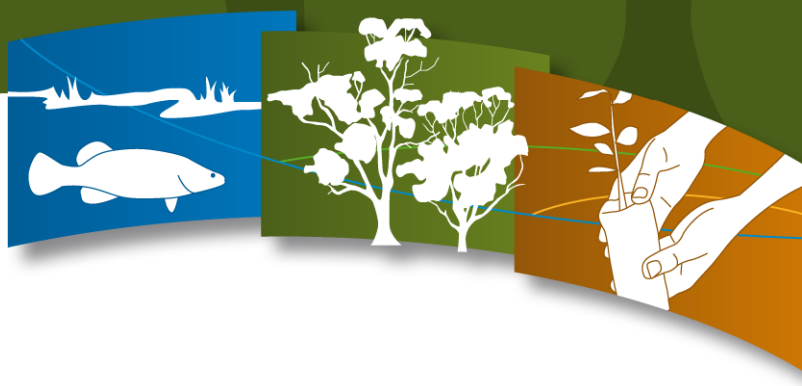
Connecting Rivers, Landscapes, People

Gunbower National Park

Ecological Objectives & Hydrological Requirements

Justification Paper

Final: December 2014



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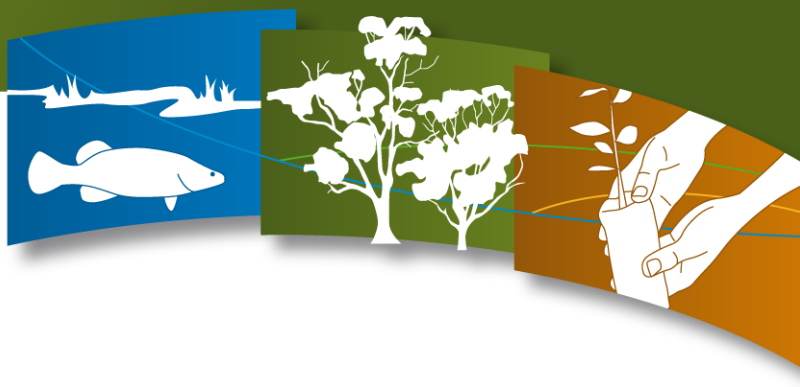

Acknowledgement of Country

The North Central Catchment Management Authority acknowledges Aboriginal Traditional Owners within the region, their rich culture and spiritual connection to Country. We also recognise and acknowledge the contribution and interest of Aboriginal people and organisations in land and natural resource management.

Document control

Revision and distribution

Version no.	Description	Issued to	Issue date
1	Draft prepared by P. Beattie	North Central CMA SDL team	August 2014
2	Updated draft prepared by P. Beattie – includes feedback from stakeholders and CMA staff.	North Central CMA SDL team	September 2014
3	Final prepared by P. Beattie – includes expert review feedback from Terry Hillman and additional information to reflect updated project scope and latest investigations.	North Central CMA SDL team	11 November 2014
4	Final (version 2) prepared by P. Beattie. Includes minor amendments following business case submission.	North Central CMA SDL team	4 December 2014

Management

Organisation	North Central Catchment Management Authority
Author(s)	Pam Beattie
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Unless otherwise stated, all photos in this report are sourced from North Central CMA.

This document should be referenced as North Central CMA (2014) *Gunbower National Park ecological objectives and hydrological requirements*, Justification report prepared for the Sustainable Diversion Limit business case.

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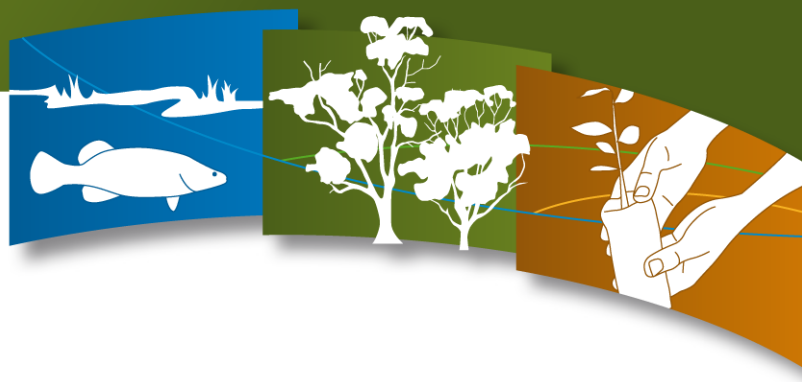


1. INTRODUCTION

1.1 Background

The Commonwealth Department of Environment (DoE) is assessing a number of Environmental Works and Measures projects across the Murray Darling Basin that aim to achieve similar or better environmental outcomes using less water than previously estimated. The water savings generated by the projects could be used to increase the Sustainable Diversion Limit set under the Murray Darling Basin Plan by reducing the amount of water needed to be recovered from agricultural and urban use for the environment.

North Central Catchment Management Authority (North Central CMA) is currently developing business cases for two such projects – the Gunbower National Park Environmental Works Project and the Guttrum and Benwell Forests Environmental Works Projects.

This document summarises the **ecological values, objectives and targets of the Gunbower National Park Environmental Works Project and the justification for the corresponding hydrological requirements** to achieve the objectives/targets. It brings together relevant information from a large body of work that exists for Gunbower Forest (mostly developed through The Living Murray Program).

The document has been divided into a series of chapters which documents the following:

- Values (i.e. what is there or what would we like there?) – this may include specific flagship species or broader ecological groupings depending on the ecological component being discussed e.g. Ecological Vegetation Classes, waterbird feeding guilds.
- Current condition and projected trajectories of condition.
- Ecological objectives/targets – these outline our goals for each ecological component considering their current condition and projected trajectories of condition.
- Hydrological requirements (i.e. what water regime is required to achieve the objectives/targets?) – based on scientific evidence where possible and/or practical experience.

The ecological components within this document have been based on those used to establish the ecological objectives and targets for the broader Gunbower Forest Icon Site – vegetation, birds and fish.

1.2 Workshop

A workshop was held on 31 July to obtain feedback on the ecological objectives and the required water regimes for the two projects mentioned above. Participants included expert ecologists, agency stakeholder representatives and North Central CMA staff including:

Kate Bennetts (Fire Flood and Fauna)

Marcus Cooling (Ecological Associates)

Doug Frood (Pathways, Bushland and Environment)

Rick Webster (Ecosurveys)

Clayton Sharpe (CPS Environmental)

Jack Smart (MDBA)

Emer Campbell (NCCMA)	Andrea Keleher (DEPI)
Tim Hoogwerf (NCCMA)	Sharada Ramamurthy (DEPI)
Genevieve Smith (NCCMA)	Stephen Nicol (DEPI)
Anna Chatfield (NCCMA)	Paul Lacy (GMW)
Chris Corr (NCCMA)	Peter Foster (Parks Victoria)
Pam Beattie (NCCMA)	Angela Gaynor (Parks Victoria)

This document captures the latest information relevant to the above aspects of the Gunbower National Park Environmental Works Project, which considers the workshop discussions and incorporates the suggestions of participants following the workshop where appropriate.

2. ECOLOGICAL VALUES

2.1 Vegetation

Gunbower Island supports a diversity of vegetation, which can be described at a number of scales. Further information on Gunbower Forest vegetation is available in the Ecological Watering Guide (North Central CMA 2014a).

Landscape components

The "landscape logic" approach describes the relationship between position in the landscape and the vegetation type, or water regime class, that has established under those flow conditions in Gunbower Forest. The elevation and flooding frequency of water regime classes within Gunbower Forest is shown in Figure 1 (Ecological Associates 2003). Within Gunbower National Park, all five water regime classes are present.

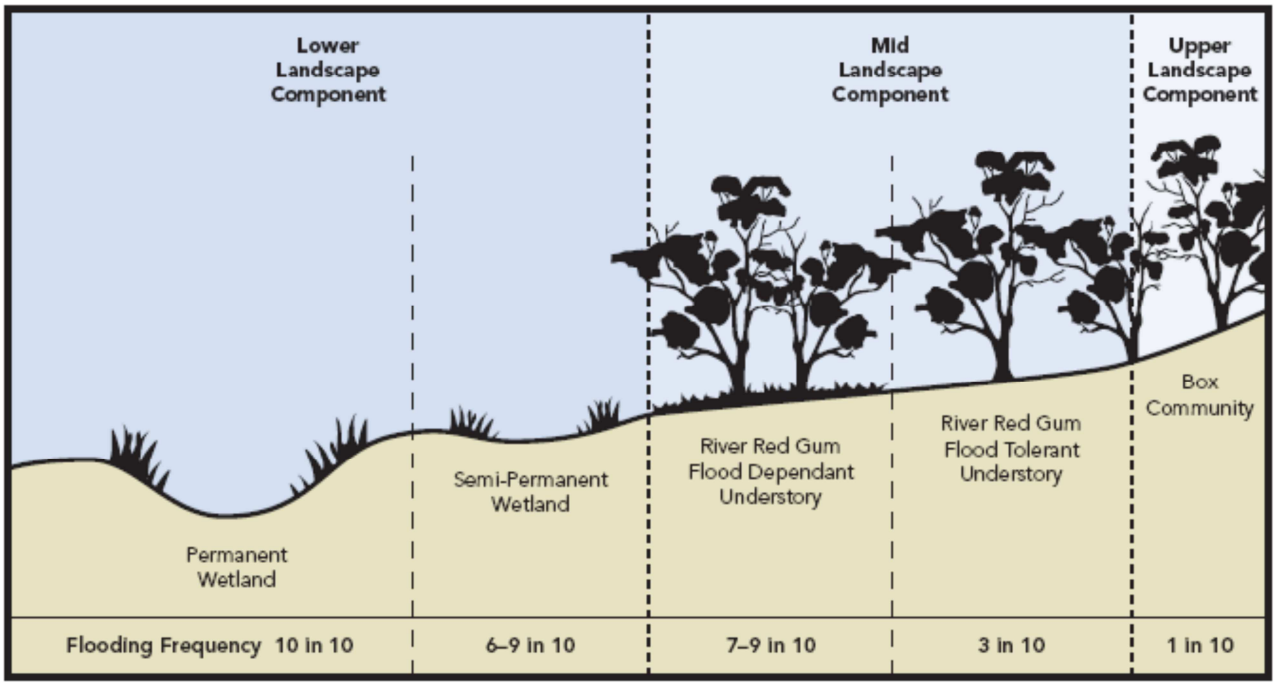


Figure 1. Schematic representation of the landscape logic approach

The landscape of upper Gunbower Forest contains wetland habitat within the forest itself, for example Black Charlie Lagoon and Pig Swamp, as well as a diverse mosaic of smaller unnamed wetlands. These wetlands provide different aquatic habitats from the lagoons along Gunbower Creek because they are forest wetlands and not old river channels. They also differ from the wetland complexes in the landscape of the lower forest because they are smaller and more diverse in size, shape and aquatic plant assemblages (Mallen-Cooper et al. 2014).

Regarding wetlands, Black Charlie Lagoon is the only permanent wetland in the Gunbower National Park. It covers 39 ha and is the deepest wetland in Gunbower Forest, being in excess of 3m deep in parts. Pig Swamp covers 55 ha and is the largest semi-permanent wetland in the National Park area.

Figure 2. Temporary wetland downstream of Black Charlie Lagoon (North Central CMA 2014a)

Ecological communities

Gunbower Forest is one of the largest remaining stands of River Red Gum forest in Australia and contains a number of vegetation communities classed as vulnerable or endangered by state and federal legislation. The River Red Gum Grassy Woodland ecological community is listed as threatened under Schedule 2 of the Flora and Fauna Guarantee Act 1988.

Gunbower Forest also contains one of the largest remnant stands of Grey Box Woodland in Victoria. The Grey Box Grassy Woodlands and Derived Native Grasslands of South-Eastern Australia ecological community is nationally endangered and is listed under the Environment Protection and Biodiversity Conservation Act (1999) (North Central CMA 2014a).

Ecological Vegetation Classes

Ecological Vegetation Classes (EVCs) describe vegetation communities in Victoria using a combination of floristics, lifeform, position in the landscape and an inferred fidelity to particular environments. Each EVC includes a collection of floristic communities (i.e. groups based on co-occurring plant species) that occur across a bio-geographic range, and although differing in species, have similar habitat and ecological processes operating. Descriptions include canopy, understorey and groundcover species and each EVC is given a bioregional conservation status. Benchmarks (standard vegetation-quality reference points) are included and can be applied when carrying out vegetation quality assessments.

Across Gunbower Forest, 23 EVCs have been recorded. These are shown in the below table. Descriptions for these EVCs are available in the Ecological Watering Guide (North Central CMA 2014a). The distribution of EVCs across Gunbower National Park is shown in Figures 3 and 4 (mapping by Ecological Associates and Kate Bennetts 2014).

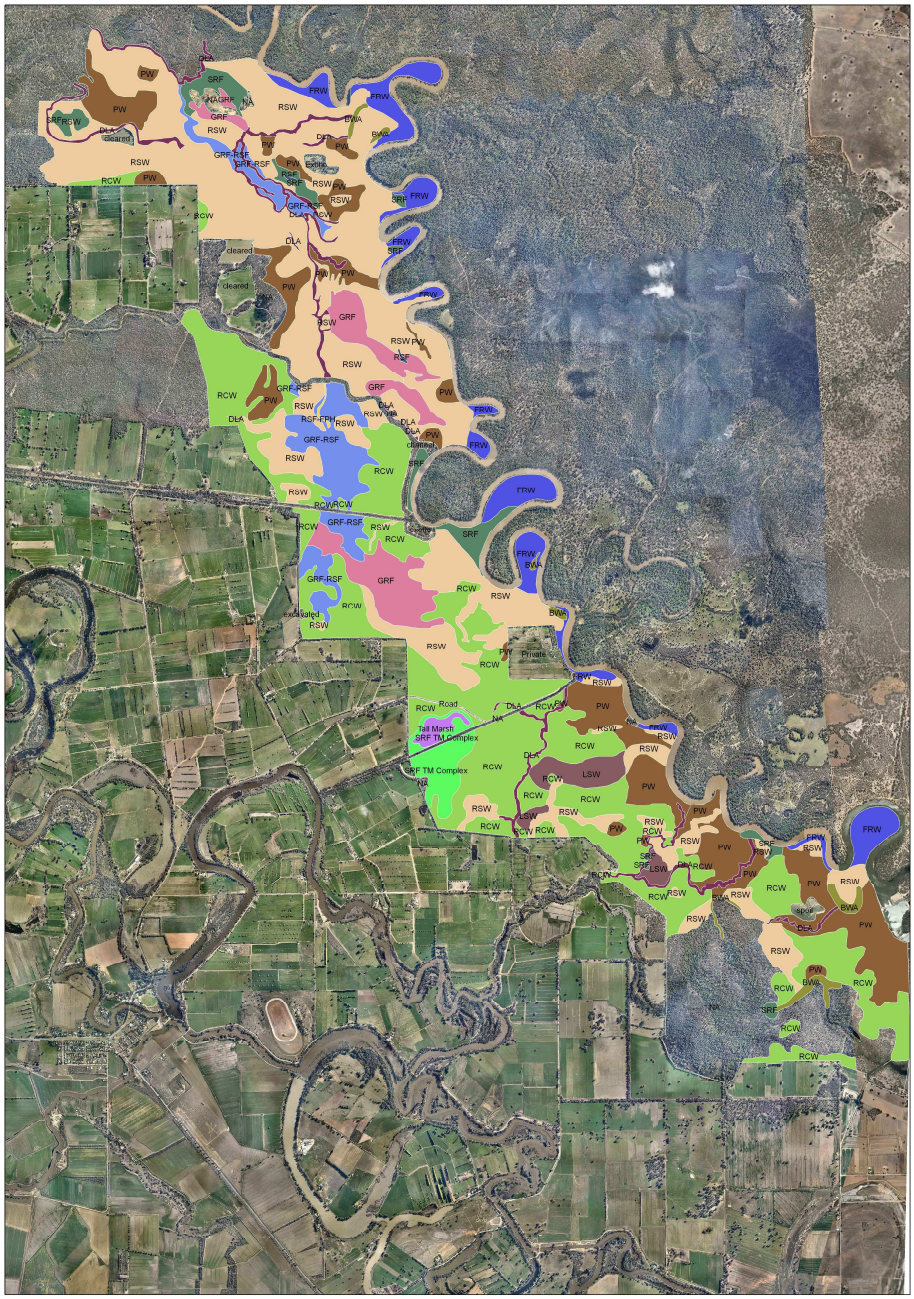


Figure 3. Ecological Vegetation Classes in Gunbower National Park

Key: RCW – Riverine Chenopod Woodland, PW – Plains Woodland, BWA – Billabong Wetland Aggregate, RSW – Riverine Swampy Woodland, LSW – Lignum Swampy Woodland, FRW – Floodplain Riparian Woodland, SRF – Sedgy Riverine Forest, GRF – Grassy Riverine Forest, SRF TM Complex – Sedgy Riverine Forest-Tall Marsh Complex, GRF-RSF – Grassy Riverine Forest- Riverine Swamp Forest Complex.

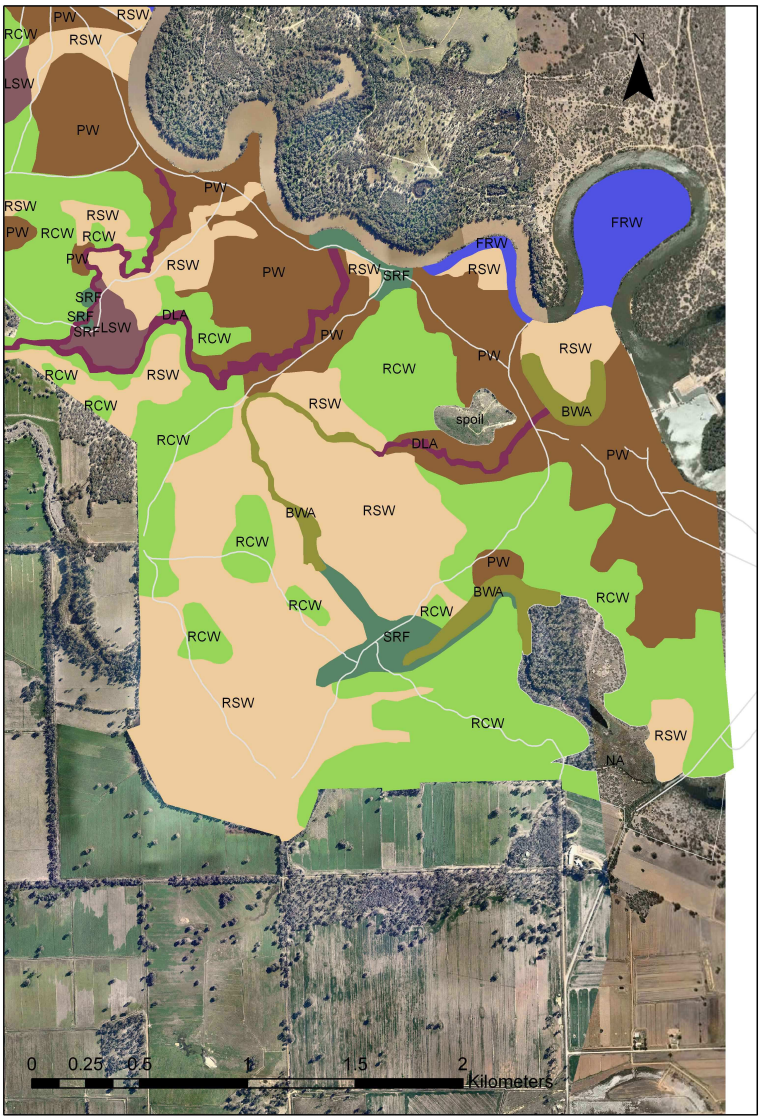
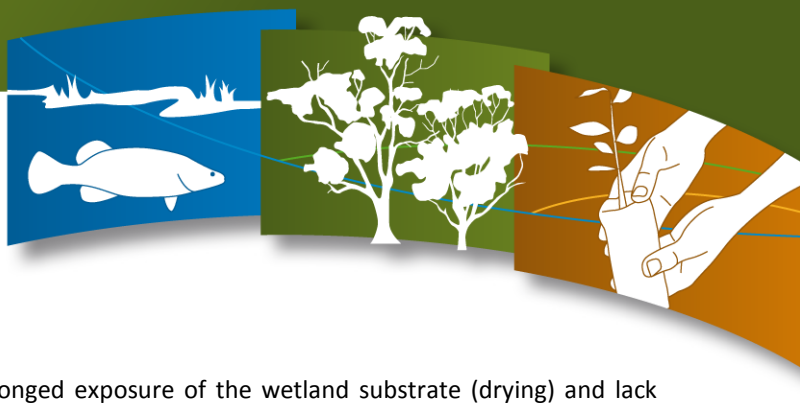


Figure 4. Ecological Vegetation Classes in the Baggots Creek area of Gunbower National Park

Plant Functional Groups

Plant Functional Groups (PFG) describe groupings of understorey vegetation based on their flood tolerance and adaptions in relation to depth, duration and frequency of flooding. Functional groups are described by their ecology, morphology and community function. They can be used to describe change at a small scale over the long term by the presence/absence and abundance of groups, which are characteristic of particular inundation conditions (e.g. wet/dry, deep/shallow/moist) (North Central CMA 2014a).

There are 8 separate PFGs identified for Gunbower Forest, as shown in the below table. These include (Australian Ecosystems 2008a):



- 1. Submerged – Adult plants do not survive prolonged exposure of the wetland substrate (drying) and lack perpetuating rootstocks. Seed or spores may persist in soil during dry times.
- 2. Amphibious fluctuation-responders floating – Aerial parts of plants survive exposure of the wetland substrate (drying) for sustained periods of time. Plants survive drying by dying back to rootstocks.
- 3. Amphibious fluctuation-responders plastic – Can actively grow when substrate exposed but still moist, but may die back to rootstocks or seed during sustained dry periods.
- 4a. Amphibious fluctuation-tolerators low growing – Perennial, maintain same general growth form during brief periods of inundation, but may die back to rootstocks if unable to develop emergent growth during sustained inundation.
- 4b. Amphibious fluctuation-tolerators low growing – Annual (or functionally so), may tolerate very brief periods of shallow flooding during growth phase, but essentially short-lived plants which germinate following flood water recession and produce inundation-tolerant seed during the drying phase.
- 5. Amphibious fluctuation-tolerators emergent – Rootstocks tolerant of shallow inundation but plant intolerant of sustained total immersion. Recruitment and/or long-term maintenance of populations are generally dependent on at least occassional inundation events.
- 6. Terrestrial damp – Rootstocks intolerant of more than superficial inundation, but occuring in areas of good soil moisture conditions, which may be influenced by proximity to river and water seepage through soil.
- 7. Terrestrial dry – Dryland plants (i.e. flood intolerant and going through life cycles independently of flooding regime).

The Plant Functional Group system is the current approach to analysing wetland flora in Gunbower Forest as part of The Living Murray monitoring program. However, it is recognised that there are limitations in characterising the inundation regime based on individual species within these groupings as the collection of species within each group can exhibit a wide range of hydrological requirements including having large variations in depth and duration. For example, group 5 includes *Eucalyptus camaldulensis*, *Carex tereticaulis*, *Juncus ingens* and *Duma (Muehlenbeckia) florulenta,* which have very different flow regimes (D. Frood, pers. comm. August 2014). There are also other limitations if regime characterisation is restricted to this scale and this set of responses.

Species

As of November 2014, around 268 species of native flora have been recorded at Gunbower Forest, including 103 threatened species. These are expected to be present in Gunbower National Park, as the Park includes the full range of habitats found in the lower forest as well as unique Box woodland habitats (K. Bennetts, pers. comm. October 2014). Of this total flora list, at least three species are listed as threatened under the Flora and Fauna Guarantee Act 1988 (Vic), and one listed as nationally threatened under the Environment Protection and Biodiversity Conservation Act (1999). The full flora list is available in the appendix.

Table 1. Example vegetation groupings in Gunbower Forest

Landscape component	Understorey Plant Functional Groups*								Ecological Vegetation Class (bold EVCs occur across >1 landscape)
	1	2	3	4a	4b	5	6	7	
Lower: Permanent Wetlands									Aquatic Herbland (EVC 653) **Drainage Line Aggregate (EVC 168)** Dwarf Floating Aquatic Herbland (EVC 949) Floodplain Grassy Wetland (EVC 809) **Floodway Pond Herbland (EVC 810)** **Rushy Riverine Swamp (EVC 804)** **Spike-sedge Wetland (EVC 819)** Submerged Aquatic Herbland (EVC 918) Un-vegetated Open Water (EVC 990) Tall Marsh (EVC 821)
Semi-permanent Wetlands									
Mid RRG Flood Dependant Understorey									**Drainage Line Aggregate (EVC 168)** Floodplain Riparian Woodland (EVC 56) **Floodway Pond Herbland (EVC 810)** Floodway Pond Herbland / Riverine Swamp Forest Complex (EVC 945) Grassy Riverine Forest (EVC 106) Grassy Riverine Forest / Floodway Pond Herbland Complex (EVC 811) Grassy Riverine Forest/ Riverine Swamp Forest Complex (EVC 812) Riverine Grassy Woodland (EVC 295) Riverine Swamp Forest (EVC 814) Riverine Swampy Woodland (EVC 815) **Rushy Riverine Swamp (EVC 804)** Sedgy Riverine Forest (EVC 816) Sedgy Riverine Forest / Riverine Swamp Forest Complex (EVC 817) **Spike-sedge Wetland (EVC 819)**
RRG Flood Tolerant Understorey									
Upper Black Box									Plains Woodland (EVC 803) Riverine Chenopodium Woodland (EVC 103)
Grey Box									

*PFG1: Submerged seed/spore born aquatic flora, PFG2: Rhizomatous aquatic flora, PFG3: Semi-aquatic flora, PFG4: Annual mudflat flora, PFG4b: Annual mudflat flora, PFGb: Annual mudflat flora, PFG5: Floodplain flora, PFG6: Moisture dependent, PFG7: Dryland species.

Shadings highlight dominance of each PFG across the landscape component water regime classes (the darker the colour the more dominant, white shows no presence) (Australian Ecosystems 2008a).

2.2 Waterbirds

Since 2008 Gunbower Forest has supported at least 131 recorded species of birds, of which 26 species are wetland birds and 10 species are threatened (Webster 2014). The Australasian Bittern (*Botaurus poiciloptilus*), which is listed as threatened under the EPBC Act was previously recorded in Pig Swamp within the Gunbower National Park (Biosis 2014).

Gunbower Forest provides suitable conditions for waterbird feeding and breeding, particularly for colonial nesting species such as egrets, ibis, spoonbills and species listed under the Japan Australia Migratory Birds Agreement (JAMBA), China Australia Migratory Birds Agreement (CAMBA) and Republic of Korea Australia Migratory Bird Agreement (ROKAMBA). In addition, the forest is one of only two sites in Victoria that supports breeding colonies of Intermediate Egrets (DSE 2003). The main guilds of wetland dependant birds that are present at Gunbower Forest include:

- Waterfowl (*Anatidae*)
- Grebes (*Podicipedidae*)
- Pelicans (*Pelecanidaea*)
- Cormorants (*Anhingidae*)
- Darter (*Phalacrocoracidae*)
- Ibis and Spoonbills (*Threskiornithidae*)
- Egrets, Herons, and Bitterns (*Ardeidae*)
- Cranes (*Gruidae*)
- Crakes, Rails, Water hens, and Coots (*Rallidaea*)
- Snipe (*Rostratulidae*, *Scolopacidae*)
- Gulls, Terns (*Laridae*)
- Plovers, Dotterals and Lapwings (*Charadriidae*)

and other wetland-dependant birds include:

- Raptors (*Accipitridae*)
- Songbirds (*Sylviidae*)
- Kingfishers (*Alcedinidae*, *Hylcyonidae*).

2.3 Native fish

Gunbower Island (including the Forest and Creek) is known to support 13 native species of fish, a number of which are considered endangered or threatened under the Federal Environment Protection and the Biodiversity Conservation (EPBC) Act and Victorian Flora and Fauna Guarantee (FFG) Act 1988. Although recent monitoring has not identified them, it is possible that there are other species present or likely to re-establish at the site (Lintermans 2007) (see below).

Detailed information on Gunbower Forest and Gunbower Creek fish is available in the Ecological Watering Guide (North Central CMA 2014a).

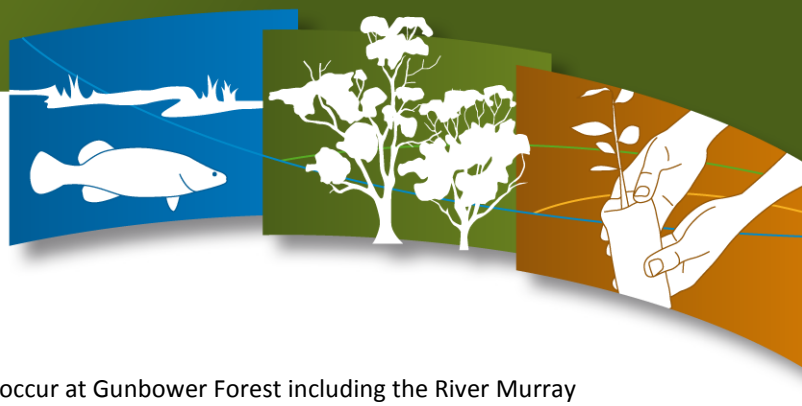


Table 2. Native fish species known and expected to occur at Gunbower Forest including the River Murray

Group	Species Name	Common Name	EPBC	FFG
KNOWN SPECIES				
Long-lived apex predators	*Maccullochella peelii peelii*	Murray cod	Vulnerable	Endangered
	Maccullochella macquariensis	Trout cod	Endangered	Critically Endangered
Flow dependent specialists	*Macquaria ambigua*	Golden perch		Vulnerable
	Bidyanus bidyanus	Silver perch		Critically Endangered
Foraging generalists	*Retropinna semoni*	Australian smelt		
	Hypseleotris spp.	Carp gudgeon (group)		
	Melanotaenia fluviatilis	Murray-Darling rainbowfish		Threatened
	Philypnodon grandiceps	Flathead gudgeon		
	Philypnodon macrostomus	Dwarf flat-headed gudgeon		
	Tandanus tandanus	Freshwater catfish		Vulnerable
	Nematalosa erebi	Bony bream		
	Craterocephalus stercusmuscarum fulvus	Un-specked hardyhead		
	Craterocephalus stercusmuscarum	Fly-specked hardyhead		
EXPECTED SPECIES				
Foraging generalist	*Macquaria australasica*	Macquarie Perch	Endangered	Endangered
Floodplain specialists	*Nanoperca australis*	Southern Pygmy Perch		
	Mogurnda adspersa	Southern Purple-spotted Gudgeon		Extinct
	Galaxias rostratus	Flat-headed Galaxias		
	Ambassis agassizii	Olive Perchlet		Extinct
	Craterocephalus fluviatilis	Murray Hardyhead	Endangered	Critically endangered
	Mogurnda adspersa	Purple-spotted Gudgeons		Threatened

Source: Sharpe (2014); Mallen-Cooper et al. (2014)

3. CONDITION

3.1 Prior to 2010-11

For ten years prior to 2010-11, the dry climatic conditions resulted in below average inflows and therefore lower water availability for regulated environmental flows. Prior to the natural flood event in 2010-11, only small areas (<2000 ha) of Gunbower Forest had been inundated since 2001. Relatively small volumes of environmental water (e.g. 19GL in 2004-5 and 7.5GL in 2009-10) were delivered to permanent and semi-permanent wetlands to create critical refuge areas in the landscape for waterbirds and to maintain wetland vegetation communities. River Red Gum communities remained largely dry throughout the forest (North Central CMA 2014b).

During this period, the condition of the vegetation communities declined (Murray Darling Basin Authority 2012). The understorey of the River Red Gum forests became increasingly dominated by terrestrial species and exhibited a significant loss of plant diversity and weed invasion (Australian Ecosystems 2009b). The extent of River Red Gum with flood dependent understorey decreased and became restricted to a narrow zone around the wetlands (Ecological Associates 2002). This resulted in an increase in the area of River Red Gum with flood tolerant understorey, which extended into the lower parts of the forest and began encroaching on formerly open wetlands (Australian Ecosystems 2009). At higher elevations, River Red Gums were being replaced by the less flood dependent black box woodlands (Ecological Associates 2003). Monitoring of canopy condition from 2005 to 2008 recorded an ongoing decline in eucalypt canopy health (Australian Ecosystems 2008; Murray Darling Basin Authority 2012).

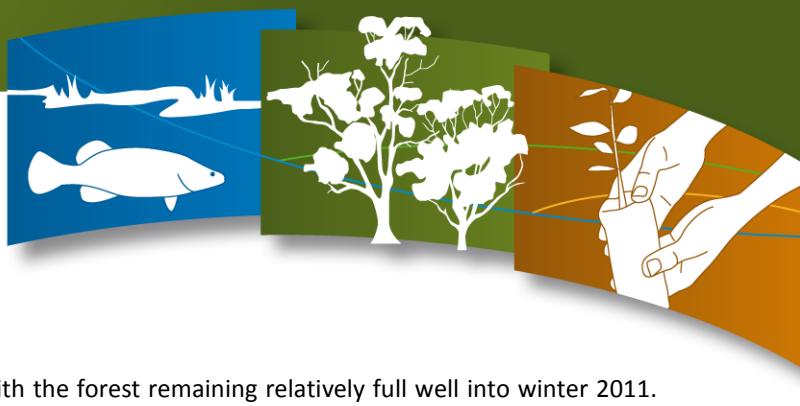
The dry climatic conditions potentially led to a decline in fauna populations and their resilience to additional stressors (Horrocks et al unpubl.). This was most evident for colonial waterbird populations — the extended periods between large floods that support large-scale breeding opportunities posed a key threat to the viability of existing populations (Murray Darling Basin Authority 2012). In 2004-5 in response to a managed environmental water event and natural inflows, the Little Gunbower Wetland Complex supported a significant colony of waterbirds (Egrets, Ibis, darter, cormorants) for the first time in a number of years. The Little Reedy Lagoon complex supported a small colony of cormorants.

The ecological processes required to sustain native fish populations, such as connectivity to the floodplain for breeding and recruitment, have been hindered (Ecological Associates 2010). The absence of the native off-channel specialists in recent surveys – pygmy perch, flat-headed galaxias and southern purple-spotted gudgeon – is largely due to the reduced flooding frequency of the River Murray. This has led to the desiccation of small permanent wetlands, which are a key habitat (Mallen-Cooper et al. 2014).

3.2 Post 2010-11

In the last four years (since 2010) Gunbower Forest has received three years of consecutive flooding. Natural flooding has included a large flood event (1 in 20 year), smaller and shorter over bank floods, and low level natural inflows. The characteristics of the past four years of flooding is summarised below (North Central CMA 2014b).

During 2010-11 Gunbower Forest received extensive natural flooding with three major flooding 'peaks' of above 45,000 ML/day passing through the forest between September 2010 and January 2011. This major flood event (1 in 20 years)



inundated approximately 9,000 ha of Gunbower Forest, with the forest remaining relatively full well into winter 2011. Floodplain and wetland dependent flora responded positively to this inundation, with diverse vegetation growth observed (North Central CMA 2014b).

Between July and September 2012 overbank flooding again occurred inundating approximately 3200 ha.

During spring 2013 a small volume of water entered low lying forest wetlands as a result of natural inflows (maximum 24,000ML/d at Torrumbarry). The natural inflows were not substantial enough to fill the wetlands and the hot summer resulted in wetland water levels receding significantly. From January to May 2014, the majority of semi-permanent and permanent wetlands within the forest had dried completely, with a few permanent wetlands containing small residual pools (North Central CMA 2014b).

Since 2012, the upper forest (Gunbower National Park) has remained dry, with the exception of water from local rainfall/leakage being retained in lower lying areas (e.g. in the Baggots Creek area) (D. Frood, pers. comm. June 2014).

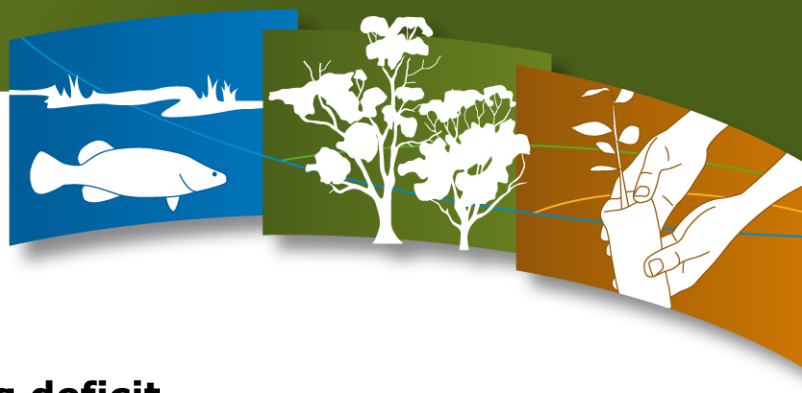
Living Murray monitoring of Gunbower Forest has captured the forests condition in response to the three years of consecutive flooding and is summarised below (North Central CMA 2014b):

- Permanent and semi-permanent wetlands showed a lack of flora species diversity and abundance which is attributed to the prolonged and deep inundation from 2010-11 floods. The subdued response differs to previous results when smaller scale natural flooding or environmental water deliveries resulted in a flourishing wetland plant community. It is thought that this subdued response was due to the deep and prolonged flooding followed by a hot and dry 2012 – 2013 summer, in combination with other factors such as water quality and carp, limiting germination and establishment of plants (Bennetts and Jolly 2013).
- Understorey vegetation in the red gum forest and woodland areas responded positively to the natural flooding. Species diversity in these areas was high due to both terrestrial species and ephemeral aquatic and floodplain flora being present.
- Tree canopy decline has halted as a result of three consecutive years of natural flooding. However the response has been less immediate than that of the understorey vegetation, suggesting that the river red gums require a longer recovery period and further flooding to consolidate new canopy growth and begin improving in health.

The flooding resulted in a positive breeding response from waterbirds. For example, during the 1 in 20 year event in 2010/11 (9,000 ha inundated, with the forest remaining relatively full well into winter 2011), waterbird feeding and nesting was observed and colonial waterbirds bred in the hundreds.

In spring 2011 colonial waterbirds (50-60 pairs of Great egrets and 100 pairs of cormorants) began breeding in Little Gunbower Wetland complex in response to the widespread flooding across the forest. Between December 2011 and February 2012, 700ML of TLM environmental water entitlement was used to maintain sufficient water levels under the colony until the breeding event was completed (North Central CMA 2012).

Between July and September 2012 overbank flooding occurred inundating approximately 3200 ha. Waterbird monitoring in the Little Gunbower Wetland Complex in November 2012 detected about 100 Little Pied and Black Cormorant nests and ten White Ibis nests (North Central CMA 2012). This breeding event did not require support with environmental water.



3.3 Ongoing expected flooding deficit

Gunbower Forest is located in an area of low rainfall and high evapotranspiration. The average annual rainfall is less than 400 millimetres per year with evapotranspiration of around 1,700 mm/y. This creates a significant water deficit and stressor to the forest, particularly in years where there are no forest inflows to maintain health of vegetation communities (Murray Darling Basin Authority 2012).

The hydrology of Gunbower Forest has changed substantially because of the regulation and diversion of River Murray flows, resulting in a reduction in the frequency and duration of flooding.

Recent modelling demonstrates that, under current river operations, intervention is needed to maintain functioning floodplain ecosystems within Gunbower Forest. Table 3 compares the frequency of selected flow thresholds under natural conditions, current conditions and under the proposed 2,750GL Basin Plan (Gippel 2014). This shows a significant reduction in a range of flow events, including the high flow events above 50GL/day when extensive inundation of Gunbower National Park can be expected.

Table 3. Spells analysis for downstream of Torrumbarry over 114 year modelled period

Flow threshold exceeded (GL/d)	Natural conditions		Current conditions *		Basin Plan (2750GL)	
	Median frequency (events/100yrs)	Median duration (days)	Median frequency (events/100yrs)	Median duration (days)	Median frequency (events/100yrs)	Median duration (days)
>10	103.5	204	103.5	83	113.2	133
>15	100.9	174	79.8	76	95.6	97
>20	98.2	149	63.2	77	80.7	87
>25	93.9	118	50.0	81	69.3	76
>30	83.3	101	45.6	67	54.4	84
>35	79.8	79	36.8	63	47.4	73
>40	68.4	84	37.7	39	40.4	62
>45	60.5	68	30.7	30	34.2	55
>50	51.8	53	24.6	37	28.1	35
>55	39.5	37	10.5	35	10.5	37

Source: Gippel 2014: * Benchmark conditions (run 6575)

The current flooding deficit is expected to increase based on the 2030 median climate change scenario (Table 4) (Murray Darling Basin Authority 2012).

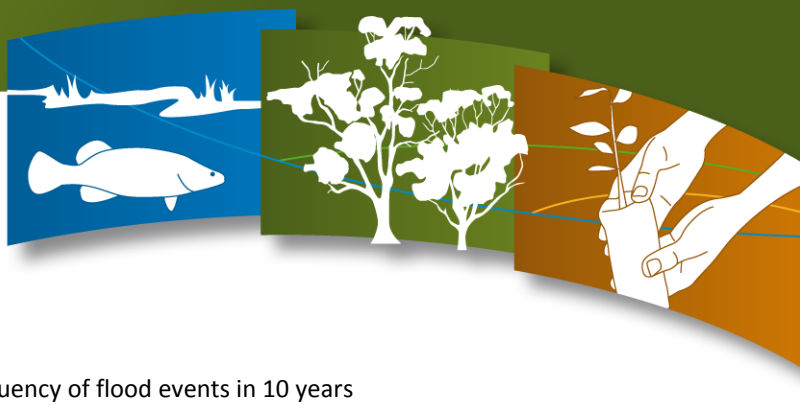
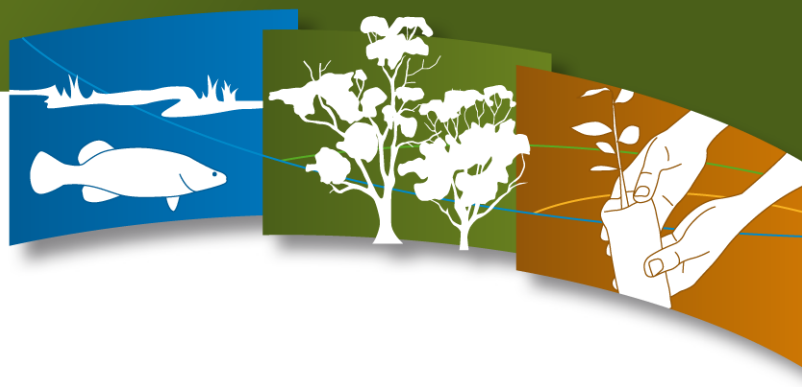


Table 4. Modelled average frequency of flood events in 10 years

Flood event	Natural conditions	Current conditions	Median climate change conditions
>25GL/day for 1 mth	8.7	4.2	3.7
>35GL/day for 2 mths	5.7	2.3	1.5
>35GL/day for 3 mths	4.5	1.5	0.9

Source: Murray Darling Basin Authority 2010



4. ECOLOGICAL OBJECTIVES AND TARGETS

Ecological objectives and targets describe the intended outcomes of environmental water delivery. They contribute towards achieving the higher level goals (vision and management goal) including:

Gunbower Forest vision (in line with The Living Murray):

To maintain and improve Gunbower Island by enabling native plants and animals to flourish, restoring the floodplain's health for future generations.

Management goal for Gunbower National Park Environmental Works Project:

Reinstate a more natural water regime that protects and enhances the ecological values within the Gunbower National Park and, where possible, supports values in downstream areas of Gunbower Island.

Two levels of objectives and targets have been developed (similar to those developed for The Living Murray Program) (Table 3). The overarching objectives capture the primary, higher level aims of the project, while the detailed objectives break the overarching objectives down into the various ecological components i.e. they describe what a 'healthy' community may include, which can then be linked to monitoring methods and reporting against targets.

The ecological objectives and targets for the Gunbower National Park project are based on the key values of the site (in line with the Victorian Waterway Management Strategy) including its:

- diversity of habitat (e.g. foraging areas) required for macro/micro invertebrates, frogs, fish and waterbirds across multiple feeding guilds e.g. dabbling ducks, deep-water foragers, fish eaters (which includes predators of frogs and yabbies), large waders, grazing waterfowl and shoreline foragers.
- ability to support native frog and native fish breeding.
- ability to support waterbird breeding events for species such as ducks, grebes, swamphens and herons in the upper part of the forest (National Park) and potentially colonial nesting species in the lower part of the forest (wetland complexes) during large flow events.
- ability to support species listed under international agreements (JAMBA, CAMBA, ROKAMBA, Bonn Convention), the Environmental Protection Biodiversity Conservation Act (1999) and the Flora and Fauna Guarantee Act (1988).
- wetlands with diverse habitat that provide opportunities for sustaining populations of small-bodied fish species. In non-flood years, these wetlands serve as refuge habitats for small-bodied native fish.

The objectives also take into consideration the:

- Hydrological changes in the system – the current and projected deficit in the water regime compared to natural inundation. Refer to previous section 'Ongoing expected flooding deficit'.
- Current condition of each value and therefore whether intervention is required. Refer to previous section for a description of condition over time.

- Inter-dependencies within the Gunbower Forest site and between local forest floodplains (e.g. Koondrook-Perricoota). For example, the success of colonial nesting waterbird breeding in the lower Gunbower Forest is dependent in part on the availability and security of foraging areas. Therefore the existing TLM objective for Gunbower Forest regarding colonial waterbird breeding in the lower forest is inter-linked with the objectives in the upper forest around inundating River Red Gum forests to provide foraging areas for waterbirds.

The overarching ecological objectives for the Gunbower National Park project and the justification for each are shown below.

Table 5. Overarching ecological objectives and their justifications for Gunbower National Park

Overarching objective	Justification
Healthy River Red Gum forests with flood dependent understorey (temporary wetlands) across Gunbower National Park	▪ Provides food and habitat for micro/macro invertebrates (which are food resources for frogs, fish and waterbirds). ▪ Helps maintain wetland productivity by providing organic inputs to the water column (e.g. carbon and nutrient inputs from leaf litter). ▪ Provides nesting material ((including hollows) and roosting habitat for waterbirds. ▪ Tree canopy decline has halted after recent flooding but further flooding is needed to consolidate new canopy growth and for health to begin improving (TLM monitoring). ▪ Flood dependent understorey reduced in extent prior to 2010. While species diversity improved after 2010-12 flooding, by 2013, the understorey vegetation had returned to pre-flood levels of diversity (Bennetts & Jolly 2013).
Drought refuge habitat provided for fauna (particularly small-bodied native fish) in Gunbower National Park through Black Charlie Lagoon.	▪ Black Charlie Lagoon is the only permanent wetland in the Gunbower National Park. ▪ Provides food and habitat for micro/macro invertebrates (which provide food resources for fish). ▪ Cameron's Creek (feeding Black Charlie Lagoon) is home to conservation significant species such as the FFG Act listed Broad-shelled tortoise and Murray-Darling Rainbowfish. These species are also expected at the wetland.
Healthy wetland bird community in Gunbower National Park through improved access to food and habitat that promotes breeding and recruitment.	▪ Rehabilitating a diversity of foraging habitat supports a high carrying capacity of waterbirds across Gunbower Forest including those residing/breeding in the upper forest and those residing/breeding in the lower forest, which use broader foraging areas (e.g. Colonial nesting species). This will promote a diverse waterbird community from a range of feeding guilds. ▪ Waterbird breeding success is correlated with the foraging area available. For example, breeding waterbirds within Gunbower Forest have been reported to move on a daily basis to the adjacent Koondrook Perricoota area for foraging (North Central CMA 2009). ▪ Pig Swamp is known to support ducks (hundreds at times including Grey Teal and Pacific Black Ducks), coots, ibis, hawks, kingfishers and mudlarks. ▪ Black Charlie Lagoon is expected to support a similar suite of birds to those in Pig Swamp. ▪ Provision of appropriate habitat will support recruitment of waterbirds at a landscape scale.

The full range of ecological objectives and targets for the project are shown below.

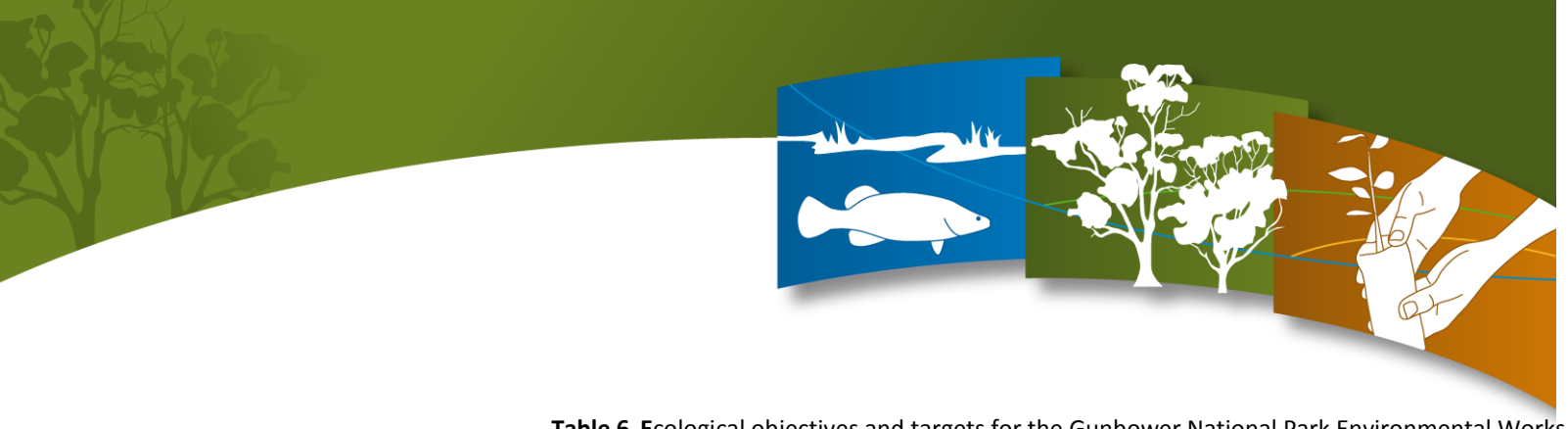
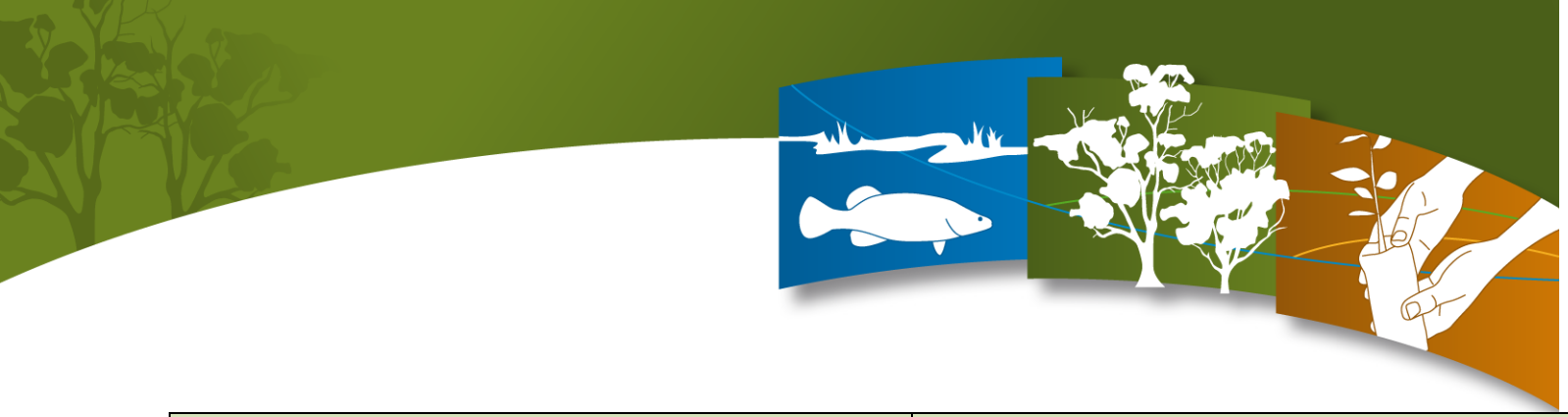


Table 6. Ecological objectives and targets for the Gunbower National Park Environmental Works Project

Objectives (by 2040)	Targets (by 2040)	Applicable values
RIVER RED GUM WITH FLOOD DEPENDENT UNDERSTOREY		
▪ Overarching: Healthy River Red Gum forests with flood dependent understorey (temporary wetlands) across Gunbower National Park.	▪ R1 (Overarching): 370 ha of River Red Gum forest with flood dependent understorey with a water regime that maximises healthy condition.	▪ FFG Act listed River Red Gum Grassy Woodland ecological community. ▪ Vulnerable Riverine Swampy Woodland (EVC 815) in Murray Fans Bioregion. ▪ Depleted Grassy Riverine Forest (EVC 106) in Murray Fans Bioregion.
▪ Achieve an appropriate cover and diversity of species characteristic of the Plant Functional Groups found in the River Red Gum forest flood dependent understorey.	▪ R2: River Red Gum with flood dependent understorey – o Plant Functional Groups 2-7 have >50% of total cover occupied by at least 2/3 of all species possible within these Plant Functional Groups.	
▪ Maximise the proportion of trees with healthy canopy condition in the River Red Gum forests with flood dependent understorey.	▪ R3: At least 75% of surveyed trees with 'healthy' canopy condition as defined by a crown condition index score of 4 or greater	
▪ Maintain and where possible increase the current diversity of threatened flora species.	▪ R4: >50% of threatened flora species previously recorded observed.	
▪ Reduce the area of high threat weed species.	▪ R5: High threat exotic plants absent in >90% of total cover.	
NATIVE FISH IN WETLANDS		
▪ Overarching: Drought refuge habitat provided for fauna (particularly small-bodied native fish) in Gunbower National Park through Black Charlie Lagoon.	▪ F1 (Overarching): Permanent wetland habitat provided in Black Charlie Lagoon in all years.	▪ Black Charlie Lagoon is the deepest wetland in Gunbower Forest, perfect for drought refuge. ▪ Diverse fish community. ▪ Aquatic species of conservation significance e.g. the FFG Act listed Murray-Darling Rainbowfish.
▪ Maintain and where possible improve the current diversity of the small-bodied native fish community in Black Charlie Lagoon.	▪ F2: The five small-bodied native fish generalist species previously recorded occur every year in Black Charlie Lagoon (Carp gudgeon, Flathead gudgeon, Un-specked hardyhead, Australian smelt and Dwarf flat-headed gudgeon).	
▪ Promote recruitment of small-bodied native fish in Black Charlie Lagoon.	▪ F3: A range of age/size classes are present for each small-bodied native fish species in Black Charlie Lagoon.	



Objectives (by 2040)	Targets (by 2040)	Applicable values
NATIVE BIRDS		
▪ Overarching: Healthy wetland bird community in Gunbower National Park through improved access to food and habitat that promotes breeding and recruitment.	▪ B1 (Overarching): Successful waterfowl breeding in 9 out of 10 years.	▪ 68 wetland birds have been recorded. ▪ Waterbird feeding and breeding habitat including Sedgy Riverine Forest/Riverine Swamp Forest Complex (EVC 817) that is depleted in the Murray Fans Bioregion.
▪ Contribute to the colonial nesting waterbird community in the lower Gunbower Forest by providing foraging areas in Gunbower National Park.	▪ B2: 450 ha of the floodplain inundated for colonial waterbird foraging 6 years in 10.	
▪ Maintain and where possible increase the current diversity of threatened wetland bird species.	▪ B3: >50% of threatened wetland bird species previously recorded observed within a ten-year period.	

5. HYDROLOGICAL REQUIREMENTS

5.1 Overview of requirements

The indicative hydrological requirements for each ecological component described through the objectives are shown below. The justification for these water requirements is provided below and is based on a substantial literature review as well as input by expert ecologists.

These hydrological requirements have been used to inform the proposed water regime for the project outlined in the next chapter.

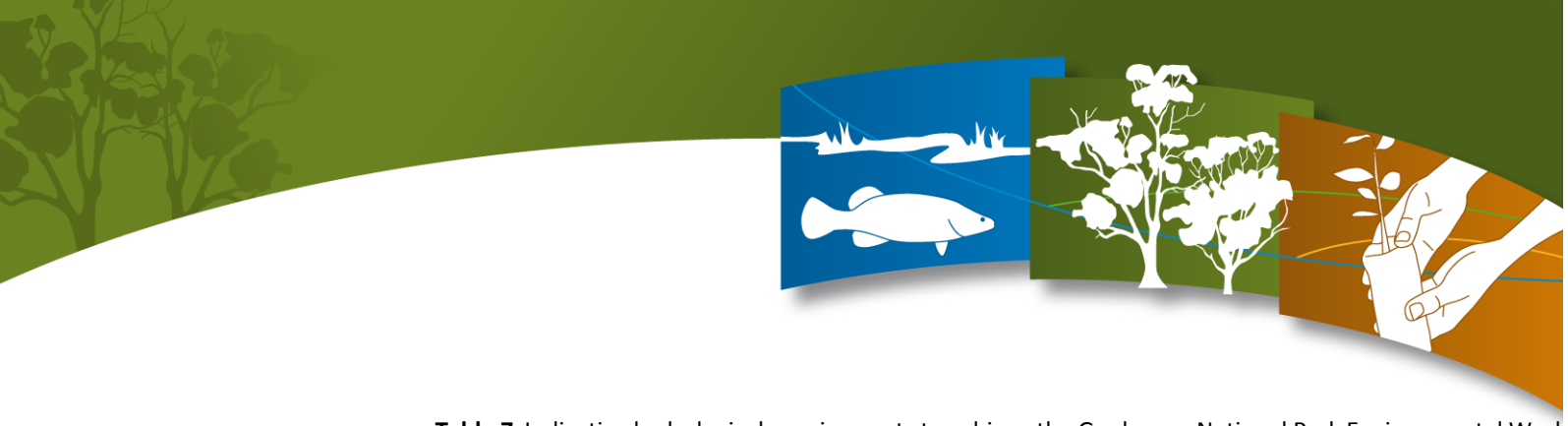
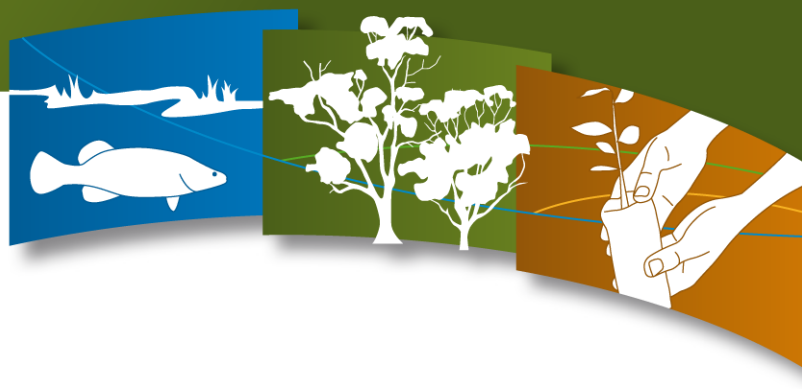


Table 7. Indicative hydrological requirements to achieve the Gunbower National Park Environmental Works Project objectives

Ecological Component	Hydrological Objectives										
	Recommended number of events in 10 years			Tolerable interval between events once wetland is dry (mths)			Duration of ponding (months)			Preferred timing of inflows	Depth (m)
	Min	Opt	Max	Min	Opt	Max	Min	Opt	Max		
Healthy River Red Gum forests with flood dependent understorey (temporary wetlands) across Gunbower National Park	5	6	6	3yrs	-	4yrs	1	-	6	Winter/ spring	Variable. Some understorey sp. prefer shallow depths <10cm during active growth but can tolerate deeper immersion for short periods.
Drought refuge habitat provided for fauna (particularly small-bodied native fish) in Gunbower National Park through Black Charlie Lagoon	9	10	10	0	0	0	12	12	12	Winter/ spring	Varies greatly depending on sp. requirements. Black Charlie Lagoon is >3m deep in some parts. Need to fluctuate depth over time to promote wetland productivity.
Healthy wetland bird community in Gunbower National Park through improved access to food and habitat that promotes breeding and recruitment	3	5	10	0	12	24	4	6	12	Late winter/ spring/ early summer	Maximise area up to 30cm deep. Need to fluctuate depth over time to promote wetland productivity.



5.2 Justification for hydrological requirements

Evidence to support the hydrological requirements for each ecological objective is outlined below. This includes a combination of primary and secondary literature/reports, as well as input by expert ecologists. A literature review is available in the Appendix.

River Red Gum with flood dependent understorey (Overarching objective: Healthy River Red Gum forests with flood dependent understorey (temporary wetlands) across Gunbower National Park)

River Red Gum forests with flood dependent understorey in the inundation footprint (through Old Cohuna Main Channel environmental water deliveries) predominantly include Grassy Riverine Forest (106), Grassy Riverine Forest – Riverine Swamp Forest Complex (EVC 812) and Riverine Swampy Woodland (EVC 815) (Ecological Associates 2014 mapping). The River Red Gum forests immediately downstream of Black Charlie Lagoon that will be watered through the project include mainly Riverine Swampy Woodland (EVC 815) with a small area of Sedgy Riverine Forest (EVC 816) adjacent to Black Charlie Lagoon (K. Bennetts 2014 survey and mapping).

The water requirements for these EVCs overlap and the water regime has been based on the tolerance limits of these EVCs (see below table).

Table 8. Water requirements for River Red Gum Forest EVCs inundated through the project

EVC	Natural flood frequency	Critical interval between events (yrs)	Minimum duration (mths)
Grassy Riverine Forest	5-10 in 10	4	1-4
Grassy Riverine Forest - Riverine Swamp Forest	6-10 in 10	3	3-6
Riverine Swampy Woodland	2-6 in 10	5	<1-2
Sedgy Riverine Forest	2-6 in 10	5	1-2

Source: Fitzsimons et al. 2011.

Native fauna in wetlands (Overarching objective: Drought refuge habitat provided for fauna (particularly small-bodied native fish) in Gunbower National Park through Black Charlie Lagoon)

Black Charlie Lagoon is the only permanent wetland in the Gunbower National Park and is categorised as Billabong Wetland Aggregate (EVC 334). It relates to the overarching wetland fauna (native fish) objective around drought refuge habitat. The water requirements have therefore been based on the need to provide water year round to support the resident small-bodied native fish community and other aquatic fauna.

The water regime specified for Black Charlie Lagoon (to achieve the ecological objectives for the project) is in line with that required to support a range of aquatic plants including algae and pondweeds (*Potamogeton* spp.), Cumbungi (*Typha* spp.) (Roberts & Marston 2011), water ribbons (*Triglochin* spp.) and clubrush (*Schoenoplectus* spp.) (Nicol et al. 2013). Such vegetation is required by species like the vulnerable (DSE 2013) Southern Pygmy Perch (*Nannoperca australis*), which was last recorded in Black Charlie Lagoon in December 1997 (Mallen-Cooper et al. 2014). While not a direct target of the project, delivering the proposed water regime for Black Charlie Lagoon will enable any re-introductions of Southern Pygmy Perch in the future to be well supported (e.g. through translocation programs), as the

water regime aligns with that reported to be required by the threatened fish species (Department for Environment and Heritage 2008; NSW Department of Primary Industries). This will help achieve the objective to improve the diversity of small-bodied native fish in the permanent wetland.

The water regime aligns with that specified in the literature for the Billabong Wetland Aggregate EVC (Fitzsimons et al. 2011) and would be adaptively managed in response to monitoring results. See Appendix 1 for further details on general wetland water requirements.

Native birds (Overarching objective: Healthy wetland bird community in Gunbower National Park through improved access to food and habitat that promotes breeding and recruitment)

The hydrological requirements for this objective relate to the general waterfowl/wetland bird community that is expected to reside in the wetland habitats available in Gunbower National Park. It does not include the hydrological requirements of colonial nesting species (e.g. Egrets), which temporarily reside and breed in the lower forest and may only occasionally use the upper forest as foraging habitat.

An expert bird ecologist has confirmed the hydrological requirements outlined above, during the Ecological Objectives refinement workshop (R. Webster, pers. comm. July 2014).

The literature strongly indicates that a dynamic system is most beneficial to native waterbirds:

- It is a diversity of healthy vegetation types across the floodplain that is likely to increase habitat diversity, food sources and therefore the diversity of waterbird species that use a wetland complex (Ecological Associates 2010).
- Natural or artificial waterbodies that offer an array of water depths and vegetation associations tend to have rich communities of invertebrates, and carry higher numbers of species and individuals of waterbirds (Broome and Jarman 1983).
- The cycle of growth and decay and thus greater availability of nutrients in the water column (Baldwin and Mitchell 2000), resulting from regular inundation and exposure of vegetation along wetland margins, or across the wetland bed, is the basis of a complex food web that provides food to the vertebrates that forage in, on and around the water (Baxter et al. 2005), and which in turn supports breeding events in many species of fish and waterbirds (Crome 1988, Junk et al. 1989, Scott 1997, Ecological Associates 2010).
- For a complex waterbird community to exist in Gunbower Forest wetlands, a mosaic of shallow gently sloping margins as well as deeper water (>30 cm) and a variety of inundated vegetation types are required (Ecological Associates 2010).
- In Gunbower Forest a drying phase across the floodplain subsequent to inundation is important to waterbird carrying capacity and species diversity (Ecological Associates 2010).

See Appendix 1 for specific details on waterbird requirements.

The wetland locations waterfowl/wetland birds use in the Gunbower National Park include Black Charlie Lagoon and Pig Swamp. Black Charlie Lagoon includes Billabong Wetland Aggregate (EVC 334), while Pig Swamp is composed of Sedgy Riverine Forest-Riverine Swamp Forest Complex (EVC 817), Tall Marsh (EVC 821) and open water. The water requirements for these EVCs are shown below.

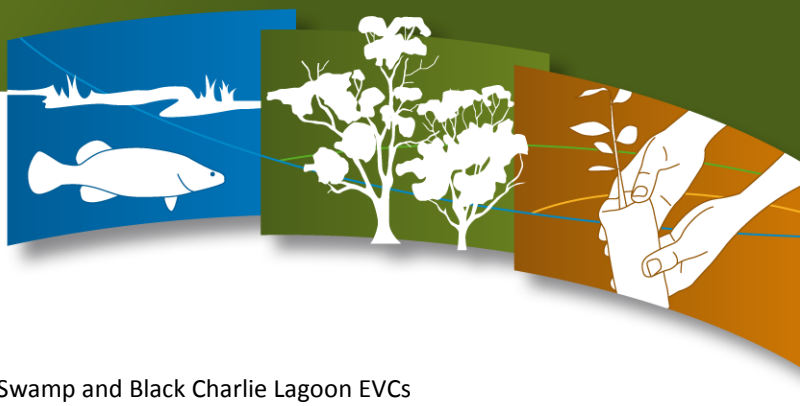
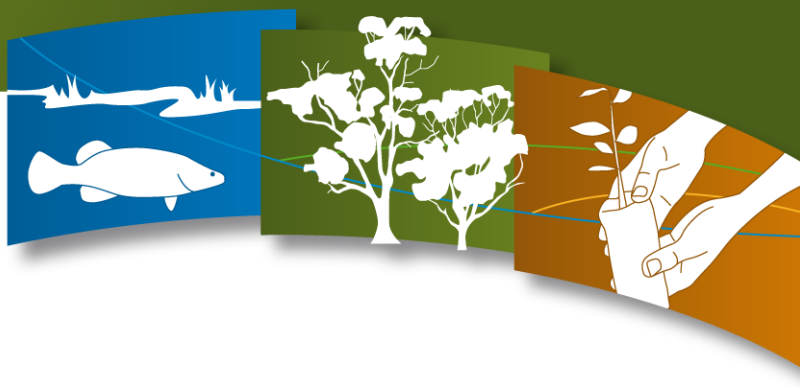


Table 9. Water requirements for Pig Swamp and Black Charlie Lagoon EVCs

Wetland	EVC	Natural flood frequency	Critical interval between events (yrs)	Minimum duration (mths)
Pig Swamp	Sedgy Riverine Forest – Riverine Swamp Forest	6-8 in 10	3	4-7
	Tall Marsh	6-10 in 10	2	6-11
Black Charlie Lagoon	Billabong Wetland Aggregate	Variable	2	>6

Source: Fitzsimons et al. 2011.

These align well with the water requirements of the waterfowl/wetland bird community expected to reside in these wetlands as shown in Table 7.



6. PROPOSED WATER REGIME

The water regime for the Gunbower National Park has been based on consideration of:

- The relationship between objectives – for example, healthy waterbirds and small-bodied native fish in the upper forest primarily relate to availability of permanent wetland.
- The natural inundation frequency as well as the water requirements of current Ecological Vegetation Classes.
- An extensive literature review.
- Risk management – e.g. water regimes that minimise risks such as blackwater.

The water regime for the Gunbower National Park may be defined for three scenarios as below.

Scenario 1 – Permanent wetland watering (Black Charlie Lagoon):

- Frequency: 10 years in 10
- Duration of inundation: 12 months
- Timing: Winter/spring, with partial drying (drawdown of water level) in late summer/autumn.
- Depth: fluctuate over time, inundate to Full Supply Level in some years.

Scenario 2 – River Red Gum forest with flood dependent understorey (Old Cohuna Main Channel):

- Frequency: 6 years in 10
- Duration of inundation: 2-4 months
- Timing: Winter/spring

Scenario 3 – River Red Gum forest with flood dependent understorey (Camerons Creek):

- Frequency: 6 years in 10
- Duration of inundation: up to 2 months
- Timing: Winter/spring

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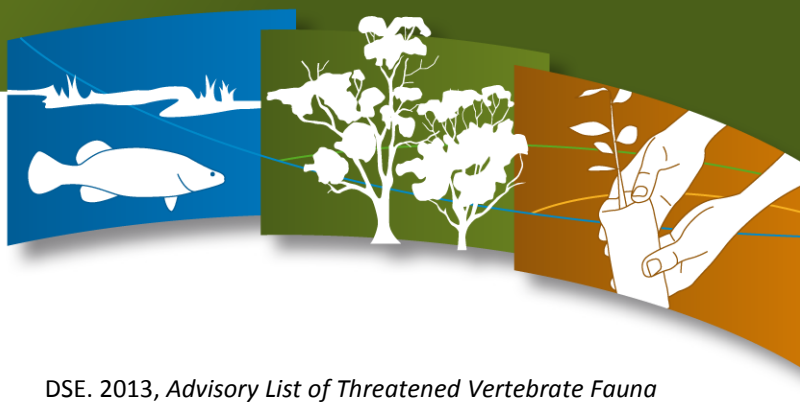

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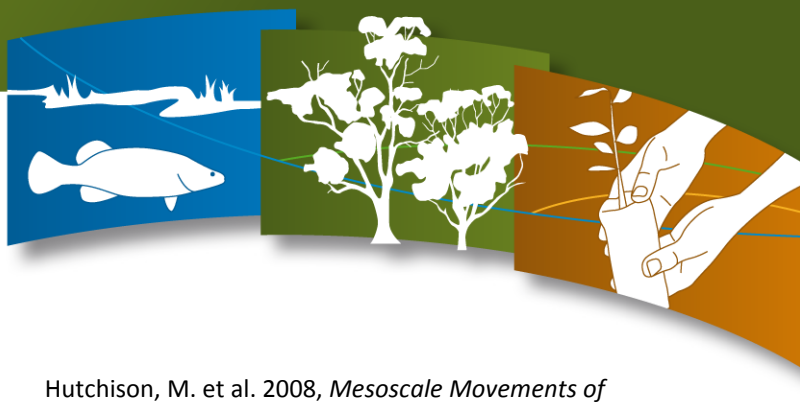

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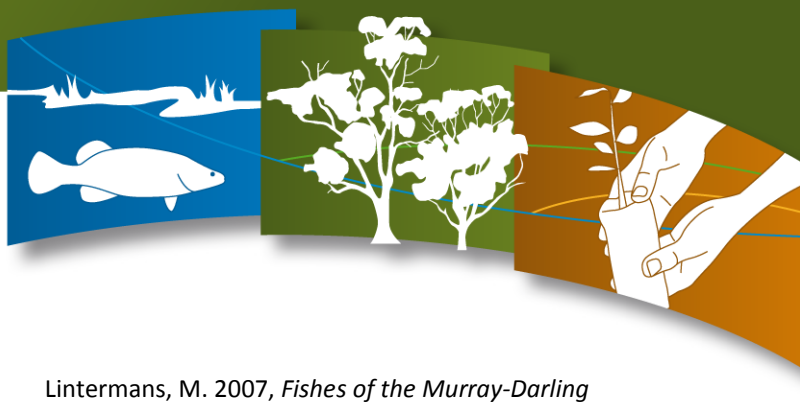

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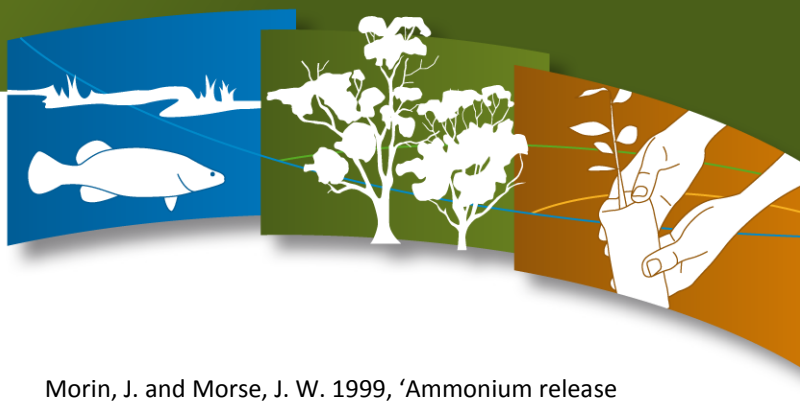

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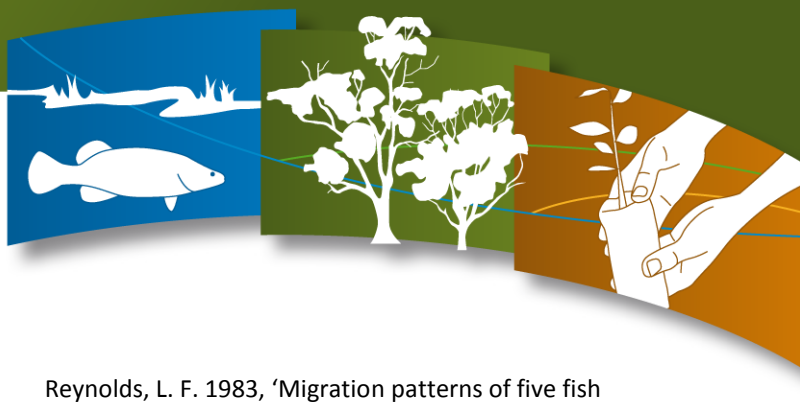

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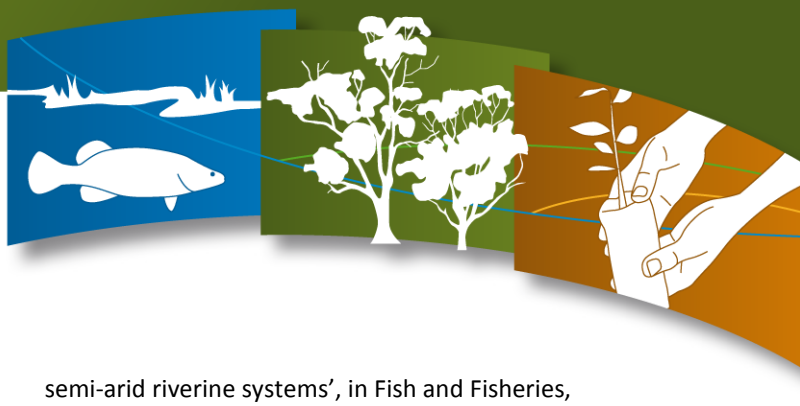

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Appendix 1: Literature review of hydrological requirements

Watering risks to be managed

Avoid water draw down in the wetlands during spring to early summer, which may result in displacement of wetland flora through **excessive River Red Gum recruitment** (Ecological Associates 2013). Insteam promote natural draw down in late summer/autumn (North Central CMA 2014). Alternatively, ensure water is available for follow-up flooding to drown red gum saplings. **Colonisation of wetlands by Giant Rush** (*Juncus ingens*) has been identified as a potential issue in Barmah Forest but it is currently not expected to be a problem in Gunbower Forest due to the different wetland geomorphology (basin-like wetlands rather than large flat wetlands with shallow inundation over large areas) (K. Stanislawski, pers. comm. May 2014). This needs to be confirmed through ongoing monitoring.

Several **aquatic weeds have the potential to expand** their distributions into Gunbower Forest through propagules being transported in environmental water and suitable conditions for growth being provided under the environmental water regimes (Ecological Associates 2010). These species need to be monitored and management actions adopted where appropriate. High threat weeds include those currently established in irrigation channels, those with limited extent along irrigation channels but with considerable potential to expand, those in scattered locations across Gunbower Forest (Water Plantain (*Alisma lanceolatum*), Flat Drain-sedge (*Cyperus eragrostis*), Annual Beard-grass (*Polypogon monspeliensis*), Clustered Dock (*Rumex conglomeratus*), Paspalum (*Paspalum dilatatum*) and Water Couch (*Paspalum distichum*)) and those with the potential to invade via irrigation channels from the broader region (Alligator Weed (*Alternanthera philoxeroides*), Senegal Tea Plant (*Gymnocoronis spilanthoides*) and Cabomba (*Cabomba caroliniana*)). Some terrestrial weeds may also benefit from increased soil moisture provided through environmental watering including Bridal Creeper (*Asparagus asparagoides*), Blackberry (*Rubus fruticosa spp. agg.*), Horehound (*Marrubium vulgare*), Patterson's Curse (*Echium plantagineum*), Prickly Pear (*Opuntia* spp.), African Box-thorn (*Lycium ferocissimum*) and thistles (namely *Sonchus* spp. and *Cirsium vulgare*) (Ecological Associates 2010).

Ensure **contingency environmental water is available to support bird breeding events** that may initiate as a result of environmental water delivery to wetland systems. Bird breeding may be a primary goal of an environmental watering event if catchment conditions are appropriate (e.g. ideal climatic cues) or it may be an unintended (but desirable) ecological outcome. Either way, if a breeding event occurs, careful monitoring of the area of inundation and water depth around breeding sites (beneath nests and in foraging areas) will need to occur. Supplementary environmental water may be required, particularly early in the breeding cycle (August to October), to maintain the depth and area of inundation in key areas so that waterbirds do not abandon their nests and chicks before they fledge (Ecological Associates 2010).

Native fish (in particular larvae) within environmental water supplies may enter Gunbower Forest during water delivery events. To **avoid fish being stranded** in Gunbower Forest, ensure a sharp drop in water level is provided in late spring or summer (to provide fish with a cue to leave the forest) followed by a gradual ongoing decline in water level (to provide fish with opportunities to leave the floodplain while the wetland and Gunbower Creek habitats are still connected) (Ecological Associates 2010).

Blackwater events occur when organic matter on the floodplain is inundated and the process of decay uses dissolved oxygen in the water much faster than it can be produced (through the air-water interface or plant photosynthesis). Low dissolved oxygen levels (below 4 mgO_2/L) can stress native fish and other aquatic animals, while very low dissolved oxygen (e.g. $0.5mgO_2/L$ anoxic conditions) can kill aquatic organisms. While blackwater is a natural phenomenon, it can be reduced by regular inundation (to avoid high loads of organic

matter build up), avoiding inundation in summer months (dissolved oxygen declines as temperature increases) and minimising the creation of still or deep water environments that are prone to stratification (Ecological Associates 2010). Avoid delivering environmental water when there is a combination of lower than normal flow in the Gunbower Creek and higher than average temperatures. For environmental watering post long, dry periods in Gunbower Forest, deliver the flow when there is moderate to high Gunbower Creek flows to allow a full assessment of water quality impacts to determine the minimal safe flow for operation. Ensure contingency water is available in upstream storages for dilution purposes if water quality deteriorates.

Permanent wetlands

Flood frequency and duration

Under natural conditions, the Murray Flows Assessment Tool (MFAT) suggested that permanent wetlands in Gunbower Forest would have rarely dried out – the inundated area fell below 20% only 8 times in the 108 year model run. On average, these events lasted 124 days and only occurred in major droughts, such as 1903, 1915 and 1982/83. Prior to regulation, longer and more frequent flood peaks (above 15,000 ML/day) maintained a high water level in the permanent wetlands. Most of the storage area (80%) was flooded 95% of the time. The duration of inundation above this water level was an average of almost 10 years per event (3140 days) (URS 2001).

Eel Grass (*Vallisneria australis)* is an example of a submerged macrophyte species in Gunbower Forest's permanent wetlands. Flood duration for Eel Grass must be long enough for the canopy to complete all phases from spring initiation to autumn build-up of underground storage. In most cases this means *Vallisneria* occurs in lakes and wetlands and parts of river channels which are permanently flooded or flooded for several years at a time (Roberts & Marston 2000), although they are often impacted by carp (D. Frood, pers. comm. August 2014).

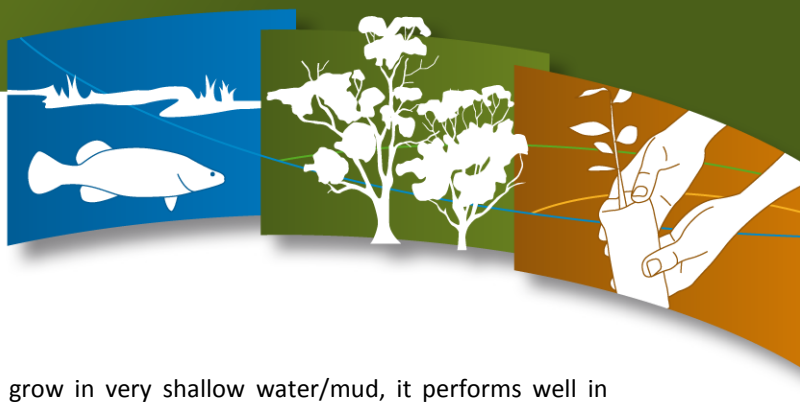
Giant Rush (*Juncus ingens*) can be found along wetland fringes and in Northern Victoria occurs where flooding lasts for 6-11 months. The optimum duration is 9 months for this species (Ward 1996). The water regime for Common Spike-sedge (*Eleocharis acuta*) has an optimum duration of 8 months in northern Victoria, though the species tolerates 3-10 months flooding (Ward 1996).

Furthermore, it is important that permanent wetlands are flooded almost annually in Gunbower Forest during drought periods if they are to provide a refuge for the survival of juvenile cohorts of waterbirds. Flooding any less regularly during drought periods would provide insufficient refuge, as the shallow wetlands would dry out. The exceptions may be deeper wetlands (e.g. Reedy Lagoon, Black Swamp, Black Charlie Lagoon), which may need to be topped up on a biannual basis to maintain a drought refuge capability (Ecological Associates 2010).

Timing and depth of flooding

It is believed both permanent and semi-permanent wetland systems evolved, prior to river regulation, under a dynamic regime with principally winter-spring flooding (Roberts & Marston, 2000) that is likely to have facilitated permanent inundation of the deepest wetlands in all but the driest of summers (Ecological Associates 2010).

Spring flooding is critical for the growth of wetland macrophytes, the maintenance of macrophyte species richness and favours better development of autotrophic biofilms. Production and species richness of aquatic macrophytes was higher in locations with spring floods rather than summer floods. The history of flood frequency did not affect production or species richness (Robertson et al. 2001). However, field observations



have found while *Eleocharis acuta* may well actively grow in very shallow water/mud, it performs well in Riverine Swamp Forest, and in association with Moira Grass in treeless vegetation which are flooded up to a metre, and is an associated species in many communities which have dried out by early summer. The water regime for this species is more about a sufficient period at suitable depth rather than what's happening at other times (D. Frood, pers. comm. August 2014).

The wetland fringes support bands of graminoids (grasses, sedges and rushes) including the Common Spike-sedge, Giant Rush and River Swamp Wallaby-grass (*Amphibromus fluitans*). All such vegetation typically prefers shallow flooding between winter and spring (i.e. less than 10 centimetres for the Common Spike-sedge and less than a metre for the Giant Rush) that is usually followed by moist summer conditions (Roberts & Marston, 2000).

In northern Victoria, Giant Rush occurs where flooding is from winter to spring. It occurs in depths of up to 1.5 m (Ward 1996). Common Spike-sedge grows in shallow depths, typically 10 cm in spring and summer (Ward 1996). In a glasshouse experiment it grew 3-4 times better at 0 cm depth than under 15 cm (Blanch and Brock 1994).

Deeper wetland profiles, as found in some permanent wetlands in Gunbower Forest, support submerged aquatic herbland vegetation characterised by macrophyte species such as Eel Grass (*Vallisneria australis*), *Chara* spp. and Water Nymph (*Najas tenuifolia*). One critical aspect of the water regime for Eel Grass is water depth. Water needs to be deep enough to accommodate leaf extension during the main growing season. A minimum of one metre is suggested, based on Briggs and Maher (1985), but no deeper than 2 m if water is turbid (e.g. 80 NTU) (Blanch et al. 1998). Season of flooding is not so important (Roberts & Marston 2000).

Semi-permanent wetlands

Flood frequency and duration

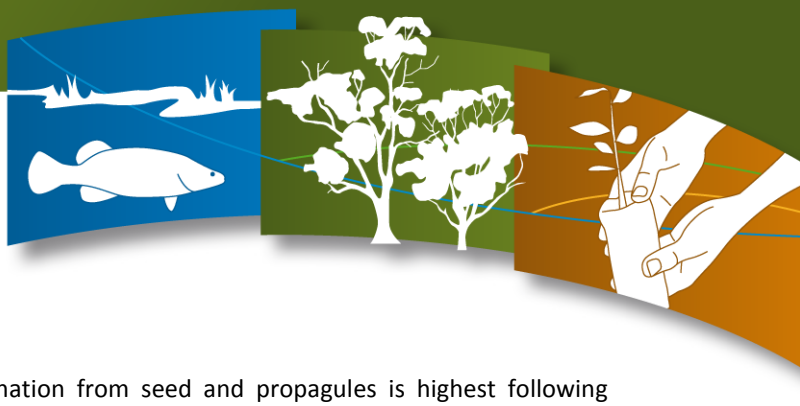
Under natural conditions, the Murray Flows Assessment Tool (MFAT) suggested that semi-permanent wetlands in Gunbower Forest would have occasionally dried out – less than 20% of the area was inundated for about a third of the time (36%). More than 80% of the storage was inundated 44% of the time, with the duration of flooding at this level being an average of almost five months (57 days) (URS 2001).

To avoid degradation of these wetlands, they require a drying phase at least every two years to maintain their biological diversity (Ecological Associates 2010).

Swamp Lily (*Ottelia ovalifolia*) is an aquatic herbland species and is found where flooding lasts 2-6 months. Clove strip (*Ludwigia peploides* subsp. *montevidensis*) is another aquatic herb and occurs where floods last 8-10 months (Ward 1996).

Timing and depth of flooding

Aquatic herblands are characterised by a diversity of small to large emergent herbs (i.e. Swamp Lily, Milfoils (*Myriophyllum* spp.), Clove-strip, and Star Fruit (*Damasonium minus*)) that emerge in shallow (often less than 50 centimetre) waters of semi-permanent wetlands, and at the seasonally inundated edge of permanent wetlands. It is a combination of wetting and drying rather than season that has been found to drive germination in similar wetland vegetation in Australia (Leck and Brock 2000). Furthermore wetland monitoring in Gunbower Forest post environmental flows suggests species diversity in this vegetation type is reduced with increasing water depth (Australian Ecosystems 2009). Roberts & Marston (2000) reported similar sensitivities



of the characteristic species and d that their germination from seed and propagules is highest following autumn and spring flooding. The persistence of aquatic herbland is hence potentially threatened by inappropriately timed or deep flooding, and at the other end of the scale shallow flooding prior to summer that promotes River Red Gum colonisation. River Red Gums in this context have the potential to shade and out compete for resources (Ecological Associates 2010).

In northern Victoria, Swamp Lily is found in shallow waters to 50 cm deep, where flooding occurs from winter to summer (Ward 1996). Clove-strip is found where flooding occurs in winter-summer, to depth of one metre (Ward 1996). Seeds germinate under water and on wet soil but require light (Yen and Myerscough 1989). Germination is temperature sensitive, with no germination at 10^{o}C compared with an optimum at 30^{o}C: at this temperature, germination starts within a day of flooding and is completed in less than 5 days, but at higher and at lower temperatures, germination is delayed, and at 40^{o}C success rate is halved (Yen and Myerscough 1989) (Roberts & Marston 2000).

River Red Gum with flood dependent understorey

Note: The below predominantly outlines supporting evidence for the hydrological requirements of River Red Gums (*Eucalyptus camaldulensis*). However, when 'designing' a water regime for a River Red Gum forest **the requirements of other species within the understorey should also be considered**. Understorey species have seasonal responses, which can lead to changes in community composition and in forest structure (Robertson et al. 2000, Bren 1987).

Cooling (2003) (pers. comm. To F. Crome) indicated that the following understorey species may be helpful in characterising the water regime for River Red Gum with flood dependent understorey - *Triglochin* spp., *Eleocharis acuta*, *Paspalidium jubiflorum*, *Alternanthera denticulata*, *Cynadon dactylon var pulchellus, Juncus subsecundus* and *Poa labillardierei* (Crome 2004). EVCs applicable to this vegetation community include Grassy Riverine Forest (EVC 106), Riverine Swamp Forest (EVC 814) and Sedgy Riverine Forest (EVC 816) (K. Bennetts, pers. comm. August 2014).

Flood frequency and duration

Results from the MFAT model suggested that under natural conditions most (80%) of the River Red Gum forest with flood dependent understorey would have been flooded about one-third (29%) of the time, with duration lasting over four months (128 days). Floods that partially (20%) inundated this Red Gum forest occurred in 93 of the 108 years modelled and lasted over five months (158 days) (URS 2001).

The minimum duration of flooding for this range of vegetation communities is 60 days according to Cunningham et al. (2009). This would include a flow peak and progressive drawdown.

Colonial waterbirds require suitable places to build their nests in order to breed successfully. For colonial stick-nesting waterbirds dense vegetation is essential for breeding (Kingsford and Norman 2002). Breeding in these species is dependent on areas of living River Red Gum that are flooded for at least four months (Briggs et al. 1997).

Current flood frequency for most of the River Red Gum forest at Barmah is about 6-8 years in every 10, on average (Bren and Gibbs 1986). Historical analyses of flood records shows that forest trees used to (prior to Hume Dam) experience inundation for 1-7 months and that this occurred primarily in winter- spring. There is increasing evidence that duration is as important as frequency, in terms of whole-forest growth responses. For

trees that have been through a dry phase, frequent short floods and longer floods both reduce water stress and hence result in greater growth (Roberts & Marston 2000).

At Barmah, River Red Gums are known to have tolerated relatively long periods of continuous flooding, estimated as 24 months (Bren 1987). This has happened at least twice in very wet periods, once in the mid-1950s and once in the mid-1970s. This estimate of 24 months is consistent with several field observations of about 2-4 years of continuous flooding, before trees show signs of stress. However, this would apply to the wettest River Red Gum communities (D. Frood, pers. comm. August 2014). Trees behind Hay Weir apparently survived 3- 4 years continuous inundation (Bren 1987); River Red Gums at Murrumbidgil Swamp on the Lachlan River which were flooded continuously between 1974 and 1977 showed no signs of stress worth reporting (Briggs and Maher 1983) in that time; four wet years killed off some low-lying trees in Barmah Forest (Chesterfield 1986). Variations in these estimates and in field observations are due to differences and patchiness in soil properties, air spaces and in root respiratory demands (Roberts & Marston 2000).

River Red Gum seedlings are sensitive to prolonged inundation or high temperatures over summer and/or frost during winter (Ecological Associates 2010).

Regarding understorey species, the following inundation frequency and duration requirements have been documented:

- *Lobelia concolor* occurs in northern Victoria where flooding lasts 1-3 months (Ward 1996).
- *Triglochin procerum* has an optimum duration in northern Victoria of 6 months, but can tolerate 1-8 months (Roberts and Marston 2000).
- *Eleocharis acuta* in northern Victoria has an optimum flood duration of 8 months, but can tolerate 3-10 months of flooding (Ward 1996).
- *Paspalidium jubiflorum* (Warrego Summer Grass) is found where flooding occurs for 2-4 months (70-140 days) per year (not necessarily consecutive) (Roberts and Marston 2000).

Timing of flooding

Flooding of River Red Gum with flood dependent understorey occurs mainly in winter and spring. Flooding in spring provides a shallow, productive habitat for aquatic plants to develop and in which small fish reproduce, and breeding waterbirds and large fish find prey. The recession of water before summer provides germination opportunities for a number of understorey species in the damp soil. A number of perennial species, such as Warrego Summer Grass and *Lobelia concolor*, grow on the forest floor over summer. Sustained flooding through summer prevents the establishment of these species, resulting in lower vegetation cover through autumn (Ecological Associates 2010).

Flood timing affects germination success for River Red Gum trees. For example, winter floods with winter recessions usually provide unfavourable water and air temperatures for seeds. Spring-summer floods followed by summer recession provide suitable germination conditions but subsequent heat and water stress can cause massive seedling mortality. Regeneration is optimised if flood recession is in spring-early summer, as this results in 'prolific' germination (Dexter 1978).

Production in River Red Gum trees was found to be higher where summer floods or spring and summer floods were received. Production was lower where only spring floods, or no floods occurred (Robertson et al. 2001).

Tree growth (i.e. wood production) in River Red Gums is greatest when flooded under warm conditions such as summer (Roberts & Marston 2000).

Interval between floods

River Red Gums in EVCs typical of the flood dependent understorey water regime class (Grassy Riverine Forest EVC 106, Riverine Swamp Forest EVC 814 and Sedgy Riverine Forest EVC 816) have a critical interval between flood events ranging from 3-5 years (Fitzsimons et al. 2011). The cumulative effect of repeated dry spells in River Red Gum with flood dependent understorey, for example at more frequent or for longer periods, is unknown. In some circumstances, and on some floodplains, River Red Gums may be largely dependent on water other than flood (surface) water, notably groundwater and/or ponded surface water (Roberts & Marston 2000).

Depth of flooding

Complete immersion, unless brief, is likely to kill River Red Gum seedlings; lower leaves of small saplings die if submerged for long periods. In general, tolerance of flooded conditions increases as seedlings become established, as root system extends and as sapling height increases (Roberts & Marston 2000). Thus two month old seedlings can survive waterlogging for one month with no obvious effect on leaf height and leaf number (Marcar 1993). Seedlings 50-60 cm tall can survive extended flooding of 4-6 months and complete immersion for a few weeks, by shedding leaves (Dexter 1978).

Regarding understorey species, the following inundation depth requirements have been documented:

- *Lobelia concolor* occurs in northern Victoria where flooding is shallow, less than 10cm deep (Ward 1996). However, it would appear to grow in sites which are subject to deeper immersion for short periods (D. Frood, pers. comm. August 2014).
- *Triglochin procerum* typically occurs in depths of 50cm but up to 1.5m. It has been found to tolerate water level increases from 0 to 50cm, from 50-100cm and from 0-100cm (Roberts and Marston 2000).
- *Eleocharis acuta* requires shallow depths, typically 10cm as preferred conditions during its period of active growth. In a glasshouse experiment, it grew 3-4 times better at 0cm depth than under 15cm (Ward 1996; Blanch and Brock 1994; Roberts and Marston 2000). However, this species does tolerate periods of deep inundation (D. Frood, pers. comm. August 2014).
- *Paspalidium jubiflorum* (Warrego Summer Grass) is found where depths are unlikely to exceed 60cm (Roberts and Marston 2000).

Waterbirds

Flood frequency

Waterbirds become sexually mature at the age of one or two years and have a life expectancy ranging from three to four years for ducks and up to eight years for larger birds such as ibis and egrets (Scott, 1997). Therefore waterbirds do not need to breed every year to sustain their populations. However, the provision of optimal breeding conditions within the forest will not necessarily guarantee a bird breeding event. Many factors may prevent the initiation of a breeding event at an artificially watered site, for example a lack of climatic cues and more attractive breeding grounds elsewhere (e.g. Koondrook-Perricoota Forest or Barmah

Forest). This occurred in 2008 at Barmah Forest where flooding of breeding areas occurred however the birds did not breed (Leslie 2008).

Duration

Before waterbirds can breed successfully they need to build up their fat reserves and this can only be achieved if there is sufficient food available. Therefore there is a lag time between the start of a flood and when the birds begin to breed. Warmer temperatures during a spring or early summer flood will result in a faster build up of food resources and therefore the lag time is generally shorter (2 - 3 months). The lag time for an autumn or winter flood is generally 3 – 6 months, with breeding commencing with the onset of spring (North Central CMA 2009).

Different species have different lag times, all of which are closely related to the type of food each individual species requires and where in the wetland food web the food resource enters the wetland and builds in number. For example ducks will breed relatively quickly requiring 1-2 months of lag time as they graze on algae and invertebrates, which are available at the start of the food web (i.e. when wetland sediments are first inundated) (North Central CMA 2009).

However, egrets require a much longer lag time, up to 7 months, as they are a piscivorous species. Native fish are one of the last food resources to build in number when the wetland is inundated. Therefore the egrets need to wait for the number of fish within the wetland to build so they have enough food resource to last the entire breeding cycle. Experience from flood events at Barmah Forest suggests that an earlier flooding onset will not stimulate birds such as egrets to breed earlier and therefore the key driver is the availability of the food resource (North Central CMA 2009).

To calculate the required duration of a flood event the lag time and the time needed to build nests, lay and incubate eggs and to fledge young (breeding time) is added together. Different species require a different length of time to complete their breeding cycles. Below is a selection of waterbirds common to Gunbower Forest and their different breeding timeframes (North Central CMA 2009).

Table 10. Waterbirds common to Gunbower Forest and their different breeding timeframe (North Central CMA 2009)

Waterbird	Lag time (mths)	Breeding time (mths)*	Minimum duration of flooding required (mths)
Ducks	2-3	2-3	4-6
Cormorants	2-3	3-4	5-7
Egrets	7-9	3	10-12

* egg laying, hatching and fledging

Other supporting evidence:

Areas inundated in late winter / early spring must persist for a minimum of 4 (rapid breeders e.g. ducks) to 7 months for the successful breeding of most waterbird species (Scott 1997, Kingsford and Auld 2005). This is because flooding prior to the end of winter will not immediately initiate bird breeding at Gunbower Forest, and this lag needs to be added to the time required for flooding by each species. Consequently, with regard to waterbird breeding, the effective flood duration must be measured from the seasonal increase in water temperatures and concomitant aquatic productivity at the start of spring (Ecological Associates 2010).

Interval between floods

Crome (1988) found that breeding for a wide variety of waterbird species only followed a rise in water level if the wetland had been completely dried out before hand. This is not true for all waterbird species with Pacific Herons and Yellow-billed Spoonbills favouring sites that have not dried out before reflooding (Briggs et al. 1997).

In Gunbower Forest a drying phase across the floodplain subsequent to inundation is important to waterbird carrying capacity and species diversity. Water bodies that are permanent, or ephemeral systems that lose their drying phase, have been shown to support a: lower density and diversity of birds; decline in invertebrate productivity; increase in abundance of introduced fish; and increase the anaerobic decomposition of organic matter (Crome 1988, Kingston et al. 2004, Gawne and Scholz 2006).

Timing

For most Australian waterbirds, breeding occurs when their food resources are approaching, or are at, a maximum (Kingsford and Norman 2002). The time of year in which flooding occurs is critical for many waterbird species. Floods in winter rarely result in immediate breeding; with many species only initiating breeding in the spring as conditions warm and food resources increase (Loyn et al. 2002; Ecological Associates 2010). The lag between flooding onset and the initiation of breeding relates to such factors as the time required for:

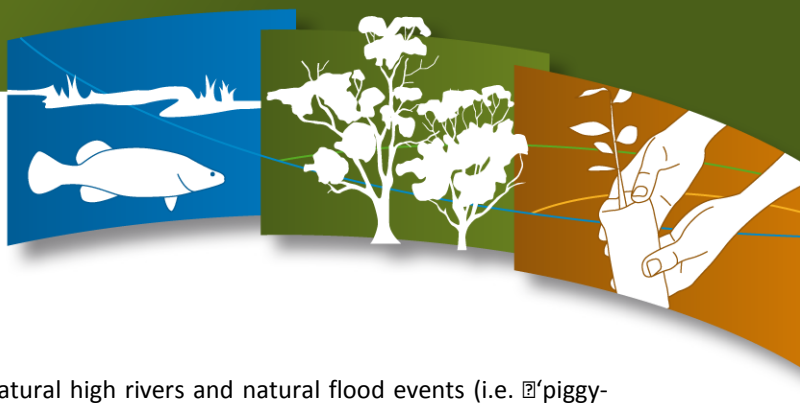
- a large and complex food web to develop, which is capable of supplying abundant food to allow birds to increase fat reserves and develop eggs;
- birds to prepare behaviourally; and
- hormone cycles to be initiated (Ecological Associates 2010).

Waterbirds that feed on animals lower in the food chain (e.g. Ibis feeding on invertebrates) can usually initiate breeding earlier than piscivores (e.g. Darter, Little Black Cormorant, and Intermediate Egrets), which require time for the fish population to develop (Crome 1988). The minimum lag from flood onset to breeding onset in most waterbird species is in the order of 2-3 months (Scott 1997), with breeding of most colonial birds in the Macquarie Marshes positively related to flow and wetland area in the three months before breeding (Kingsford and Auld 2005). This lag time and the causative factors behind it are poorly understood (Ecological Associates 2010).

The most successful waterbird breeding events occur following a flood in late winter, spring or early summer (Scott, 1997), with nesting beginning after birds have had enough time to consume sufficient wetland biota (invertebrates, small fish and aquatic plants) to build up fat reserves (North Central CMA 2009).

To increase the likelihood of waterbirds breeding successfully from an artificial watering event in the Gunbower Forest, the flooding should be timed to occur in conjunction with climatic cues. Waterbirds have shown a markedly greater breeding response in these situations than where the flooding occurs independently of such cues (Keith Ward GBCMA, pers. comm. 10/11/2009). Climatic cues include:

- High rainfall in the catchment – will influence available environmental water allocation and potentially influence bird behaviour.



- Natural flood events – taking advantage of natural high rivers and natural flood events (i.e. ‘piggy-backing’ on natural event to extend flood duration) is likely to increase the chance of a successful breeding event.
- Flooding at neighbouring sites – flooding at Koondrook-Perricoota Forest and/or Barmah- Millewa Forest is likely to impact upon the behaviour of the birds. For example, breeding waterbirds within Gunbower Forest have been reported to move on a daily basis to the adjacent Koondrook Perricoota area for foraging. Waterbird breeding success is correlated with the foraging area available.

Depth

Change in depth is an important aspect of waterbird hydrological requirements:

- Many waterbird species will not breed in wetlands with highly controlled water regimes where for example water levels are held at constant levels for extended periods, or alternatively are subject to rapid and/or erratic changes in depth (Briggs et al. 1997); and
- inundation and exposure of wetlands needs to occur over seasonal and annual time frames, as long-term rapid and/or erratic changes in water levels within a wetland can result in low numbers of aquatic invertebrates (Briggs et al. 1997), the food of many waterbirds.

Darters and Cormorants are predominately fish eaters and require open water between 0.6m and 2m deep to obtain food (Ecological Associates 2010).

Wading waterbirds predominantly forage in water up to a maximum depth of approximately 30 cm. World-wide the greatest diversity and abundance of foraging waterbirds is found in water depths of between 10 and 20 cm (Isola et al. 2000, Taft et al. 2002). Natural or artificial waterbodies that offer an array of water depths and vegetation associations tend to have rich communities of invertebrates, and carry higher numbers of species and individuals of waterbirds (Broome and Jarman 1983). While larger birds will use deeper water in which to forage, they prefer shallow water when food is available (Gawlik 2002), as it is more profitable using less energy to forage (Lovvorn 1994). Piscivores, for example, feed on fish in shallow water in preference to those in deeper water, and the density of prey at which the birds will stop searching increases with increasing depth – being almost twice as high at 28 cm as it is at 10 cm (Gawlik 2002). Maximising the area inundated up to 30 cm in depth in Gunbower Forest will increase waterbird species diversity and numbers able to forage in wetlands.

Appendix 2: Flora species recorded in Gunbower Forest

Source:
Kate Bennetts (Fire Flood & Flora) Gunbower species list collated from wetland and understorey monitoring for The Living Murray program (2005-2013) - excel spreadsheet
Biosis, 2014. *Flora and Fauna Assessment of the Gunbower National Park and Guttrum and Benwell State Forests*, Report for North Central Catchment Management Authority, Authors: Steer, R., Thomas, G. & Howells, B. Biosis Pty Ltd, Wangaratta. Project no. 18342.

Key:
EPBC Act – CR (critically endangered), EN (endangered), VU (vulnerable)
DSE (2005) Advisory List (VIC) – e (endangered), v (vulnerable), r (rare)
FFG Act – L (listed as threatened), P (protected – public land only)

Species Name	Common Name	Water regime class	EPBC	VIC	FFG	IUCN
Acacia acinacea	Gold-dust Wattle	GB				VU
Acacia brachybotrya	Grey Mulga					
Acacia dealbata subsp. dealbata	Silver Wattle	RRGFDU				
Alisma plantago-aquatica	Water Plantain	PW				
Alternanthera denticulata	Lesser Joyweed	PW SPW RRGFDU RRGFTU BB GB				
Alternanthera nodiflora	Common Joyweed	GB			k	
***Alternanthera* sp. 1 (Plains)**	Plains Joyweed	RRGFDU RRGFTU BB GB			k	CR
Amphibromus fluitans	River Swamp Wallaby-grass	PW SPW RRGFDU RRGFTU	V	X		EN

Species Name	Common Name	Water regime class	EPBC	VIC	FFG	IUCN
Amphibromus nervosus	Common Swamp Wallaby-grass	PW SPW RRGFDU RRGFTU BB GB				EN
Amphibromus spp.	Swamp Wallaby-grass	PW SPW				
Amyema miquellii	Box Mistletoe					
Anthosachne scabra s.l.	Common Wheat-grass					
Aphanes australiana	Australian Piert					
Arthropodium minus	Small Vanilla-lily	GB				CR
Atriplex eardleyae	Small Saltbush	RRGFTU BB				
Atriplex leptocarpa	Slender-fruit Saltbush	PW RRGFDU RRGFTU				LC
Atriplex nummularia* subsp. *nummularia	Old-man Saltbush					
Atriplex pseudocampanulata	Mealy Saltbush	BB			r	
Atriplex pumilio	Mat Saltbush	RRGFDU				
Atriplex semibaccata	Berry Saltbush	PW SPW RRGFDU RRGFTU BB GB				LC
Atriplex suberecta	Sprawling Saltbush	RRGFDU GB				
Austrostipa elegantissima	Feather Spear-grass	BB				CR
Austrostipa nodosa	Knotty Spear-grass	RRGFTU				CR

Species Name	Common Name	Water regime class	EPBC	VIC	FFG	IUCN
		GB				
Austrostipa scabra	Rough Spear-grass	RRGFTU BB GB				LC
Austrostipa scabra subsp. falcata	Rough Spear-grass	RRGFTU BB GB				LC
Austrostipa spp.	Spear-grass	RRGFDU RRGFTU BB GB				
Azolla filiculoides	Pacific Azolla	PW SPW RRGFDU RRGFTU BB GB				
Azolla pinnata	Ferny Azolla	PW SPW RRGFDU				
Azolla spp.	Azolla	PW				
Boerhavia dominii	Tah-vine	RRGFDU RRGFTU				
Bolboschoenus medianus	Marsh Club-sedge	RRGFDU				
Brachyscome basaltica var. gracilis	Woodland Swamp-daisy	RRGFDU RRGFTU BB GB				
Brachyscome ciliaris var. brachyglottis	Variable Daisy	RRGFTU				
Brachyscome diversifolia	Tall Daisy	GB				
Brachyscome readeri	Reader's Daisy	GB			r	
Bulbine semibarbata	Leek Lily	BB				

Species Name	Common Name	Water regime class	EPBC	VIC	FFG	IUCN
Calandrinia spp.	Purslane	BB				
Calandrinia calyptrata	Pink Purslane					
Callitriche sonderi	Matted Water-starwort	PW SPW RRGFDU BB GB				EN
Callitriche spp.	Water-starwort	PW SPW RRGFDU RRGFTU				
Callitriche umbonata	Winged Water-starwort	SPW RRGFDU		X	r	CR
Calocephalus sonderi	Pale Beauty-heads	RRGFTU BB				EN
Calotis cuneifolia	Blue Burr-daisy	RRGFDU RRGFTU BB GB			r	
Calotis hispidula	Hairy Burr-daisy	BB				LC
Calotis scabiosifolia var. scabiosifolia	Rough Burr-daisy	BB				
Calotis scapigera	Tufted Burr-daisy					
Cardamine moirensis	Riverina Bitter-cress	PW SPW RRGFDU RRGFTU BB GB			r	
Carex inversa	Knob Sedge	PW SPW RRGFDU RRGFTU BB GB				

Species Name	Common Name	Water regime class	EPBC	VIC	FFG	IUCN
Carex tereticaulis	Poong'ort	SPW RRGFDU RRGFTU BB GB				
Cardamine moirensis	Riverina Bitter-cress					
Cassinia arcuata	Drooping Cassinia					
Centella cordifolia	*Centella*					
Centipeda cunninghamii	Common Sneezeweed	PW SPW RRGFDU RRGFTU BB GB				
Centipeda minima subsp. minima s.s.	Spreading Sneezeweed	PW SPW RRGFDU RRGFTU GB				
Ceratophyllum demersum	Hornwort	PW SPW RRGFDU			k	
Chamaesyce drummondii	Flat Spurge	PW SPW RRGFDU RRGFTU BB GB				LC
Characeae spp.	Stonewort	PW SPW				
Chenopodium desertorum subsp desertorum	Frosted Goosefoot					
Chenopodium desertorum subsp. microphyllum	Small-leaf Goosefoot	BB GB				
Chenopodium desertorum subsp. rectum	Frosted Goosefoot	BB			v	

Species Name	Common Name	Water regime class	EPBC	VIC	FFG	IUCN
Chenopodium pumilio	Clammy Goosefoot	PW SPW RRGFDU RRGFTU BB GB				LC
Chloris spp.	Windmill Grass	RRGFDU BB				
Chloris truncata	Windmill Grass	RRGFTU BB GB				LC
Cotula australis	Common Cotula	RRGFDU RRGFTU GB				
Craspedia paludicola	Swamp Billy-buttons	RRGFDU RRGFTU				EN
Crassula colorata	Dense Crassula	RRGFTU BB				
Crassula helmsii	Swamp Crassula	RRGFTU BB				
Crassula peduncularis	Purple Crassula					
Crassula sieberiana	Sieber Crassula	RRGFDU BB GB				
Cymbonotus preissianus	Austral Bear's-ear					
Cynodon dactylon var. pulchellus	Native Couch	PW RRGFDU RRGFTU BB			k	
Cyperus difformis	Variable Flat-sedge	RRGFDU				
Cyperus exaltatus	Tall Flat-sedge	PW BB GB				

Species Name	Common Name	Water regime class	EPBC	VIC	FFG	IUCN
Cyperus gunnii subsp. gunnii	Flecked Flat-sedge	RRGFDU RRGFTU				
Cyperus spp.	Flat Sedge	PW				
Damasonium minus	Star Fruit	PW SPW RRGFDU RRGFTU BB GB				EN
Daucus glochidiatus	Australian Carrot	RRGFDU RRGFTU BB GB				LC
Deyeuxia quadriseta	Reed Bent-grass	RRGFDU RRGFTU				LC
Dianella admixta	Black-anther Flax-lily	GB				EN
Dianella spp. aff. longifolia (Riverina)	Pale Flax-lily	RRGFTU			v	CR
Dichondra repens	Kidney-weed	RRGFDU				
Dillwynia cinerascens	Grey Parrot-pea	GB				
Dysphania glomulifera subsp. glomulifera	Globular Pigweed	PW GB				
Dysphania pumilio	Clammy Goosefoot					
Eclipta platyglossa	Yellow Twin-heads	SPW RRGFDU RRGFTU GB				LC
Einadia hastata	Saloop	RRGFDU RRGFTU BB GB				

Species Name	Common Name	Water regime class	EPBC	VIC	FFG	IUCN
Einadia nutans subsp. nutans	Nodding Saltbush	PW SPW RRGFDU RRGFTU BB GB				VU
Elatine gratioloides	Waterwort	PW SPW RRGFDU RRGFTU BB GB				
Eleocharis acuta	Common Spike-sedge	PW SPW RRGFDU RRGFTU BB GB				EN
Eleocharis pallens	Pale Spike-sedge	RRGFDU			k	
Eleocharis pusilla	Small Spike-sedge	RRGFDU RRGFTU BB GB				
Elymus scaber var. scaber	Common Wheat-grass	RRGFTU GB				
Enchylaena tomentosa var. tomentosa	Ruby Saltbush	PW SPW RRGFDU RRGFTU BB GB				EN
Enteropogon acicularis	Spider Grass	RRGFTU BB GB				EN
Epilobium billardierianum	Variable Willow-herb	PW SPW RRGFDU RRGFTU				
Epilobium billardierianum subsp. Billardierianum	Smooth Willow-herb					

Species Name	Common Name	Water regime class	EPBC	VIC	FFG	IUCN
Epilobium billardierianum subsp. cinereum	Grey Willow-herb	RRGFDU RRGFTU GB				
Epilobium hirtigerum	Hairy Willow-herb	SPW RRGFDU RRGFTU BB				
Eragrostis infecunda	Southern Cane-grass	BB				LC
Erodium crinitum	Blue Heron's-bill					
Eucalyptus camaldulensis	River red-gum					
Eucalyptus largiflorens	Black box					
Eucalyptus microcarpa	Grey box					
Euchiton collinus	Creeping Cudweed	GB				
Euchiton involucratus s.s.	Star Cudweed	BB				
Euchiton involucratus s.l.	Common cudweed					
Euchiton sphaericus	Annual Cudweed	PW SPW RRGFDU RRGFTU BB GB				
Eulalia aurea	Silky Browntop	RRGFDU				
Euphorbia drummondii	Flat Spurge					
Eutaxia microphylla var. microphylla	Common Eutaxia	GB				
Exocarpos strictus	Pale-fruit Ballart	RRGFDU RRGFTU				LC
Galium gaudichaudii	Rough Bedstraw	PW				

Species Name	Common Name	Water regime class	EPBC	VIC	FFG	IUCN
Geococcus pusillus	Earth Cress					
Geranium sp.	Crane's Bill					
Geranium sp. 2	Variable Crane's-bill	RRGFDU				LC
Geranium sp. 5	Naked Crane's-bill					LC
Glinus lotoides	Hairy Carpet-weed	PW SPW RRGFDU BB GB				
Glinus oppositifolius	Slender Carpet-weed	SPW				
Gnaphalium sp.	Cudweed					
Gnaphalium polycaulon	Indian Cudweed	PW SPW RRGFDU RRGFTU GB				
Goodenia fascicularis	Silky Goodenia	RRGFDU RRGFTU BB GB				
Goodenia glauca	Pale Goodenia	BB				
Goodenia gracilis	Slender Goodenia	RRGFDU RRGFTU BB GB				
Goodenia heteromera	Spreading Goodenia	RRGFDU				
Goodenia pinnatifida	Cut-leaf Goodenia	GB				EN
Goodenia pusilliflora	Small-flower Goodenia	BB				LC
Gratiola pumilo	Dwarf Brooklime	RRGFTU BB			r	

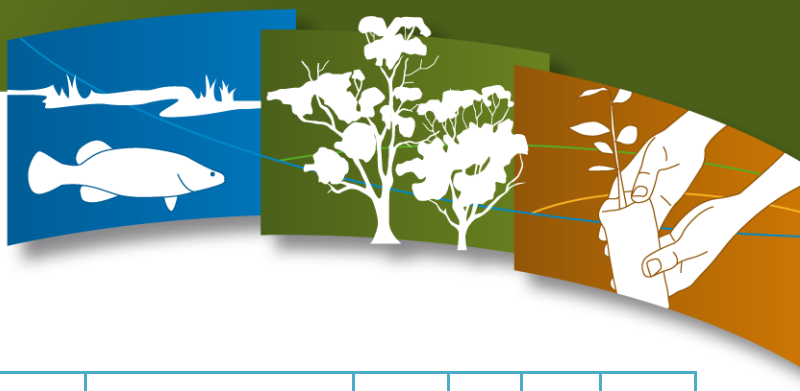
Species Name	Common Name	Water regime class	EPBC	VIC	FFG	IUCN
Haloragis aspera	Rough Raspwort	BB				LC
Haoragis heterophylla	Varied Raspwort					
Helichrysum luteoalbum	Jersey Cudweed					
Helichrysum rutidolepis	Pale Everlasting	RRGFTU				
Hypoxis glabella var. glabella	Tiny Star	BB				LC
Isolepis spp.	Club sedge					
Juncus amabilis	Hollow Rush	PW SPW RRGFDU RRGFTU BB GB				
Juncus aridicola	Tussock Rush	SPW RRGFDU RRGFTU BB GB				
Juncus australis	Austral Rsuh	RRGFDU				
Juncus flavidus	Gold Rush	PW SPW RRGFDU RRGFTU GB				
Juncus holoschoenus	Joint-leaf Rush	RRGFDU RRGFTU				
Juncus ingens	Giant Rush	PW SPW RRGFDU				
Juncus pallidus	Pale Rush	PW SPW RRGFDU				
Juncus subsecundus	Finger Rush	RRGFDU RRGFTU BB				

Species Name	Common Name	Water regime class	EPBC	VIC	FFG	IUCN
		GB				
Juncus usitatus	Billabong Rush	PW SPW RRGFDU				
Lachnagrostis filiformis s.s.	Common Blown-grass	PW SPW RRGFDU RRGFTU BB GB				LC
Landoltia punctata	Thin Duckweed	PW SPW RRGFDU BB				
Lemna disperma	Common Duckweed	PW SPW RRGFDU RRGFTU				
Lepidium pseudohyssopifolium	Native Peppercress	GB			k	
Limosella australis	Austral Mudwort	RRGFDU				
Linum marginale	Native Flax	RRGFTU				
Lobelia concolor	Poison Pratia	RRGFDU RRGFTU BB				
Lobelia pratioides	Poison Lobelia	PW RRGFDU				
Ludwigia peploides subsp. montevidensis	Clove-strip	PW SPW RRGFDU				
Lycopus australis	Australian Gipsywort					

Species Name	Common Name	Water regime class	EPBC	VIC	FFG	IUCN
Lythrum hyssopifolia	Small Loosestrife	PW SPW RRGFDU RRGFTU BB GB				
Lythrum salicaria	Purple Loosestrife	RRGFDU				
Maireana brevifolia	Short-leaf Bluebush	RRGFDU RRGFTU BB GB				LC
Maireana decalvans	Black Cotton-bush	RRGFDU RRGFTU BB GB				LC
Maireana enchylaenoides	Wingless Bluebush	BB GB				LC
Maireana humillima	Dwarf Bluebush	BB				CR
Malva spp.	Mallow	RRGFTU				
Marsilea costulifera	Narrow-leaf Nardoo	PW SPW RRGFDU RRGFTU BB GB				
Marsilea drummondii	Common Nardoo	RRGFDU RRGFTU BB GB				
Marsilea hirsuta	Short-fruit Nardoo	PW SPW RRGFDU				
Marsilea spp.	Nardoo	RRGFDU RRGFTU BB				
Mentha australis	River Mint	RRGFDU				EN

Species Name	Common Name	Water regime class	EPBC	VIC	FFG	IUCN
Mimulus gracilis	Slender Monkey-flower	RRGFDU RRGFTU BB GB				CR
Minuria integerrima	Smooth Minuria	BB			r	
Muehlenbeckia florulenta	Tangled Lignum	BB				LC
Myosurus australis	Mousetail					
Myriophyllum caput-medusae	Coarse Water-milfoil	PW SPW				LC
Myriophyllum crispatum	Upright Water-milfoil	PW SPW RRGFDU RRGFTU BB				LC
Myriophyllum papillosum	Robust Water-milfoil	PW SPW RRGFDU RRGFTU				LC
Myriophyllum spp.	Water-milfoil	PW SPW				
Myriophyllum verrucosum	Red Water-milfoil	SPW				LC
Najas tenuifolia	Water Nymph	PW SPW			r	
Nitella spp.	Stonewort	PW SPW				
Nymphoides crenata	Wavy Marshwort	PW RRGFDU RRGFTU		L	v	EN
Olearia pimeleoides	Pimelea Daisy-bush	GB				
Ophioglossum lusitanicum	Austral Adder's-tongue	RRGFTU				
Ottelia ovalifolia subsp.	Swamp Lily	PW SPW				EN

Species Name	Common Name	Water regime class	EPBC	VIC	FFG	IUCN
ovalifolia		RRGFDU				
Oxalis perennans	Grassland Wood-sorrel	SPW RRGFDU RRGFTU BB GB				LC
Parietaria debilis s.s.	Shade Pellitory					
Paspalidium jubiflorum	Warrego Summer-grass	PW SPW RRGFDU RRGFTU BB GB				VU
Persicaria decipiens	Slender Knotweed	PW SPW RRGFDU				LC
Persicaria hydropiper	Water Pepper	PW				LC
Persicaria lapathifolia	Pale Knotweed	PW RRGFDU GB				LC
Persicaria prostrata	Creeping Knotweed	PW SPW RRGFDU RRGFTU				LC
Phragmites australis	Common Reed	RRGFDU				VU
Picris spp.	Picris	RRGFDU				
Pittosporum angustifolium	Weeping Pittosporum	RRGFTU GB				
Plantago cunninghamii	Clay Plantain	RRGFTU BB GB				
Plantago drummondii	Dark Plantain	BB				
Plantago gaudichaudii	Narrow Plantain	BB				



Species Name	Common Name	Water regime class	EPBC	VIC	FFG	IUCN
		GB				
Plantago varia	Variable Plantain	BB				
Poa labillardierei var. labillardierei	Common Tussock-grass	RRGFDU RRGFTU				VU
Polygonum plebeium	Small Knotweed	PW SPW RRGFDU RRGFTU				NT
Potamogeton cheesemanii	Red Pondweed	RRGFDU RRGFTU BB				
Potamogeton ochreatus	Blunt Pondweed	PW SPW				
Potamogeton spp.	Bondweed	PW				
Potamogeton sulcatus	Furrowed Pondweed	PW SPW				
Potamogeton tricarinatus	Floating Pondweed	PW				
Pseudognaphalium luteoalbum	Jersey Cudweed	PW SPW RRGFDU RRGFTU BB GB				
Pseudoraphis spinescens	Spiny Mud-grass	PW SPW RRGFDU RRGFTU				
Ptilotus spathulatus f. spathulatus	Pussy Tails	GB				
Ranunculus inundatus	River Buttercup	RRGFDU RRGFTU				
Ranunculus lappaceus	Australian buttercup					

Species Name	Common Name	Water regime class	EPBC	VIC	FFG	IUCN
Ranunculus pumilio	Ferny Small-flower Buttercup	SPW RRGFDU				LC
Ranunculus sessiliflorus subsp. sessiliflorus	Annual Buttercup	SPW RRGFDU				LC
Rhagodia spinescens	Hedge Saltbush	PW SPW RRGFDU RRGFTU BB				EN
Riccia duplex	Floating Crystalwort	PW SPW				
Ricciocarpos natans	Fringed Heartwort	PW SPW				
Rorippa eustylis	Dwarf Bitter-cress	PW SPW GB			r	
Rorippa laciniata	Jagged Bitter-cress	PW SPW				
Rumex bidens	Mud Dock	PW SPW RRGFDU				LC
Rumex brownii	Slender Dock	PW SPW RRGFDU RRGFTU BB GB				LC
Rumex dumosus	Wiry Dock	PW				VU
Rumex tenax	Narrow-leaf Dock	PW BB				NT
Rytidosperma caespitosum	Common Wallaby-grass	RRGFDU RRGFTU BB GB				LC

Species Name	Common Name	Water regime class	EPBC	VIC	FFG	IUCN
Rytidosperma duttonianum	Brown-back Wallaby-grass	RRGFDU RRGFTU BB GB				EN
Rytidosperma erianthum	Hill Wallaby-grass	RRGFDU BB				NT
Rytidosperma fulvum	Copper-awned Wallaby-grass	GB				NT
Rytidosperma racemosum var. racemosum	Slender Wallaby-grass	RRGFDU RRGFTU				LC
Rytidosperma setaceum var. setaceum	Bristly Wallaby-grass	SPW RRGFDU RRGFTU BB GB				LC
Rytidosperma spp.	Wallaby-grass	PW				
Salsola tragus	Prickly Saltwort	SPW				
Salsola tragus subsp. tragus	Prickly Saltwort	RRGFDU RRGFTU BB GB				
Sclerolaena diacantha	Grey Copperburr	RRGFDU RRGFTU BB GB				
Sclerolaena muricata	Black Roly-poly	RRGFTU BB				LC
Senecio campylocarpus	Floodplain Fireweed	PW RRGFDU			r	
Senecio cunninghamii var. cunninghamii	Branching Groundsel					
Senecio quadridentatus	Cotton Fireweed	PW SPW RRGFDU RRGFTU GB				LC

Species Name	Common Name	Water regime class	EPBC	VIC	FFG	IUCN
Senecio runcinifolius	Tall Fireweed	PW SPW RRGFDU RRGFTU GB				
Senna artemisioides spp. agg.	Desert Cassia	GB				
Sida corrugata	Variable Sida	RRGFTU BB GB				
Sigesbeckia orientalis subsp. orientalis	Indian Weed	RRGFDU GB				
Solanum esuriale	Quena	RRGFTU BB				EN
Solanum spp.	Nightshade	BB				
Solenogyne dominii	Smooth Solenogyne	RRGFDU BB				
Spergularia marina	Salt Sand-spurrey	RRGFDU				
Spirodela spp.	Duckweed	RRGFDU				
Stellaria angustifolia	Swamp Starwort	RRGFDU RRGFTU BB				
Stellaria caespitosa	Matted Starwort	PW SPW RRGFDU RRGFTU GB				
Stemodia florulenta	Blue Rod	RRGFDU				
Stemodia glabella s.s.	Smooth Blue-rod	BB			k	
Stuartina muelleri	Spoon cudweed					
Swainsona procumbens	Broughton Pea	BB				CR

Species Name	Common Name	Water regime class	EPBC	VIC	FFG	IUCN
Teucrium racemosum	Grey Germander	BB				CR
Teucrium racemosum	Grey Germander	GB				CR
Triglochin multifructa	Northern Water-ribbons	SPW RRGFDU				EN
Triglochin procera	Water Ribbons	PW SPW RRGFDU RRGFTU BB GB				EN
Triglochin spp.	-	RRGFDU RRGFTU				
Typha domingensis	Narrow-leaf Cumbungi	PW SPW RRGFDU RRGFTU				
Typha orientalis	Broad-leaf Cumbungi	SPW RRGFTU GB				
Typha spp.	Cumbunghi	RRGFDU				
Urtica incisa	Scrub Nettle	RRGFDU BB				LC
Utricularia australis	Yellow Bladderwort	PW SPW				
Utricularia australis	Yellow Bladderwort	PW SPW				
Vallisneria americana var. americana	Eel Grass	PW SPW				EN
Vittadinia cervicularis var. cervicularis	Annual New Holland Daisy	BB				
Vittadinia condyloides	Club-hair New Holland Daisy					

Species Name	Common Name	Water regime class	EPBC	VIC	FFG	IUCN
Vittadinia cuneata	Fuzzy New Holland Daisy	RRGFDU RRGFTU BB GB				LC
Vittadinia cuneata var. cuneata	Fuzzy New Holland Daisy	RRGFDU RRGFTU BB GB				LC
Vittadinia gracilis	Woolly New Holland Daisy	SPW RRGFDU RRGFTU BB GB				LC
Vittadinia spp.	New Holland Daisy	RRGFDU RRGFTU				
Wahlenbergia communis s.s.	Tufted Bluebell					
Wahlenbergia fluminalis	River Bluebell	PW SPW RRGFDU RRGFTU BB GB				
Wahlenbergia gracilis	Sprawling Bluebell					
Xerochrysum bracteatum	Golden Everlasting	PW SPW RRGFDU RRGFTU BB GB				
Zygophyllum glaucum	Pale Twin-leaf	BB				