives which will contribute to the maintenance of the ecological character of the Ramsar site include BMF5_2023, BMF6_2023, BMF7_2023, BMF8_2023 and BMF10_2023
Relevant objective(s)	None specified – new objective
Comments/rationale	As the site contains two Ramsar sites, it meets the PEA 1(a). The Barmah Forest Ramsar site meets listing criteria as a wetland of international importance for (Hale 2022): **Criteria 1:** A wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region. **Criteria 2:** A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities. This criterion is only applied to wetland dependent flora, fauna and ecological communities, and the site regularly supports three plant and five animal species listed under the EPBC Act and / or IUCN Red List: • Australasian bittern (*Botaurus poiciloptilus*) – endangered (EPBC Act and IUCN) • Superb parrot (*Polytelis swainsonii*) – vulnerable (EPBC Act) • Murray cod (*Maccullochella peelii*) – endangered (EPBC Act) and critically endangered (IUCN) • Silver perch (*Bidyanus bidyanus*) – critically endangered (EPBC Act) (currently being reassessed) • Trout cod (*Maccullochella macquariensis*) – endangered (EPBC Act) and vulnerable (IUCN) • Mueller daisy (*Brachyscome muelleroides*) – vulnerable (EPBC Act) • Swamp wallaby grass (*Amphibromus fluitans*) – vulnerable (EPBC Act) • Winged peppercress (*Lepidium monoplocoides*) – endangered (EPBC Act). **Criterion 3:** A wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region. • 553 native species of flora and 273 fauna at Barmah • the site is bioregionally significant with respect to Moira grass (*Pseudoraphis spinescens*). **Criterion 4:** A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions • At least 31 species of wetland dependent bird species have been recorded breeding - includes colonial nesting of ibis, herons and egrets. • supports breeding of three species of turtle and six species of frog. • drought refuge for many species of fish, waterbirds, frogs and turtles.

	Criterion 6: A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of waterbird. • During spring and summer period Barmah Forest Ramsar site may support in excess of 4% and as much as 8% of the south eastern Australian population of Australasian bitterns. **Criterion 8:** A wetland should be considered internationally important if it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend. The Central Murray Forest Ramsar site meets listing criteria as a wetland of international importance for (RIS 2015): **Criteria 1:** A wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region. **Criteria 2:** A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities. This criterion is only applied to wetland dependent flora, fauna and ecological communities, and the site regularly supports three plant and five animal species listed under the EPBC Act and / or IUCN Red List: • Australasian bittern (*Botaurus poiciloptilus*) – endangered (EPBC Act and IUCN) • Australian painted snipe (*Rostratula australis*) – vulnerable (EPBC Act) • Superb parrot (*Polytelis swainsonii*) – vulnerable (EPBC Act) • Murray cod (*Maccullochella peelii*) – endangered (EPBC Act) and critically endangered (IUCN) • Silver perch (*Bidyanus bidyanus*) – critically endangered (EPBC Act) (currently being reassessed) • Trout cod (*Maccullochella macquariensis*) – endangered (EPBC Act) and vulnerable (IUCN) • Swamp wallaby grass (*Amphibromus fluitans*) – vulnerable (EPBC Act) **Criterion 4:** A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions (RIS 2015) • The site provides habitat for migratory birds with 11 species listed in migratory bird agreements between Australia and Japan (JAMBA), China (CAMBA) and the Republic of Korea (ROKAMBA)recorded from within the site. These species are Australian painted snipe (*Rostratula benghalensis australis*), eastern great egret (*Ardea modesta*), cattle egret (*Ardea ibis*), sharp-tailed sandpiper (*Calidris acuminata*), greenshank (*Tringa nebularia*), marsh sandpiper (*Tringa stagnatilis*), Latham's snipe (*Gallinago hardwickii*), glossy ibis (*Plegadis falcinellus*), Caspian tern (*Hydropogne caspia*), red-necked stint (*Calidris ruficollis*) and white-bellied sea-eagle (*Haliaeetus leucogaster*). • important in supporting breeding of colonial nesting waterbirds • In 1998, 2000, 2005, 2010 and 2012 environmental flows were used to extend the duration of natural floods. These managed floods triggered and maintained waterbird breeding events with successful nesting of thousands of birds

	• provides refuge for mobile and sedentary fauna during environmentally stressful periods. **Criterion 8:** A wetland should be considered internationally important if it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend. Parks Victoria (2020) strategic plan for the Barmah Forest Ramsar site and Barmah National Park overarching goal is to: *Improve the health of the floodplain marshes of Barmah Forest, increasing the extent and cover of Moira grass and associated wetland vegetation.* Which contributes to the Barmah-Millewa EWMP (MDBA 2012), to: • Restore the extent and distribution of healthy wetland and floodplain vegetation communities; • Provide suitable feeding and breeding habitat for a range of waterbirds, including colonial nesting species; • Support successful breeding and recruitment of native fish species; and, • Provide high quality feeding, breeding and nursery habitat for native frogs, turtles and crayfish
PEA/PEF criteria met	PEA 1(a): a declared Ramsar site
Basin Plan Chapter 8 (EWP) objective(s)	8.05,2(a) An objective is to protect and restore a subset of all water-dependent ecosystems of the Murray-Darling Basin, including by ensuring that: declared Ramsar wetlands that depend on Basin water resources maintain their ecological character; and (Note: see paragraph 21(3)(c) of the Act.
Schedule 7 targets	There are improvements in: 2(c) river, floodplain and wetland types including the condition of priority environmental assets and priority ecosystem functions
BEWS outcome (codes as per DELWP 2022c)	Not specified.
LTWP objective(s) and targets	**Victorian Murray LTWP (DEWLP 2022c)** Not specified. **NSW Murray-Lower Darling LTWP (DPIE 2020a)** Not specified.

Objective 2– Supports species listed under international agreements

Mapping element	Description

BMF2_2023 environmental objective	By 2033 continue to support migratory waterbirds listed under international treaties on a semi-regular basis at Barmah-Millewa Forest icon site.
BMF2_2023 targets	No target as cascading outcome achieved by other objectives for ecosystem type and biodiversity – see BMF5_2023 which will support habitat outcomes for migratory species.
Relevant objective(s)	None specified – new objective
Comments/rationale	Both components of the icon site list PEA1(b): supports migratory species listed under JAMBA, CAMBA, RoKAMBA or Bonn as being met. • DPIE (2020b) includes 6 threatened and 10 migratory spp. • DEWLP (2021c) doesn't list numbers, and the objective/target is about habitat for breeding, so likely a miscommunication referring to Australian migratory or nomadic species. • At Barmah the focus is Australian nomadic species which breed at Barmah, and this will be captured under ecosystem function objectives for colonial nesting species. • Also, Robinson (2018) noted that migratory waterbird species are so infrequent in Millewa forest that they are insensitive as an indicator of condition. Migratory waterbird species likely to occur at the site include (from Harrington and Hale 2011): • Australian painted snipe (*Rostratula australis*) • Caspian tern (*Sterna caspia*) • Cattle egret (*Ardea ibis*) • Common greenshank (*Tringa nebularia*) • Eastern great egret (*Ardea modesta*) • Glossy ibis (*Plegadis falcinellus*) • Latham's snipe (*Gallinago hardwickii*) • Marsh sandpiper (*Tringa stagnatilis*) • Red-necked stint (*Calidris ruficollis*) • Sharp-tailed sandpiper (*Calidris acuminata*) • White-bellied sea eagle (*Haliaeetus leucogaster*) **Outcome:** It was agreed that migratory species, whilst they occur at the site, are not a significant target group for environmental watering. As both components of the site list PEA 1b as being met a cascading objective is included, but direct monitoring of this objective won't be undertaken.

PEA/PEF criteria met	PEA 1(b) with environmental watering, capable of supporting a species listed in or under the JAMBA, CAMBA, ROKAMBA or the Bonn Convention
Basin Plan Chapter 8 (EWP) objective(s)	8.05,2(b) An objective is to protect and restore a subset of all water-dependent ecosystems of the Murray-Darling Basin, including by ensuring that: water-dependent ecosystems that depend on Basin water resources and support the life cycles of species listed under the Bonn Convention, CAMBA, JAMBA or ROKAMBA continue to support those species
Schedule 7 targets	Not specified.
BEWS outcome (codes as per DELWP 2022c)	Not specified.
LTWP objective(s) and targets	**Victorian Murray LTWP (DEWLP 2022c)** Not specified. **NSW Murray-Lower Darling LTWP (DPIE 2020a)** Not specified.

Objective 3 – Supports rare ecosystem type

Mapping element	Description
BMF3_2023 environmental objective	A positive trajectory in the condition of representative ecosystem types (i.e., Water Regime Classes/ANAE) at Barmah-Millewa Forest by 2033.
BMF3_2023 targets	No target specified – cascading outcome achieved by meeting objectives BMF5_2023, BMF6_2023
Relevant objective(s)	None specified in MDBA (2012) – new objective
Comments/rationale	Both components of the site list PEA criterion 2(c): represents a rare example of a particular type of water-dependent ecosystem in the Murray-Darling Basin as being met at the site. The Barmah-Millewa Forest is the largest river red gum forest in the world and is a key reason for both components being listed as Wetlands of International Importance under the Ramsar Convention. Watering objectives for the condition of floodplain and palustrine vegetation condition will support meeting this objective. **Outcome:** retain an objective for rare ecosystem type and achieve as a cascading outcome from non-woody and woody vegetation objectives.

PEA/PEF criteria met	PEA 2(c) represents a rare example of a particular type of water-dependent ecosystem in the Murray-Darling Basin
Basin Plan Chapter 8 (EWP) objective(s)	8.05,2(c) An objective is to protect and restore a subset of all water-dependent ecosystems of the Murray-Darling Basin, including by ensuring that: water-dependent ecosystems are able to support episodically high ecological productivity and its ecological dispersal
Schedule 7 targets	There are improvements in: 2(c) river, floodplain and wetland types including the condition of priority environmental assets and priority ecosystem functions
BEWS outcome (codes as per DELWP 2022c)	Not specified.
LTWP objective(s) and targets	**Victorian Murray LTWP (DEWLP 2022c)** Not specified. **NSW Murray-Lower Darling LTWP (DPIE 2020a)** Not specified.

Objective 4 – Supports threatened species and communities

Mapping element	Description
BMF4_2023 environmental objective	By 2034, maintain the presence of water-dependent threatened species recorded at Barmah-Millewa Forest icon site.
BMF4_2023 targets	No target as cascading outcome achieved by other objectives for ecosystem type and biodiversity. Relevant objectives which will contribute to supporting threatened species include BMF5_2023, BMF6_2023, and BMF7_2023. See Table 7 and Table 8 for listed threatened species that occur at Barmah-Millewa Forst icon site.
Relevant objective(s)	D4: Maintain and restore the abundance of legislatively threatened water dependent flora species D14: Facilitate the recovery of rare native fish species. NSW19 NF6: A 25% increase in abundance of mature (harvestable sized) golden perch & Murray cod NSW26 OS3a: Maintain & increase number of wetland sites occupied by the threatened southern bell frog NSW27 OS3b: Maintain & increase number of wetland sites occupied by the threatened Sloane's froglet

Comments/rationale	Two objectives for Barmah refer to threatened species, and the PEA criteria are listed as met for nationally and state listed species. Murray crayfish, several flora, fish and waterbird species are listed (see section 5.1.2 above) and regularly occur in the site. The NSW LTWP includes objectives for two threatened frogs, but this were identified as not being relevant to the Millewa component (P. Childs pers. comm., May 2023). There is an ongoing bittern monitoring program under the TLM intervention monitoring in Millewa (Znidersic and Towsey 2022). Discussions with site managers for Barmah and Millewa components of the site indicated that specific monitoring for threatened species was not to be included in the EWMP. Survey and other monitoring activities will record threatened species as encountered. Watering of other ecosystem condition and function outcomes should support these key species. Barmah Forest Ramsar site is listed under criteria 2 for supporting threatened species including the following water-dependent species (from Hale 2022): • Australasian bittern (B*otaurus poiciloptilus*) – endangered (EPBC Act and IUCN) • Superb parrot (*Polytelis swainsonii*) – vulnerable (EPBC Act) • Murray cod (*Maccullochella peelii*) – endangered (EPBC Act) and critically endangered (IUCN) • Silver perch (*Bidyanus bidyanus*) – critically endangered (EPBC Act) • Trout cod (*Maccullochella macquariensis*) – endangered (EPBC Act) and vulnerable (IUCN) • Mueller daisy (*Brachyscome muelleroides*) – vulnerable (EPBC Act) • Swamp wallaby grass (*Amphibromus fluitans*) – vulnerable (EPBC Act) • Winged peppercress (*Lepidium monoplocoides*) – endangered (EPBC Act) *Amphibromus fluitans* is listed as Vulnerable under the EPBC Act and in NSW under the TSC Act. It is monitored under Ramsar monitoring. **Outcome:** retain an objective for threatened species but change to a presence index rather than a measure of abundance and achieve as a cascading outcome from non-woody and woody vegetation objectives. The rare species indices may need to be developed.
PEA/PEF criteria met	PEA 4(a) supports a listed threatened ecological community or listed threatened species. PEA 4(c) supports one or more native water-dependent species treated as threatened or endangered (however described) under State or Territory law.
Basin Plan Chapter 8 (EWP) objective(s)	8.05, 3(a) An objective is to protect and restore biodiversity that is dependent on Basin water resources by ensuring that: water-dependent ecosystems that support the life cycles of a listed threatened species or listed threatened ecological community, or species treated as threatened or endangered (however described) in State law, are protected and, if necessary, restored so that they continue to support those life cycles.
Schedule 7 targets	There is improvement in:

	2(f) recruitment and populations of native water-dependent species, including vegetation, birds, fish and macroinvertebrates.
BEWS outcome (codes as per DELWP 2022c)	Not specified.
LTWP objective(s) and targets	**Victorian Murray LTWP (DEWLP 2022c)** Not specified. **NSW Murray-Lower Darling LTWP (DPIE 2020a)** Not specified.

Objective 5 - Non-woody aquatic vegetation

Mapping element	Description
BMF5_2023 environmental objective	By 2034, a positive trajectory in the condition of native non-woody aquatic vegetation in permanent river and creek, temporary river and creek, temporary marsh and permanent lake Water Regime Classes at Barmah-Millewa Forest.
BMF5_2023 targets	**Condition** By 2033, improve the condition of non-woody wetland vegetation at Barmah-Millewa Forest measured as increased number of sites within each WRC (>20%) in compliance with all indices as detailed in Robinson (2018a, b) including: • Native species richness • Total cover • Native cover Permanent creeks include Gulpa Creek and Budgee Creek in Barmah, Gulpa Creek in Millewa Temporary creeks include Toupna Creek and Towrong Creek in Millewa Temporary marshes include Harbours Lake and Steamer Plain in Barmah, Duck Hole Plain and AlgabohnyahPlain in Millewa Permanent lakes include Barmah Lake and Millewa Lake

	Extent By 2033, increase the extent of open water and non-woody wetland vegetation in Millewa Forest measured as increased area of Phragmites by 15% compared to 2020 baseline. • Relevant areas for monitoring include: Moira Forest, including the Moira-Sheldrakes area, and remnants of Algabohnyah • and Porters plains, Millewa Forest west from James Swamp to the Edward River, and along the Towrong Creek from where the creek re-enters the forest from Dudley's and becomes a braided system to the Edward River, and including the area of forest along the Edward River where the Geraphna Creek and Winter creeks return flows from the Cornalla to the Edward River.
Relevant objectives	D1 Promote vegetation with an appropriate abundance and richness of native species in wetlands and ephemeral creeks. D9 Promote the open character of the Moira grass plains and restore the total area dominated by Moira grass plants. D6 Successful growth and flowering of Moira grass plants. D21 Promote healthy and diverse vegetation communities, with an emphasis on restoring natural extent and distribution of giant rush (*Juncus ingens*), Moira grass *(Pseudoraphis spinescens*), river red gum (*Eucalyptus camaldulensis*) forest and river red gum woodland in at least 55% of the Barmah–Millewa icon site. D26 Promote vegetation with an appropriate abundance and richness of native species in wetlands and ephemeral creeks. VIC1 Va. Promote healthy and diverse vegetation communities, with an emphasis on restoring natural extent and distribution of giant rush in at least 55% of the Barmah–Millewa icon site. VIC2 Vb. Promote healthy and diverse vegetation communities, with an emphasis on restoring natural extent and distribution of Moira grass in at least 55% of the Barmah–Millewa icon site. NSW2 NV1: Maintain the extent and viability of non-woody vegetation communities occurring with or closely fringing river channels NSW3 NV2a: Maintain the extent and viability of non-woody vegetation communities occurring in wetlands and on floodplains (semi-permanent, intermittent, temporal and ephemeral wetlands)
Comments/rationale	Assume D1 is about non-woody vegetation but not clear. Relevant WRC are those in bold: • **Permanent rivers and creeks** • **Temporary rivers and creeks** • **Sedge/forb/grass floodplain** • River red gum floodplain forest

	• River red gum floodplain woodland • Box floodplain woodlands • **Permanent marsh** • Temporary swamps • **Temporary marshes** • **Permanent lakes** • **Temporary lakes** Millewa marshes are managed for open water outcomes and to promote Phragmites growth to reach natural extent and distribution. In Barmah the marshes are managed for Moira grass outcomes and Phragmites is considered a problem native species. **Outcome:** only two WRC were to be included in the objective for non-woody vegetation outcomes – namely permanent rivers and creeks and temporary marshes.
PEA/PEF criteria met	PEA 1(a) A water-dependent ecosystem is an environmental asset that requires environmental watering if it is: a declared Ramsar wetland. PEA 3(a) (iii) provides vital habitat, including: important feeding, breeding and nursery sites for native water-dependent biota. PEA 3(b) is essential for maintaining, and preventing declines of, native water-dependent biota. PEF 1(e) An ecosystem function requires environmental watering to sustain it if it provides vital habitat, including: a vital habitat that is essential for preventing the decline of native water-dependent biota.
Basin Plan Chapter 8 (EWP) objective(s)	8.05,3(b) An objective is to protect and restore biodiversity that is dependent on Basin water resources by ensuring that: representative populations and communities of native biota are protected and, if necessary, restored. 8.06,5 An objective is to support habitat diversity for biota at a range of scales (including, for example, the Murray-Darling Basin, riverine landscape, river reach and asset class). 8.06,6(a) An objective is to protect and restore ecosystem functions of water-dependent ecosystems that maintain populations (for example recruitment, regeneration, dispersal, immigration and emigration) including by ensuring that: flow sequences, and inundation and recession events, meet ecological requirements (for example, cues for migration, germination and breeding). 8.07,4 An objective is to provide wetting and drying cycles and inundation intervals that do not exceed the tolerance of ecosystem resilience or the threshold of irreversible change.
Schedule 7 targets	There is improvement in:

	2(e) condition, diversity, extent and contiguousness of native water-dependent vegetation. 2(f) recruitment and populations of native water-dependent species, including vegetation, birds, fish and macroinvertebrates.
BEWS outcome (codes as per DELWP 2022c)	B2.13 By 2024, increased periods of growth for communities that form extensive stands within wetlands and low-lying floodplains including Moira grasslands in Barmah–Millewa Forest

LTWP objective(s) and targets	**Victorian Murray LTWP (DEWLP 2022c)**
	VM2: Improve the species richness of aquatic vegetation in wetlands.
	VM3: Improve the species richness of in-channel aquatic vegetation.
	VM4: Improve the extent of aquatic vegetation.
	
	NSW Murray-Lower Darling LTWP (DPIE 2020a)
	
	NV1: Maintain the extent and viability of non-woody vegetation communities occurring with or closely fringing river channels.
	
	NV2a: Maintain the extent and viability of non-woody vegetation communities occurring in wetlands and on floodplains (semi-permanent, intermittent, temporal and ephemeral wetlands).
	
	5-year targets
	• NV1: No loss of existing non-woody vegetation occurring within channels or closely fringing river channels.
	• NV2a: Over a 5-year rolling period, maintain the extent of non-woody, inundation dependent vegetation occurring in wetlands & floodplains.
	  ○ No loss of key species, populations or communities occurring in wetlands or on floodplains evaluated at selected sites only.
	  ○ No loss of key species, populations or communities occurring in wetlands or on floodplains. Evaluated at selected sites only.
	
	10-year targets
	• NV1: Increase extent & viability of water-dependent non-woody vegetation in at least 50% representative sites4 (10-years) & in at least 75% representative sites (20-years) within channels or closely fringing river channels.
	• NV2a: Increase viability of key species, populations or communities in at least 40% representative sites (within 10-year period actively managed floodplain, current constraints) & in at least 60% representative sites (within 20-year period, actively managed floodplain, constraints relaxed) following inundation events.

Objective 6 - Woody vegetation objective

Mapping element	Description
BMF6_2023 environmental objective	A positive trajectory in condition of native woody vegetation associated with river red gum forest and woodlands Water Regime Classes on the managed floodplain at Barmah-Millewa Forest by 2033.
BMF6_2023 targets	**River red gum tree condition and recruitment** By 2033 a positive trajectory in condition of 20% in woody vegetation at 80% of sites assessed. OR By 2033 a positive trajectory of >35% over any 5-year rolling period in condition status (as per Cunningham et al. 2009) of closely fringing river channels. AND By 2033 at least two recruitment events where germination and seedling establishment are sustained In Millewa Forest. AND **River red gum understorey condition** By 2033, a positive trajectory in condition in understory vegetation in floodplain river red gum forest, floodplain river red gum woodland and temporary swamp Water Resource Class sites measured as compliance with indices as detailed Robinson 2018. • Characteristic Plant Functional Group species richness for each WRC • Characteristic Plant Functional Group species cover for each WRC Condition of plant functional groups at 70% of the monitored sites measured by: • native species richness • native species cover/abundance Understorey condition is measured at 11 sites including (Arcadis 2021): Barmah Forest: Boal's Deadwoods, Top Island (Burnt), Top Island (Original), Little Rushy Swamp, Top Lake, Steamer Plain. Millewa Forest: Walthours Lagoon, Reed Beds Swamp, Black Gate Lagoon, Duck Lagoon, Algeboia Plain.
Relevant objectives	D7 Promote populations of healthy trees in forests and woodlands with appropriate density, recruitment and habitat trees.

	D8An appropriate diversity and abundance of native understorey species in forests and woodlands. D21 Promote healthy and diverse vegetation communities, with an emphasis on restoring natural extent and distribution of giant rush (*Juncus ingens*), Moira grass *(Pseudoraphis spinescens*), river red gum (*Eucalyptus camaldulensis*) forest and river red gum woodland in at least 55% of the Barmah–Millewa icon site. D27 An appropriate diversity and abundance of native understorey species in forest and woodlands. VIC3 Vc. Promote healthy and diverse vegetation communities, with an emphasis on restoring natural extent and distribution of river red gum forest in at least 55% of the Barmah–Millewa icon site. VIC4 Vd. Promote healthy and diverse vegetation communities, with an emphasis on restoring natural extent and distribution of river red gum woodland in at least 55% of the Barmah–Millewa icon site. VIC5 Ve. Promote healthy and diverse vegetation communities, with an emphasis on restoring natural extent and distribution of black box woodland in at least 55% of the Barmah–Millewa icon site. ONSW1 Maintain and improve the viability and extent of river red gum, black box and coolabah communities, lignum shrublands and non-woody wetland and in-channel vegetation. NSW4 NV2b: Maintain the extent and viability of non-woody vegetation communities occurring in wetlands and on floodplains (ephemeral **understorey** vegetation within forests, woodlands and open floodplain areas) NSW5 NV3: Maintain the extent and maintain or improve the condition of river red gum communities closely fringing river channels. NSW6 NV4a: Maintain the extent and maintain or improve the condition of river red gum forest. NSW7 NV4b: Maintain the extent and maintain or improve the condition of river red gum woodland.
Comments/rationale	Relevant WRC are those in bold: • **Permanent rivers and creeks** • **Temporary rivers and creeks** • Sedge/forb/grass floodplain • **River red gum floodplain forest** • **River red gum floodplain woodland** • Box floodplain woodlands • Permanent marsh • **Temporary swamps** • Temporary marshes • Permanent lakes

	• Temporary lakes In the Vic LTWP the TLM objective is split into 5 objectives (see Vb - Ve) but same magnitude of change kept for all vegetation groups. This is not considered appropriate. Black box not overtly mentioned in original objectives for the Barmah section of the icon site. **Outcome:** tree and understorey condition in three WRC are the focus of the objective and targets. Only river red gum forest and woodland included – black box is not within scope currently in Victoria
PEA/PEF criteria met	PEA 3(b): Is essential for maintaining, and preventing declines of, native water-dependent biota. PEF 1(e): An ecosystem function requires environmental watering to sustain it if it provides vital habitat, including: a vital habitat that is essential for preventing the decline of native water-dependent biota.
Basin Plan Chapter 8 (EWP) objective(s)	8.05,3(b): An objective is to protect and restore biodiversity that is dependent on Basin water resources by ensuring that: representative populations and communities of native biota are protected and, if necessary, restored.
Schedule 7 targets	There are improvements in: 2(c) river, floodplain and wetland types including the condition of priority environmental assets and priority ecosystem functions 2(e) condition, diversity, extent and contiguousness of native water-dependent vegetation; 2(f) recruitment and populations of native water-dependent species, including vegetation, birds, fish and macroinvertebrates.
BEWS outcome (codes as per DELWP 2022c)	B2.2: No decline in the condition of river red gum and black box across the Basin B2.7: Maintain extent of water-dependent vegetation near river channels and on low-lying areas of the floodplain. Improve condition of black box and river red gum (90,600ha RRG, 41,700ha BB NSW & Vic).
LTWP objective(s) and targets	**Victorian Murray LTWP (DEWLP 2022c)** VM5: Improve the condition of river red gum dominated EVCs Target: The condition or riparian EVCs in the asset is better at the end than at the start of a ten year monitoring period as measured by the following sub-targets: - health of adult trees - recruitment and survival of juvenile trees - native species richness - native species cover/abundance

	- recruitment of understorey vegetation
	
	NSW Murray-Lower Darling LTWP (DPIE 2020a)
	
	NV2b: Maintain the extent and viability of non-woody vegetation communities occurring in wetlands and on floodplains (ephemeral understorey vegetation within forests, woodlands and open floodplain areas).
	
	5-year targets
	• Over a 5-year rolling period, maintain the extent of non-woody, inundation dependent vegetation occurring in wetlands & floodplains.
	  ○ No loss of key species, populations or communities occurring in wetlands or on floodplains evaluated at selected sites only.
	  ○ No loss of key species, populations or communities occurring in wetlands or on floodplains. Evaluated at selected sites only.
	
	10-year target
	• Increase viability of key species, populations or communities in at least 40% representative sites (within 10-year period actively managed floodplain, current constraints) & in at least 60% representative sites (within 20-year period, actively managed floodplain, constraints relaxed) following inundation events.
	
	NV3: Maintain the extent and maintain or improve the condition of river red gum communities closely fringing river channels.
	• Maintain the 2016 mapped extent7 of river red gum communities closely fringing river channels.
	
	5-year targets
	• Over a 5-year rolling period, maintain the proportion of river red gum communities closely fringing river channels (within 50 m) that are in moderate or good condition.
	• Over a 5-year rolling period, no further decline in the condition of river red gum communities closely fringing river channels (within 50 m) that are in poor or degraded condition.
	
	10-year targets
	• Over a 5-year rolling period, increase9 the proportion of river red gum communities closely fringing river channels (within 50 m) that are in moderate or good condition8 by at least 35% (within the 10-year period) & at least 65% (within the 20-year period)
	• Over a 5-year rolling period, improve the condition score of at least 20% (within the 10-year period) & at least ≥40% (within the 20-year period) of River red gum communities closely fringing river channels (within 50 m) that are in poor, degraded or severely degraded condition by at least one condition score.

	NV4a: Maintain the extent and maintain or improve the condition of river red gum forest. • Maintain the 2016 mapped extent of river red gum forest and woodland communities. *5-year target* • Over a 5-year rolling period, maintain the proportion of river red gum forests & woodlands in moderate or good condition. *10-year target* • Over a 5-year rolling period, maintain the proportion of river red gum forests & woodlands in moderate or good condition. NV4b: Maintain the extent and maintain or improve the condition of river red gum woodland. • Maintain the 2016 mapped extent of river red gum forest and woodland communities. *5-year targets* • Over a 5-year rolling period, no further decline in the condition of river red gum forests & woodlands in poor or degraded condition. • Over a 5-year rolling period, increase the abundance of river red gum seedlings & saplings in degraded river red gum forests & woodlands on the activity-managed floodplain. *10-year targets* • Over a 5-year rolling period, increase the proportion of river red gum forests & woodlands in moderate or good condition by at least 25% (within 10-year period, on the actively managed floodplain – current constraints) & at least 50% (within 20-year period, on the actively managed floodplain – constraints relaxed) • Over a 5-year rolling average, improve the condition score of at least 15% (within 10-year period, on the actively managed floodplain, current constraints) & at least 30% (within 20-year period, on the actively managed floodplain, constraints relaxed) of river red gum forests & woodlands in poor, degraded or severely degraded condition by at least one condition score • Support successful recruitment of river red gum trees in the long-term by increasing the abundance of young adult trees (10–30 cm DBH) compared to the previous target periods.

Objective 7 - Restore representative subpopulations of native water dependent fauna

Mapping element	Description

BMF7_2023 environmental objective	Restore representative subpopulations of native water dependent biota at Barmah-Millewa Forest, by 2033.
BMF7_2023 targets	**Plants:** By 2033 increase the extent (cover) of Category 1 Moira grass swards at six key wetland sites in Barmah-Millewa Forest by 30% compared to 2014 (approximately 28 ha) Sites to be assessed as per Vivian et al. (2015). • Category 1 is defined as a distinct patch, or sward, of *P. spinescens*, with a relatively clear boundary. *P. spinescens* is the dominant (often only) species in the patch (Vivian et al. 2015). • Extent in 2014 of all Moira grass assessed at 31 lakes and treeless plains was approximately 1460 ha using 2012 aerial imagery. • Extent of Category 1 Moira grass at six sites was approximately 28ha, with most found at Steamer Plain. • Six key wetlands included: Steamer Plain, Bucks Lake, Harbours Lake, Hut Lake, Top Lake and Little Rushy Swamp. **Waterbirds:** By 2033, the total species richness of waterbirds in each surveyed wetland at Barmah-Millewa Forest should be at least ≥0.7 (best achievable reference based on total species richness indices to be developed as per Robinson 2018) in 8 years out of any 10-year period where conditions are suitable. Measured as index score per wetland/year and moving smoothed average for each wetland. AND By 2030, average total species richness for waterbirds at Barmah-Millewa Forest ≥0.8 in 8 years out of any 10-year period where conditions are suitable. Measured as moving smoothed average across all wetlands. OR By 2033, maintain a 5-year rolling average of 23 or more waterbird species across all sites assessed within Barmah-Millewa Forest with all functional groups represented. **Fish:** By 2033, fish populations in permanent and temporary river WRC at Barmah-Millewa Fores will be composed predominantly of native fish as measured by abundance, biomass and species (see Robinson 2015, Raymond et al. 2020) *Population indices*

	• The proportion of fish abundance that is native. • The proportion of fish biomass that is native (average of site scores). • The proportion of fish species that is native. AND By 2033, positive trajectory in native fish communities of permanent and temporary river WRC across the whole Barmah-Millewa Forest measured as number of native species, large bodied fish and extent of occurrence (see Robinson 2015, Raymond 2020). *Community indices* • The expected number of historic native species collected. • The number of large-bodied native fish above or below length at maturity. • Extent, the number of sites each native species is detected in. **Turtles:** By 2033, maintain the condition of broad-shelled turtle (*Chelodina expansa*), snake-necked turtle (*Chelodina longicollis*) and Murray River turtle (*Emydura macquarii*) subpopulations at Barmah-Millewa Forest measured by the following (from Howard et al. 2021): *Recruitment metrics* • Proportion of inhabited sites with juvenile turtle detections. • Proportion of sub-adult turtles compared to historical levels (species-specific). *Relative abundance metrics* • Mean CPUE (catch-per-unit-effort) per site. • Mean CPUE per site per species. • Mean CPUE per species per habitat type and water permanence. *Distribution metrics* • Species occurrence at sites over time. *Body condition metric* • Mean body condition per species per year

	Note that post 2023-24 sampling undertake a refinement of metrics and update targets to specify a magnitude of change. **Frogs:** By 2033, maintain presence of common native frog species at Barmah-Millewa Forest in 50-75% of survey sites annually. Species include Peron's tree frog (*Litoria peroni*), Eastern banjo frog (*Limnodynastes dumerilii*), barking marsh frog (*L. fletcheri*), spotted marsh frog (*L. tasmaniensis*), plains froglet (*Crinia parinsignifera*) and the common froglet (*C. signifera*). Sampling design for monitoring to be refined to account for different life history traits. OR By 2033, maintain subpopulations of common native frog species at Barmah-Millewa Forest measured as per Howard et al. 2021). Species include Peron's tree frog (*Litoria peroni*), Eastern banjo frog (*Limnodynastes dumerilii*), barking marsh frog (*L. fletcheri*), spotted marsh frog (*L. tasmaniensis*), plains froglet (*Crinia parinsignifera*) and the common froglet (*C. signifera*). Sampling design for monitoring to be refined to account for different life history traits. Metrics are (from Howard et al. 2021): *Community composition* • Community composition, overall. *Community composition, pooled site average* • Relative abundance. • Calling activity over time, all sites (not reported this year). • Calling activity, per site (not reported this year). Recruitment metrics are used to assess breeding objective – see BMF11_2023. **Crayfish:** By 2033, positive trajectory in condition of the subpopulation of Murray River crayfish in riverine WRC at Barmah-Millewa Forest measured as per Raymond et al. (2017, 2020) including: • yield an Index of Abundance (IOA). • subpopulation sex-ratios. • subpopulation size structure. **Woodland birds:** Maintain species richness of woodland birds at Barmah-Millewa icon site to average more than 75% of best achievable point of reference assessed every 3-5 years (see Tzaros and Tzaros 2022): • Total species richness – seasonal and annual.

	• Victorian Woodland Bird Community species richness. • Tree hollow using species.. • Dietary guilds. . Monitoring to occur at 20 sites across four habitat types as described in Tzaros and Tzaros (2022). Woodland bird species as per Tzaros and Tzaros (2022).
Relevant objectives	D18: Promote sustainable Murray Crayfish populations in Barmah-Millewa Forest waterways and the adjacent River Murray channel. NSW9 WB1: Maintain the number and type of waterbird present NSW10 WB2: Increase total waterbird abundance NSW14 NF1: No loss of native fish species NSW15 NF2: Increase the distribution and abundance of short to moderate lived generalist native fish species NSW16 NF3: Increase the distribution and abundance of short to moderate-lived floodplain specialist native fish species VIC7 Fa: Promote successful recruitment of native fish species by improving flow variability in spring and early summer to replicate natural cues, and by inundation of floodplain and wetland areas to provide breeding and nursery habitat. NSW19 NF6: A 25% increase in abundance of mature (harvestable sized) golden perch & Murray cod NSW20 NF7: Increase the prevalence and/or expand the population of key short to moderate-lived floodplain specialist native fish species into new areas (within historical range) NSW21 NF8: Increase the prevalence and/or expand the population of key moderate to long-lived riverine specialist native fish species into new areas (within historical range) NSW22 NF9: Increase the prevalence and/or expand the population of key moderate to long-lived flow pulse specialists native fish species into new areas (within historical range) NSW23 NF10: Increase the prevalence and/or expand the population of key moderate to long-lived diadromous native fish species into new areas NSW24 OS1: Maintain species richness of flow-dependent frog communities NSW28 OS4: Maintain water-dependant species richness

Comments/rationale	Supporting representative populations is about abundance and distribution measures not about habitat, breeding, or movement. **Plants:** Many threats may impede Moira grass recovery, however, reducing grazing pressure and applying ideal depth and duration of flooding were identified by Nicol et al. (2018) as the most likely to achieve recovery of Moira grass within Barmah Forest. Mitigation of threats to Moira grass are covered in BMF14_2023 **Waterbirds:** The primary focus for waterbird outcomes is to focus on supporting colonial nesting species. The watering requirements for successful breeding will also support diversity in habitat and therefore species richness. **Fish:** *No loss of native fish species* doesn't map specifically to Barmah objectives, but intent of B29 may overlap to some degree. Based on a review of Robinson (2015) and Raymond et al. (2017) the TLM condition monitoring indices can mostly be covered under sustaining representative populations of native water dependent species. Reference to life span as per NSW LTWP objectives doesn't map to Barmah fish objectives. Have nominated to split the fish condition indices into two parts; this objective and target includes the community **Turtles:** Turtles have significant cultural importance. They are predominantly associated with the permanent rivers and permanent lakes. **Frogs:** D16 is about abundance of subpopulations not about habitat as per D23. D17 and D18 are about breeding of frogs, not about habitat as per D23. **Crayfish:** Probably not able to set targets in terms of a magnitude of change – data are still variable and may need to be revisited in a few years to set a magnitude of change in population metrics. **Woodland birds** The Victorian Woodland Bird Community is a group of bird species characteristically found within temperate woodland habitats of Victoria (FFG SAC 2000) which includes the 'woodland-dependent' group 7 that makes up the Victorian

	temperate woodland bird community listed under the FFG Act as a threatened ecological community. Adopting method as per recent monitoring report by Tzaros and Tzaros (2022). **Outcome:** this objective and associated targets are about supporting representative subpopulations and focus on measures of abundance and species richness. Habitat, breeding, and movement outcomes are covered elsewhere under ecosystem functions.
PEA/PEF criteria met	PEA 3(a)(iii) provides vital habitat, including: important feeding, breeding and nursery sites for native water-dependent biota
Basin Plan Chapter 8 (EWP) objective(s)	8.05,3(b) An objective is to protect and restore biodiversity that is dependent on Basin water resources by ensuring that: representative populations and communities of native biota are protected and, if necessary, restored.
Schedule 7 targets	There are improvements in: 2(c) river, floodplain and wetland types including the condition of priority environmental assets and priority ecosystem functions 2(f) recruitment and populations of native water-dependent species, including vegetation, birds, fish and macroinvertebrates
BEWS outcome (codes as per DELWP 2022c)	B3.1: That the number and type of water bird species present in the Basin will not fall below current observations B4.1: No loss of native fish species currently present within the basin
LTWP objective(s) and targets	**Victorian Murray LTWP (DEWLP 2022c)** VM2 Improve the species richness of aquatic vegetation in wetlands VM3 Improve the species richness of in-channel aquatic vegetation VM4 Improve the extent of aquatic vegetation VM14 Improve the abundance of large-bodied native fish VM15 Maintain the abundance of small-bodied native fish in wetlands *Target* • In small wetlands, maintain the presence of small-bodied native fish every year in the ten year monitoring period and; • in large or network wetlands, the average number of sites where small-bodied native fish species are detected in the first

	five years is not less than in the last five years of a ten year monitoring program. VM18 Maintain species richness of native fish VM20 Maintain species richness of frog communities **NSW Murray-Lower Darling LTWP (DPIE 2020a)** WB1: Maintain the number and type of waterbird present *5-year target* • Maintain a 5-year rolling average of 23 or more waterbird species across the 5 functional groups in the Mid Murray *10-year target* • Identify at least 67 waterbird species in the Mid Murray in a 10-year period WB2: Increase total waterbird abundance *5-year target* • Total waterbird abundance of the 5 functional groups maintained in the Mid Murray compared to 5-year 2012–16 period *10-year target* • Total waterbird abundance increased by 20–25% in the Mid Murray compared to the 5-year 2012–16 period, with increases in all functional groups NF1: No loss of native fish species *5-year target* • All known species detected annually *10-year target* • Fish community status improved by one category compared to 2014 assessment NF2: Increase the distribution and abundance of short to moderate lived generalist native fish species NF3: Increase the distribution and abundance of short to moderate-lived floodplain specialist native fish species *Targets* • Increased distribution & abundance of short to moderate-lived species compared to 2014 assessment • No more than one year without detection of immature fish (short-lived) • No more than two years without detection of immature fish (moderate-lived species)

	NF7: Increase the prevalence and/or expand the population of key short to moderate-lived floodplain specialist native fish species into new areas (within historical range) *Targets* flathead galaxias, Murray hardyhead, southern pygmy perch, olive perchlet, purple-spotted gudgeon1 • Adults detected annually in specified PUs • No more than 1 year without detection of immature fish in specified PUs (short-lived) • No more than 2 years without detection of immature fish in specified PUs (moderate-lived species) *10-year target* • Increased distribution and abundance in specified PUs NF8: Increase the prevalence and/or expand the population of key moderate to long-lived riverine specialist native fish species into new areas (within historical range) *Targets* trout cod, Macquarie perch, freshwater catfish, two-spined blackfish, Murray crayfish, purple-spotted gudgeon, olive perchlet • Adults detected annually in specified PUs • No more than 2 years without detection of immature fish in specified PUs (moderate-lived species) • No more than 4 years without detection of immature fish in specified PUs (long-lived species) NF9: Increase the prevalence and/or expand the population of key moderate to long-lived flow pulse specialists native fish species into new areas (within historical range) *5-year target* Silver perch • Adults detected annually in specified PUs *10-year target* Silver perch Increased distribution & abundance in specified PUs

	NF10: Increase the prevalence and/or expand the population of key moderate to long-lived diadromous native fish species into new areas *Target* short-headed lamprey, pouched lamprey, short-finned eel • Adults detected annually in specified PUs OS1: Maintain species richness of flow-dependent frog communities *Target* • Detect all flow-dependent frog species known from the Mid Murray (9 species) regions based on comprehensive surveys over the 2010–2017 period OS4: Maintain water-dependant species richness *Target* • Over the longer term (20 years) no reduction in the number and range of water-dependent species that are found throughout the catchment.

16.2.2 Ecosystem function

Objective 8 - Ecosystem functions that support populations - waterbird breeding

Mapping element	Description
BMF8_2023 environmental objective	By 2033, regularly support non-colonial waterbird breeding and small-scale colonial breeding events at Barmah-Millea Forest icon site.
BMF8_2023 targets	By 2033, maintain successful non-colonial breeding in 9 out of 10 years. AND By 2033, support small scale colonial breeding events in 3 out of 10 years when suitable conditions are present. • Key sites for Millewa are (Borrell 2018): ○ St Helena Swamp, Reed Beds wetland complex (North and South), Picnic Point (not on park), Barmah Lake, War Plain and Boals Deadwood • Colonial nesting species may include (from Borrell 2018):

	○ Australian white ibis *Threskiornis molucca*; ○ Royal spoonbill *Platalea regia*; ○ Eastern great egret *Ardea modesta*; ○ Intermediate egret *Ardea intermedia*; ○ Nankeen night heron *Nycticorax caledonicus*; ○ Little black cormorant *Phalacrocorax sulcirostris*; ○ Little pied cormorant *Microcarbo melanoleucos*; ○ Australasian darter *Anhinga novaehollandiae*.
Relevant objectives	D23: Promote and/or sustain successful breeding events for thousands of colonial and migratory waterbirds in at least 3 years in 10 by inundating selected floodplain and wetland areas to provide suitable nesting and feeding habitat. NSW11 WB3: Increase breeding activity in non-colonial nesting waterbirds NSW12 WB4: Increase opportunities for colonial waterbird breeding events
Comments/rationale	No real issues with this objective and target.
PEA/PEF criteria met	PEF 1(c): a diversity of important feeding, breeding and nursery sites for native water-dependent biota
Basin Plan Chapter 8 (EWP) objective(s)	8.06,6(a) An objective is to protect and restore ecosystem functions of water-dependent ecosystems that maintain populations (for example recruitment, regeneration, dispersal, immigration and emigration) including by ensuring that: flow sequences, and inundation and recession events, meet ecological requirements (for example, cues for migration, germination and breeding); 8.06,6(b) An objective is to protect and restore ecosystem functions of water-dependent ecosystems that maintain populations (for example recruitment, regeneration, dispersal, immigration and emigration) including by ensuring that: habitat diversity, extent, condition and connectivity that supports the life cycles of biota of water-dependent ecosystems (for example, habitats that protect juveniles from predation) is maintained.
Schedule 7 targets	There is improvement in: 2 (f) recruitment and populations of native water-dependent species, including vegetation, birds, fish and macroinvertebrates
BEWS outcome (codes as per DELWP 2022c)	B3.3: Breeding events (the opportunities to breed rather than the magnitude of breeding per se) of colonial nesting waterbirds to increase by up to 50% compared to the baseline scenario B3.4: Breeding abundance (nests and broods) for all of the other functional groups to increase by 30-40% compared to the baseline scenario, especially in locations where the Basin Plan improves over bank flows

LTWP objective(s) and targets	**Victorian Murray LTWP (DELWP 2022c)** VM10: Improve breeding opportunities for colonial nesting waterbirds Target: The minimum water regime required for colonial nesting waterbird breeding is met over a ten-year monitoring period. VM11: Improve breeding opportunities for waterbirds Target: Not specified **NSW Murray-Lower Darling LTWP (DPIE 2020a)** WB3: Increase breeding activity in non-colonial nesting waterbirds *5-year target* • Total abundance of non-colonial waterbirds in the Mid Murray maintained & breeding recorded in at least 1 non-colonial waterbird species compared to the 5-year 2012–16 baseline period *10-year target* • Total abundance of non-colonial waterbirds in the Mid Murray maintained & breeding recorded in at least 1 non-colonial waterbird species compared to the 5-year 2012–16 baseline period WB4: Increase opportunities for colonial waterbird breeding events Support active waterbird colonies in the Mid Murray by maintaining the water depth & duration of flooding (as required) to support breeding through to completion (from egg laying through to fledging including post-fledgling care) & maintain duration of flooding in key foraging habitats to enhance breeding success & the survival of young *5-year target* • In line with natural cues initiate & support small-scale colonial waterbird breeding in the Mid Murray in at least 2 colony sites in 2/5 years *10-year target* • In line with natural cues initiate & support small-scale colonial waterbird breeding in the Mid Murray in at least 3 colony sites in 3/10 years

Objective 9 - Ecosystem functions that support populations - waterbird feeding

Mapping element	Description

BMF9_2023 environmental objective	By 2033, maintain or increase representative species richness of shallow-water and deep-water feeding guilds of waterbird (F2 and F3, respectively, after Jaensch 2002) at Barmah-Millewa Forest.
BMF9_2023 targets	By 2033, functional guild richness at individual wetlands (F2 and F3 feeding guilds, Jaensch 2002) of waterbirds at Barmah-Millewa Forest ≥0.5 in 8 years out of any 10-year period (where conditions are suitable). Measured as index score per wetland/year and moving smoothed average for each wetland. • Representative F2 species include Pacific black duck (*Anas superciliosa*), white-faced heron (E*gretta novaehollandiae)*, yellow-billed spoonbill (*Platalea flavipes*), Australasian shoveler (*Anas rhynchotis*), black swan (*Cygnus atratus*), Australasian grebe (*Tachybaptus novaehollandiae*), • Representative F3 species include Australian pelican (*Pelecanus conspicillatus*), great cormorant (*Phalacrocorax carbo*), little black cormorant (*Phalacrocorax sulcirostris*), white-bellied sea eagle (*Haliaeetus leucogaster*), black swan (*Cygnus atratus*), Pacific black duck (*Anas superciliosa*), Australasian grebe (*Tachybaptus novaehollandiae*) AND By 2030, average function guild species richness (F2 and F3 feeding guilds, Jaensch 2002) of waterbirds at Barmah-Millewa Forest ≥0.7 in 8 years out of any 10-year period where conditions are suitable. Measured as moving smoothed average across all wetlands. Monitoring sites are (NSW National Parks and Wildlife Service 2021): Barmah Forest: Pig Hole, Steamer Plain, Barmah Lake, Goose Swamp, Bunyip Hole, Top Island, Boals Deadwood. Murray Valley National Park (precinct): Horseshoe Lagoon (Gulpa Is), Reed Beds Nort (Moira), Reed Beds South (Moira), Duck Lagoon (Moira), Moira Lake (Moira) and St Helena Swamp (Millewa).
Relevant objectives	D22: Facilitate healthy and diverse vegetation to provide suitable, breeding and foraging habitat for a diverse range of waterbirds and bush birds. NSW13 WB5: Maintain the extent and improve condition of waterbird habitats
Comments/rationale	Jaensch (2002) is a different functional guild classification than currently used for Millewa (Robinson 2021). Jaensch (2002) doesn't confound habitat and diet. If the target is to retain the wording 'to support feeding and habitat areas', then the Jaensch approach would be preferable as it doesn't mix habitat with diet as the Kingsford method does Robinson (2018) refinement relevant to Millewa only, so may need an additional piece of work by Wayne Robinson.
PEA/PEF criteria met	PEF 1(c): a diversity of important feeding, breeding and nursery sites for native water-dependent biota
Basin Plan Chapter 8 (EWP) objective(s)	8.06,6(b) An objective is to protect and restore ecosystem functions of water-dependent ecosystems that maintain populations (for example recruitment, regeneration, dispersal, immigration and emigration) including by ensuring that:

	habitat diversity, extent, condition and connectivity that supports the life cycles of biota of water-dependent ecosystems (for example, habitats that protect juveniles from predation) is maintained.
Schedule 7 targets	There is improvement in: 2 (f) recruitment and populations of native water-dependent species, including vegetation, birds, fish and macroinvertebrates
BEWS outcome (codes as per DELWP 2022c)	B3.2: A significant improvement in waterbird populations in the order of 20 to 25% over the baseline scenario, with increases in all waterbird functional groups
LTWP objective(s) and targets	**Victorian Murray LTWP (DELWP 2022c)** VM13: Improve feeding areas for waterbirds **NSW Murray-Lower Darling LTWP (DPIE 2020a)** WB5: Maintain the extent and improve condition of waterbird habitats *Target* • Maintain or increase extent & improve condition of waterbird foraging & breeding locations in the Mid Murray (to be evaluated under targets set for native vegetation)

Objective 10 – Ecosystem functions that support populations - fish

Mapping element	Description
BMF10_2023 environmental objective	By 2033 support ecosystem functions support successful breeding and recruitment of native fish across the whole Barmah-Millewa Forest in permanent and temporary riverine WRCs
BMF10_2023 targets	By 2033, support recruitment in permanent and temporary river WRC at Barmah-Millewa Forest (see Robinson 2015, Raymond et al. 2020) including: • large bodied species: Murray cod, trout cod, golden perch, silver perch and bony herring to facilitate subpopulation expansion. • Small bodied species: Murray rainbowfish, flat-headed gudgeon, un-specked hardyhead, Australian smelt and carp gudgeons. *Recruitment as per Robinson 2015, Raymond et al. 2020)*

	• The number of sites with recruits. • The number of species with recruits. • The number of recruits as a proportion of population.
Relevant objectives	NSW17 NF4: Improve native fish population structure for moderate to long-lived flow pulse specialist native fish species. NSW18 NF5: Improve native fish population structure for moderate to long-lived riverine specialist native fish species. NSW19 NF6: A 25% increase in abundance of mature (harvestable sized) golden perch & Murray cod
Comments/rationale	The Millewa Native Fish Strategy (DPIE 2022) goal is *Build native fish populations and recover threatened and locally extinct species.* The objectives are stated as (DPIE 2022): • Restore annual recruitment and healthy demographics for Murray cod and trout cod populations • Provide regular spawning, recruitment and dispersal opportunities for golden perch, silver perch, and bony herring populations, and facilitate population expansion. • Increase abundance and distribution of existing small-bodied native fish species including Murray rainbowfish, flat-headed gudgeon, un-specked hardyhead, Australian smelt and carp gudgeons, among others • Reintroduce locally extinct native fish species including southern purple-spotted gudgeon, river blackfish, catfish, Murray galaxias, olive perchlet, southern pygmy perch and, use these as source populations for further recovery. Subpopulations of Murray cod and trout cod are likely driven by local recruitment with management of these species should focus on local-scale actions, such as resnagging, and water delivery that promotes local juvenile survival and recruitment. Golden perch and silver perch are likely driven by immigration so management for these species should focus on connectivity of reaches by constructing fishways and delivering water that triggers migratory movements (NSW DPIE 2022). **Outcome:** focus of objective and targets is on population dynamics, namely recruitment metrics. Abundance of mature golden perch and Murray cod are not addressed in the EWMP.
PEA/PEF criteria met	PEF 1(c): a diversity of important feeding, breeding and nursery sites for native water-dependent biota PEF 1(e): a vital habitat that is essential for preventing the decline of native water-dependent biota.
Basin Plan Chapter 8 (EWP) objective(s)	8.06,6(a) An objective is to protect and restore ecosystem functions of water-dependent ecosystems that maintain populations (for example recruitment, regeneration, dispersal, immigration and emigration) including by ensuring that: flow sequences, and inundation and recession events, meet ecological requirements (for example, cues for migration, germination and breeding);

	8.06,6(b) An objective is to protect and restore ecosystem functions of water-dependent ecosystems that maintain populations (for example recruitment, regeneration, dispersal, immigration and emigration) including by ensuring that: habitat diversity, extent, condition and connectivity that supports the life cycles of biota of water-dependent ecosystems (for example, habitats that protect juveniles from predation) is maintained.
Schedule 7 targets	There is improvement in: 2 (f) recruitment and populations of native water-dependent species, including vegetation, birds, fish and macroinvertebrates
BEWS outcome (codes as per DELWP 2022c)	B4.2: Improved population structure of key fish species through regular recruitment B4.4: Expanded distribution of key fish species and populations B4.5: Improved community structure of key native fish species
LTWP objective(s) and targets	**Victorian Murray LTWP (DELWP 2022c)** VM15: Improve abundance of large-bodied native fish. VM16: Maintain abundance of small-bodied native fish in wetlands. **NSW Murray-Lower Darling LTWP (DPIE 2020a)** NF4: Improve native fish population structure for moderate to long-lived flow pulse specialist native fish species. *Targets* golden perch, silver perch • Juvenile & adult fish detected annually • No more than two consecutive years without recruitment in moderate-lived species • No more than four consecutive years without recruitment in long-lived species NF5: Improve native fish population structure for moderate to long-lived riverine specialist native fish species. *5-year target* Murray cod, trout cod, Macquarie perch, river blackfish, two-spined blackfish, freshwater catfish (eel-tailed catfish), Murray crayfish, southern pygmy perch, purple spotted gudgeon, olive perchlet • Minimum of 1 significant recruitment event in 5 years *10-year target* Murray cod, trout cod, Macquarie perch, river blackfish, two-spined blackfish, freshwater catfish (eel-tailed catfish), Murray crayfish, southern pygmy perch, purple spotted gudgeon, olive perchlet

	• Minimum of 2 significant recruitment events in 10 years

Objective 11 – Ecosystem functions that support populations – other water dependent species

Mapping element	Description
BMF11_2023 environmental objective	By 2033 support successful breeding and recruitment of frogs at Barmah-Millewa Forest.
BMF11_2023 targets	By 2033, maintain subpopulations of common native frog species at Barmah-Millewa Forest measured as per Howard et al. (2021). Target species include Peron's tree frog (*Litoria peroni*), Eastern banjo frog (*Limnodynastes dumerilii*), barking marsh frog (*L. fletcheri*), spotted marsh frog (*L. tasmaniensis*), plains froglet (*Crinia parinsignifera*) and the common froglet (*C. signifera*). Sampling design for monitoring to be refined to account for different life history traits. Metrics are (from Howard et al. 2021): <u>*Recruitment metrics*</u> • Evidence of breeding, overall • Evidence of breeding, species per habitat type • Relative abundance of recruits – CPUE, all sites pooled • Relative abundance of recruits – CPUE, per site
Relevant objectives	D19: Facilitate successful breeding and feeding opportunities for native frog species by seasonal inundation of selected floodplain and wetland areas for appropriate season and duration as required for each species. D20: Facilitate successful breeding of native turtle species by inundation of selected floodplains and wetland areas to provide suitable breeding and nursery habitat. D25: Provide high quality feeding, breeding and nursery habitat for native frogs, turtles and crayfish. NSW25 OS2: Maintain successful breeding opportunities for flow-dependent frog species.
Comments/rationale	No issues with this objective – site managers expressed agreement that frog breeding was to be included in the EWMP.
PEA/PEF criteria met	PEF 1(c): a diversity of important feeding, breeding and nursery sites for native water-dependent biota. PEF 1(e): a vital habitat that is essential for preventing the decline of native water-dependent biota.

Basin Plan Chapter 8 (EWP) objective(s)	8.06,6(a) An objective is to protect and restore ecosystem functions of water-dependent ecosystems that maintain populations (for example recruitment, regeneration, dispersal, immigration and emigration) including by ensuring that: flow sequences, and inundation and recession events, meet ecological requirements (for example, cues for migration, germination and breeding); 8.06,6(b) An objective is to protect and restore ecosystem functions of water-dependent ecosystems that maintain populations (for example recruitment, regeneration, dispersal, immigration and emigration) including by ensuring that: habitat diversity, extent, condition and connectivity that supports the life cycles of biota of water-dependent ecosystems (for example, habitats that protect juveniles from predation) is maintained.
Schedule 7 targets	There are improvements in: 2 (f) recruitment and populations of native water-dependent species, including vegetation, birds, fish and macroinvertebrates
BEWS outcome (codes as per DELWP 2022c)	Not specified.
LTWP objective(s) and targets	**Victorian Murray LTWP (DELWP 2022c)** Not specified. **NSW Murray-Lower Darling LTWP (DPIE 2020a)** OS2: Maintain successful breeding opportunities for flow-dependent frog species. *5-year target* • Establish baseline data on the number and distribution of wetlands with breeding activity of flow-dependant frog species. *10-year target* • Maintain proportion of wetlands sites where breeding activity of flow-dependent frog species is detected in the Lower Darling, Lower Murray and Mid Murray regions compared to comprehensive surveys in the 2019–2024 period.

Objective 12 – Ecosystem functions that support populations – connectivity/dispersal

Mapping element	Description

BMF12_2023 environmental objective	By 2033, support access to habitat for small bodied fish and movement of large bodied riverine native fish by ensuring that flow sequences, and inundation and recession events, meet ecological requirements of key species in Barmah-Millewa Forest.
BMF12_2023 targets	**Small bodied fish – off channel species**: No target as cascading outcome achieved by other objectives for ecosystem type and biodiversity, and ecosystem function. Relevant objectives which will contribute to cascading outcome include BMF7_2023, BMF5_2023, BMF6_2023, BMF10_2023 **Large bodied fish movement:** No target as cascading outcome achieved by other objectives for ecosystem type and biodiversity, and ecosystem function. Relevant objectives which will contribute to cascading outcome include BMF7_2023, BMF5_2023, BMF6_2023, BMF10_2023
Relevant objectives	NSW31 EF3a: Provide movement & dispersal opportunities within catchments for water-dependent biota to complete lifecycles
Comments/rationale	Connectivity of riverine and floodplain ecosystems within the icon site is predominantly focused on allowing movement of fish; however, the role of connectivity in productivity, management of litter accumulation re black water events and contribution of carbon to the mainstream of the Murray were all discussed. **Outcome:** connectivity is to focus on movement of fish.
PEA/PEF criteria met	PEF 1 (b) pathways for the dispersal, migration and movement of native water-dependent biota; PEF 1 (c) a diversity of important feeding, breeding and nursery sites for native water-dependent biota; PEF 3 (a) for dispersal and re-colonisation of native water-dependent communities; or PEF 3 (b) for migration to fulfil requirements of life-history stages; PEF 4 (a) lateral connections for foraging, migration and re-colonisation of native water-dependent species and communities.
Basin Plan Chapter 8 (EWP) objective(s)	8.06,3(b)(i) An objective is to protect and restore connectivity within and between water-dependent ecosystems, including by ensuring that: ecological processes dependent on hydrologic connectivity: (i) longitudinally along watercourses; 8.06,3(b)(ii) An objective is to protect and restore connectivity within and between water-dependent ecosystems, including by ensuring that: ecological processes dependent on hydrologic connectivity: (ii) laterally between watercourses and their floodplains (and associated wetlands)
Schedule 7 targets	There is improvement in:

	2 (b) hydrologic connectivity between the river and floodplain and between hydrologically connected valleys.
BEWS outcome (codes as per DELWP 2022c)	B1.2: 30% overall increase in flows in the River Murray: from increased tributary contributions from the Murrumbidgee, Goulburn, Campaspe, Loddon and Lower Darling catchments collectively
LTWP objective(s) and targets	**Victorian Murray LTWP (DELWP 2022c)** VM1: Improve connectivity between floodplains, anabranches and wetlands **NSW Murray-Lower Darling LTWP (DPIE 2020a)** EF3a: Provide movement & dispersal opportunities within catchments for water-dependent biota to complete lifecycles ○ Dispersal of eggs, larvae, propagules & seeds downstream and into off-channel habitats ○ Migration to fulfil life-history requirements ○ Foraging of aquatic species ○ Recolonisation after disturbance *Targets* • Rates of fall does not exceed the 5th percentile of modelled natural rates during regulated water deliveries. • Period for which instream freshes are held at constant level (± 5%) does not exceed modelled natural durations. • At least 2 fresh events per year in relevant planning units to inundate in-channel habitat & provide movement & breeding cues for native fish & other aquatic biota. • Floodplains wetlands to undergo a drying phase (partial or full draw down) for at least 60 days, 6–10 years in 10 years (including Lower Murray wetlands & floodplains influenced by weir pools).

16.2.3 Ecosystem resilience, climate change and other risk factors

Objective 13 - Provide refugia

Mapping element	Description

BMF13_2023 environmental objective	By 2033, regularly provide refugia to support the long-term survival of water-dependent biota on the managed floodplain of the Barmah-Millewa Forest icon site and Gulpa Creek during drought.
BMF13_2023 targets	By 2033, maintain permanent water refugia in Gulpa Creek, Moira Lake Reed Beds Swamp and Duck Lagoon during periods of regional drought (i.e., serious rainfall deficiency).
Relevant objectives	NSW29 EF1: Provide & protect a diversity of refugia across the landscape.
Comments/rationale	Key refugia in the Millewa Forest include effluent and anabranch creeks – which provide refuge for native fish, turtles and water rats (DPIE 2020a). Key Australasian bittern breeding sites such as Moira Lake, Reed Beds Swamp and Duck Lagoon are also identified as refuge sites to be managed in drought.
PEA/PEF criteria met	PEA 3(a)(i) provides vital habitat, including: a refugium for native water-dependent biota during dry spells and drought; PEF 1(a) a refugium for native water-dependent biota during dry periods and drought.
Basin Plan Chapter 8 (EWP) objective(s)	8.07,2 An objective is that water-dependent ecosystems are resilient to climate change, climate variability and disturbances (for example, drought and fire). 8.07,3 An objective is to protect refugia in order to support the long-term survival and resilience of water dependent populations of native flora and fauna, including during drought to allow for subsequent recolonisation beyond the refugia.
Schedule 7 targets	There are improvements in: 2(c) river, floodplain and wetland types including the condition of priority environmental assets and priority ecosystem functions
BEWS outcome (codes as per DELWP 2022c)	Not specified.
LTWP objective(s) and targets	**Victorian Murray LTWP (DELWP 2022c)** Not specified. **NSW Murray-Lower Darling LTWP (DPIE 2020a)** EF1: Provide & protect a diversity of refugia across the landscape. ○ Water depth & quality in pools (in channel), core wetlands & lakes ○ Condition of vegetation in core wetlands & riparian zones

	Targets • Very low flows (VFs) & baseflows (BF1) are provided at target magnitudes & durations as specified in PU EWRs • Cease-to-flow (CTF) periods do not exceed maximum durations as specified in PU EWRs • Adequate water depth is maintained in key refuge pools during dry times

Objective 14 - Mitigate the impact of invasive species and feral animals

Mapping element	Description
BMF14_2023 environmental objective	By 2033, mitigate the impact of invasive species and feral animals on floodplain and wetland ecosystems and native water-dependent species at Barmah-Millewa Forest icon site
BMF14_2023 targets	**Horses:** Cascading outcome reliant of current Pest Plant and Animal management activities as per Parks Victoria (2020) and YYTOLMB (2020). **Pigs and other feral herbivores:** Cascading outcome reliant of current Pest Plant and Animal management activities as per Parks Victoria (2020). AND **Invasive natives:** By 2033, reduce encroachment of invasive native flora species (giant rush and river red gum) by 20% at nominated sites to support Moira grass recovery. AND Control arrowhead invasion at nominated sites by 80% to support Moira grass recovery (Victoria Parks 2020).
Relevant objectives	D5: Restrict the abundance, spread and incursion of invasive aquatic species.
Comments/rationale	*The long-term aim for feral horses in Barmah Forest is to reduce their numbers to zero, thereby alleviating the total grazing and trampling pressure caused by this introduced species* (Parks Victorian 2020). An intermediate action is to install enclosures in key areas to mitigate grazing pressure from horses.

	Reduce total grazing pressures and other impacts exerted by feral pigs and introduced large herbivores on Moira grass, other floodplain marsh communities, and Aboriginal Cultural sites by implementing strategies and actions to minimise those impacts. (Parks Victorian 2020). Weeds - A future complementary analysis could be to score weediness in conjunction with the PFG index (Robinson 2018 veg report) Two native plant species, giant rush (*Juncus ingens*) and river red gum (*Eucalyptus camaldulensis*), are recognised as potential invasive species encroaching Moira grass floodplain marshes. The goal for reducing the impacts of these two species is: *To reduce the encroachment of invasive native flora species (giant rush and river red gum), and control arrowhead invasion, to support Moira grass recovery.* **Outcome:** as both horse and other feral animal control are not undertaken with the management of environmental water, the targets and implementation of mitigation of these threats are captured in other management plans for the icon site.
PEA/PEF criteria met	PEA 3(b) is essential for maintaining, and preventing declines of, native water-dependent biota. PEF 1(e) a vital habitat that is essential for preventing the decline of native water-dependent biota.
Basin Plan Chapter 8 (EWP) objective(s)	8.07,4 An objective is to provide wetting and drying cycles and inundation intervals that do not exceed the tolerance of ecosystem resilience or the threshold of irreversible change. 8.07,5 An objective is to mitigate human-induced threats (for example, the impact of alien species, water management activities and degraded water quality).
Schedule 7 targets	There are improvements in: 2(c) river, floodplain and wetland types including the condition of priority environmental assets and priority ecosystem functions
BEWS outcome (codes as per DELWP 2022c)	Not specified.
LTWP objective(s) and targets	**Victorian Murray LTWP (DELWP 2022c)** Not specified. **NSW Murray-Lower Darling LTWP (DPIE 2020a)** Not specified.

17 Appendix 4: Details of water management infrastructure

17.1 Water regulating structures in Barmah Forest

Table 40. Summary of structure information (Jacobs 2018).

#	Name	Type	Lat	Long	Asset register
1	Flat Swamp regulator	Secondary regulator	-35.8607	145.2438	Parks Victoria
2	Sandspit regulator	Primary regulator	-35.8374	145.1956	MDBA, GMW (As MDBA asset) and Parks Victoria
3	Gulf Creek 1 regulator	Primary regulator	-35.8416	145.1518	MDBA, GMW (As MDBA asset) and Parks Victoria
4	Gulf Creek 2 regulator	Primary regulator	-35.8408	145.1521	MDBA, GMW (As MDBA asset) and Parks Victoria
5	Unnamed structure (tertiary regulator d s Gulf)	Tertiary regulator	-35.8406	145.1531	None
6	Stewarts Kitchen regulator	Secondary regulator	-35.834	145.1358	MDBA & GMW (As MDBA asset)
7	Unnamed structure (tertiary regulator d/s Stewarts Kitchen)	Tertiary regulator	-35.833	145.1344	None
8	Bull Paddock regulator	Secondary regulator	-35.8299	145.1249	MDBA & GMW (As MDBA asset)
9	Red Tank regulator	Tertiary regulator	-35.8302	145.0968	None
10	Sapling Landing	Tertiary regulator	-35.8361	145.0909	Parks Victoria
11	Punt Paddock regulator	Primary regulator	-35.8304	145.0855	MDBA & GMW (As MDBA asset)
12	Green Engine	Tertiary regulator	-35.8318	145.0768	Parks Victoria
13	Big Woodcutter 2 Tertiary	Tertiary regulator	-35.8384	145.0592	Parks Victoria
14	Big Woodcutter regulator	Primary regulator	-35.8386	145.0582	MDBA & GMW (As MDBA asset)
15	Little Woodcutter 1 regulator	Tertiary regulator	-35.839	145.0532	MDBA
16	Little Woodcutter 2 regulator	Tertiary regulator	-35.8389	145.0508	MDBA
17	Little Woodcutter 3 regulator	Tertiary regulator	-35.8383	145.0497	MDBA
18	Little Woodcutter 4 regulator	Tertiary regulator	-35.8391	145.0457	MDBA & Parks Victoria

#	Name	Type	Lat	Long	Asset register
19	Boals Creek regulator	Primary regulator	-35.8537	145.024	MDBA, GMW (As MDBA asset) and Parks Victoria
20	Sapling Creek regulator	Primary regulator	-35.855	145.0046	MDBA & GMW (As MDBA asset)
21	Island Creek regulator	Primary regulator	-35.8556	144.9986	MDBA, GMW (As MDBA asset) and Parks Victoria
22	Unnamed structure (tertiary regulator d/s Island Creek regulator)	Tertiary regulator	-35.861	144.9737	Parks Victoria
23	Two-mile Gully regulator	Tertiary regulator	-35.956	144.9894	None
24	Dharnya tertiary regulator	Tertiary regulator	-35.9601	144.9652	None
25	Goose Neck tertiary regulators	Tertiary regulator	-35.9712	144.9725	None
26	Goose Swamp tertiary regulators	Tertiary regulator	-35.9729	144.9713	None
27	Green Deadwoods	Tertiary regulator	-35.8383	145.2083	Parks Victoria
28	Burnt Landing	Tertiary regulator	-35.8421	145.1796	Parks Victoria
29	Hooks Territory regulator	Tertiary regulator	-35.8341	145.1581	Parks Victoria
30	Mill Log	Tertiary regulator	-35.8256	145.122	Parks Victoria
31	Sapling Landing	Tertiary regulator	-35.8379	145.0574	Parks Victoria
32	Green Engine	Tertiary regulator	-35.8309	145.086	Parks Victoria
33	Flat Swamp	Tertiary regulator	-35.8514	145.2325	Parks Victoria
34	Tongalong Creek 1	Tertiary regulator	-35.8433	145.2234	Parks Victoria
35	Frenchmans	Tertiary regulator	-35.8296	145.1413	Parks Victoria
36	Burnt Landing	Tertiary regulator	-35.829	145.1232	Parks Victoria
37	Tarragon Lodge	Tertiary regulator	-35.9764	144.9757	Parks Victoria
38	Tongalong Creek 2	Tertiary regulator	-35.8498	145.2303	Parks Victoria
39	Stewarts Kitchen 3	Tertiary regulator	-35.8321	145.1284	Parks Victoria
40	Red Tank Tertiary Regulator	Tertiary regulator	-35.8285	145.102	Parks Victoria
41	Bull Paddock 4	Tertiary regulator	-35.8273	145.1181	Parks Victoria
42	Gulf Tertiary Effluent Pipe	Tertiary regulator	-35.5043	145.0918	Parks Victoria

17.2 Water regulating structures in Millewa Forest

Table 41. Summary of structure information (B. Cronin, NSW NPWS, pers. comm.).

#	Regulator	Ownership	Easting	Northing
1	Toupna	Bullatale Irrigation	339393	6033266
2	Gloweries	NPWS	337436	6032947
3	House Creek	State Water	334736	6032488
4	Pinch Gut	State Water	331412	6033683
5	Mary Ada	State Water	330850	6034477
6	Maddens	Decommissioned	330563	6034332
7	Potts Creek	State Water	329777	6034341
8	Fishermans	State Water	325971	6033634
9	Nine Panel	State Water	323937	6032833
10	Nestrons	State Water	322823	6032285
11	Thistle	Decommissioned	321594	6031266
12	Walthours	State Water	319854	6030833
13	Edward River Off	State Water	319237	6030921
14	Warrick	State Water	316802	6029642
15	Porters	State Water	316966	6027133
16	O'Shannassy	State Water	316357	6024694
17	Swifts	State Water	315447	6023589
18	Bunnydigger	State Water	314962	6022356
19	Moira Creek	State Water	315103	6019175
20	Little Edwards	State Water	315782	6035531
21	Collins	State Water	316314	6037553
22	McLaurens	State Water	316449	6037966
23	Correys	State Water	316292	6038144
24	Bonners	State Water	316230	6038400
25	Husseys	State Water	316288	6038621
26	Dwyers	State Water	316278	6038674
27	Opitz	State Water	316402	6038884
28	Crumps	State Water	316492	6039328
29	V Block	State Water	316292	6039547
30	Edwards	State Water	315689	6039695

#	Regulator	Ownership	Easting	Northing
31	Mains	State Water	315129	6039818
32	Buchanans	State Water	314817	6039810
33	Atkinsons	State Water	314313	6040801
34	Keech	State Water	314572	6040998
35	Black Swamp	State Water	314309	6042128
36	Taylors	State Water	314035	6042492
37	Wragges	State Water	314217	6042643
38	Horseshoe Lagoon	NPWS	311860	6039977
39	Horseshoe Lagoon	NPWS	311942	6039904
40	Horseshoe Lagoon	State Water	311805	6039891
41	Horseshoe Lagoon	NPWS	312145	6039248
42	McCartneys	State Water	311376	6037387
43	Torrumbarry	State Water	271547	6019492
44	Tumudgery	State Water	286750	6080549
45	Niemur	State Water	275274	6088994
46	Reed Bed	State Water	270551	6091989
47	Unnamed	State Water	273624	6018512
48	Unnamed	State Water	605781	6004925

18 Appendix 5: Conceptual models of key aquatic plants

Research into the life history and response to management interventions for Moira grass and giant rush has improved our conceptual understanding of these key species. Figure 16 illustrates the response to watering of Moira grass and Figure 17 to Figure 19 illustrate the growth, establishment, and suppression of giant rush in response to water regimes. These models help inform management decision regarding timing, duration and depth of environmental water.

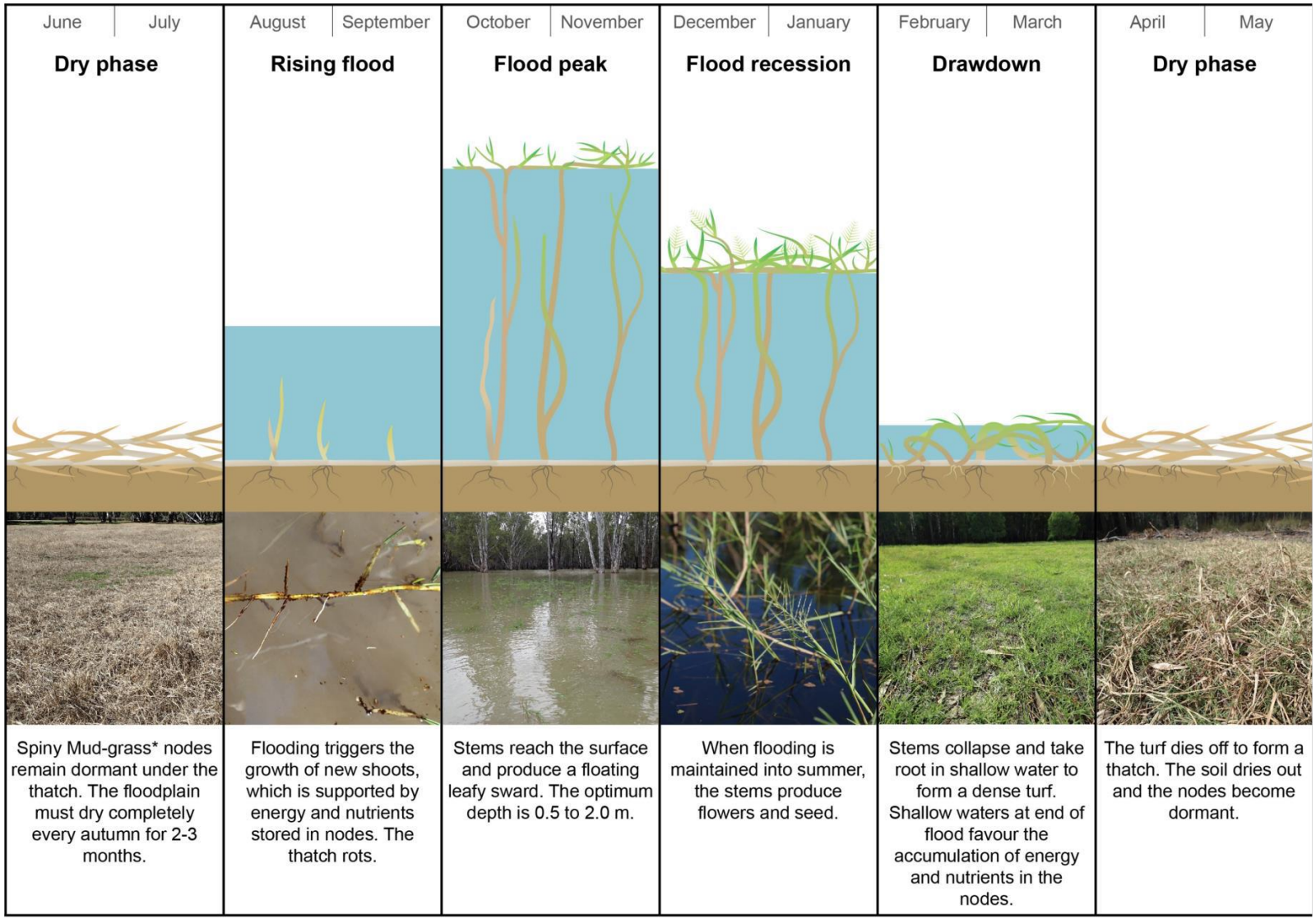

Figure 16. Conceptual model of Moira grass response to water regime (from Cooling et al. 2019).

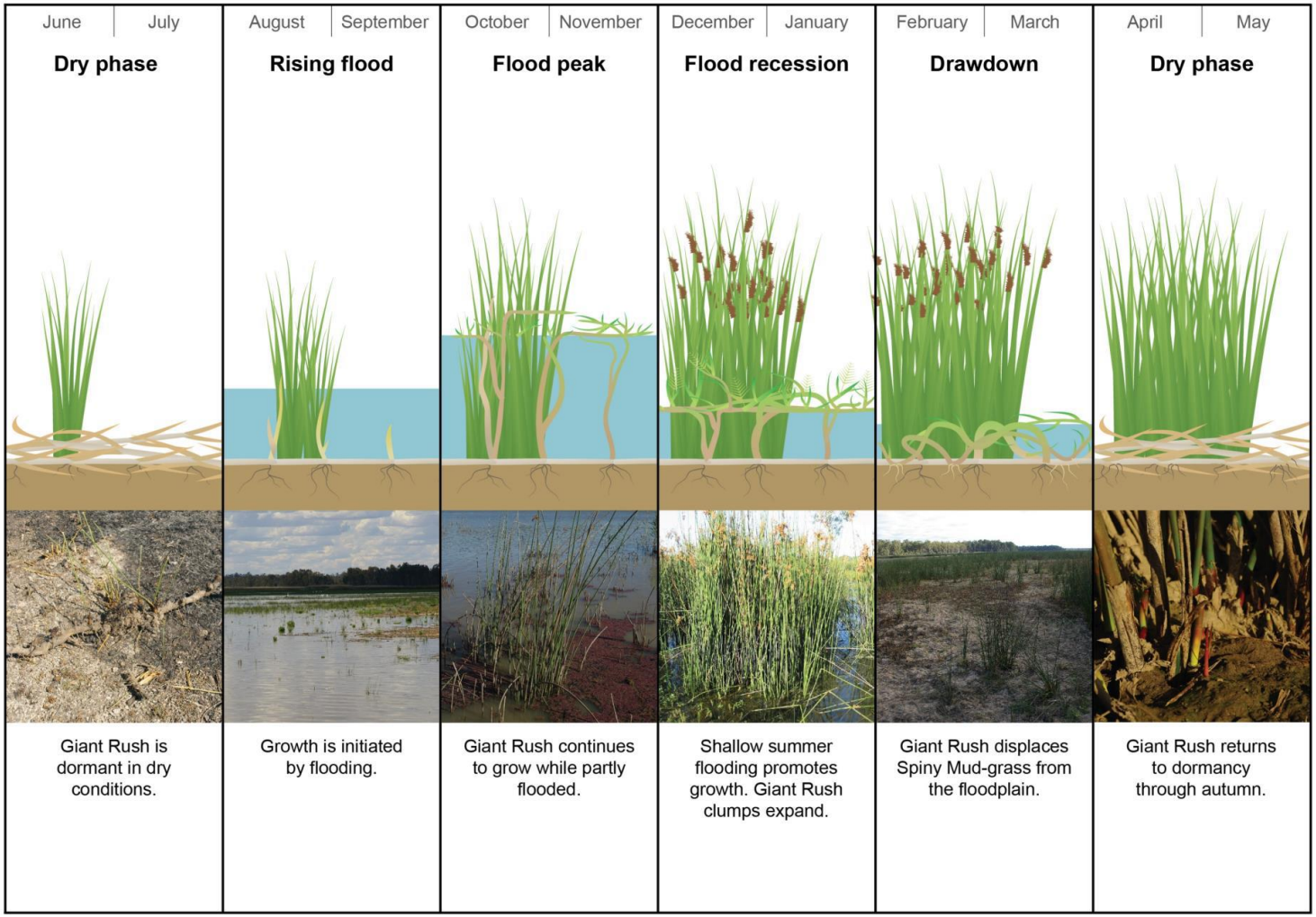

Figure 17. Conceptual model of growth pattern of giant rush stands (Cooing et al. 2019).

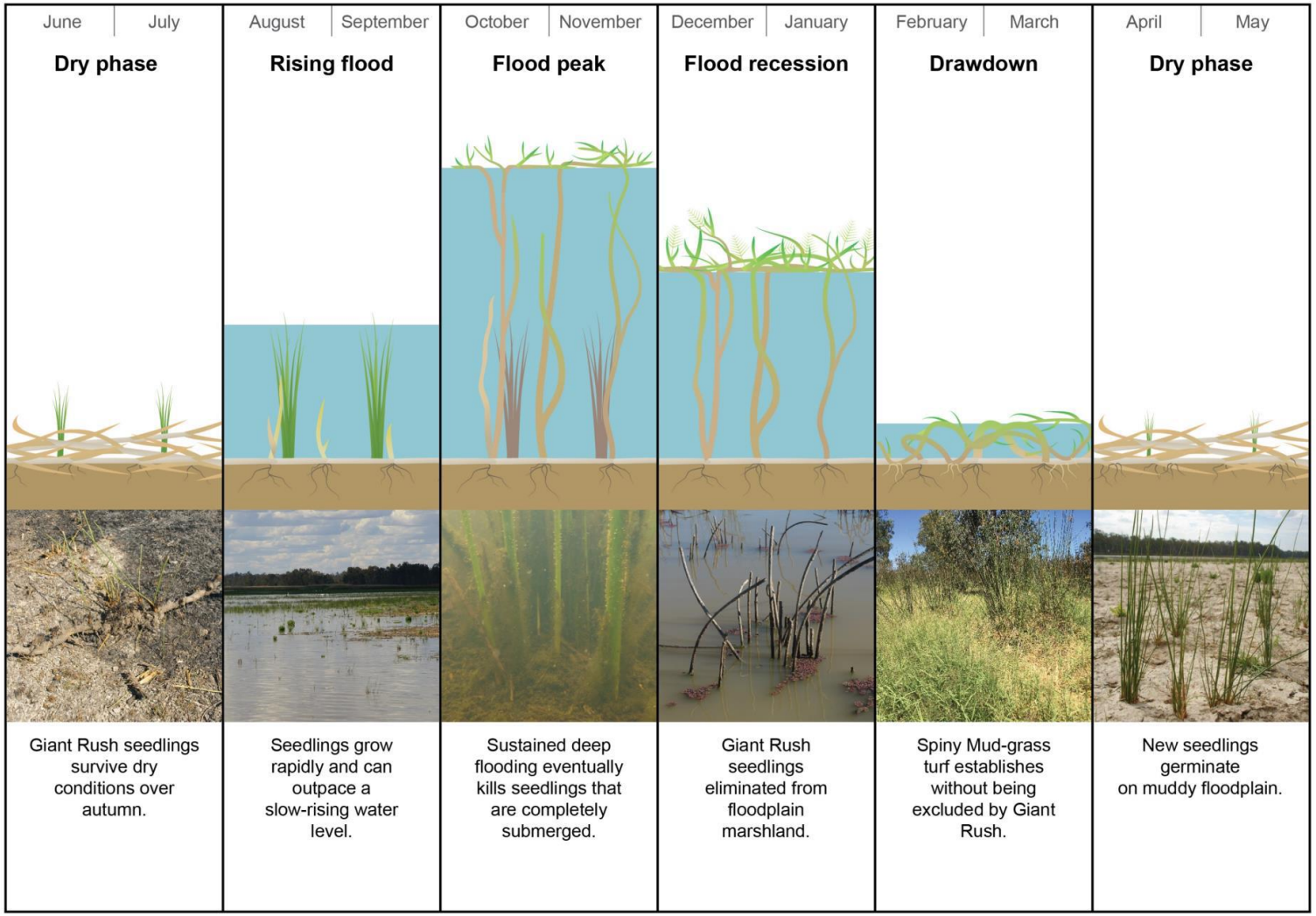

Figure 18. Conceptual model for suppressing giant rush seedlings (Cooling et al. 2019).

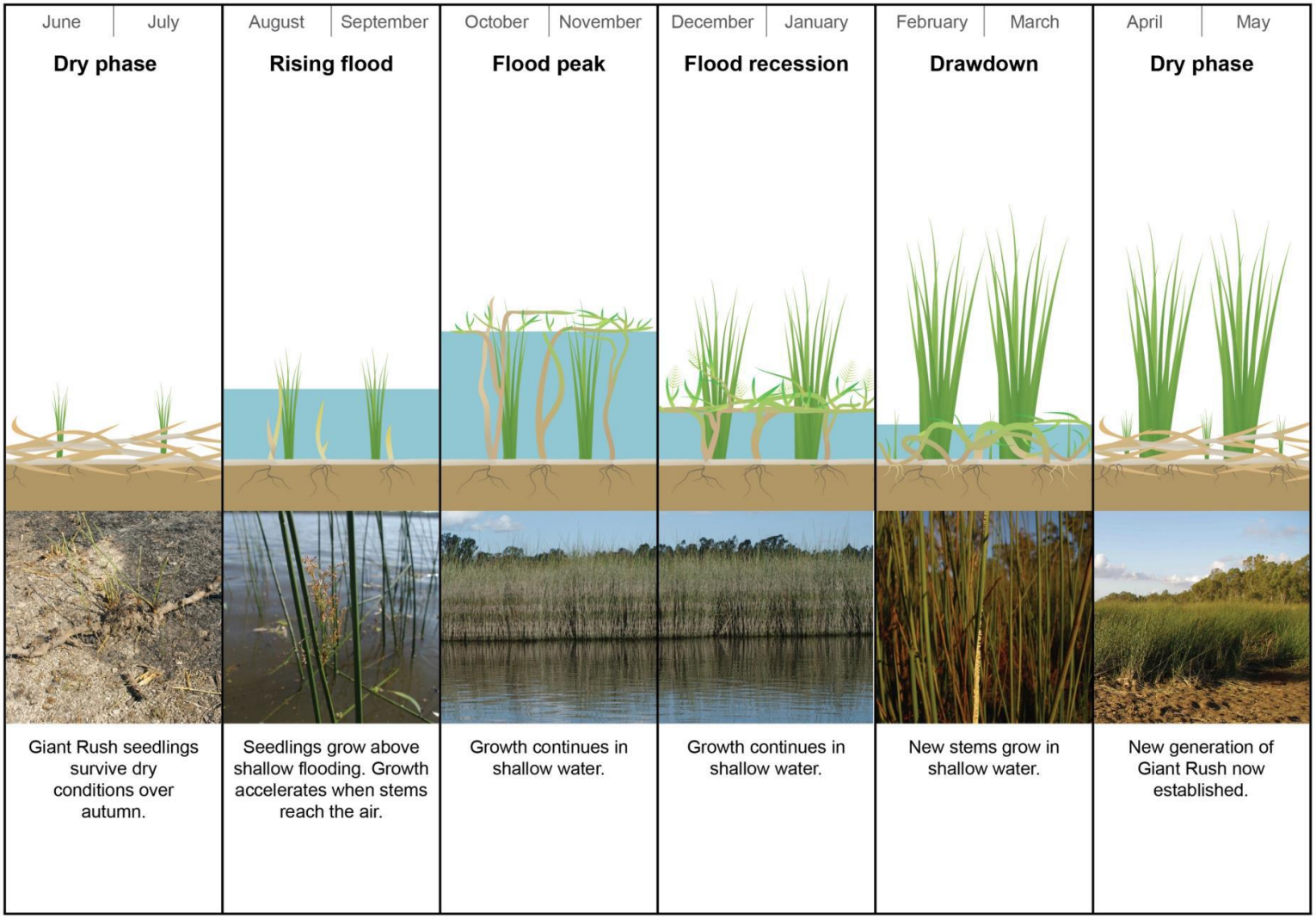

Figure 19. Conceptual model of establishment of giant rush seedlings (Cooling et al. 2019).