Connecting Rivers, Landscapes, People

Guttrum Forest

Ecological Objectives & Hydrological Requirements

Justification Paper

Final: December 2014

NORTH CENTRAL
Catchment Management Authority
Connecting Rivers, Landscapes, People

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

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Management

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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 Guttrum Forest Environmental Works Project and the justification for the corresponding hydrological requirements** to achieve the objectives/targets.

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 for the Gunbower Forest National Park Environmental Works project and the broader Gunbower Forest TLM 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)

Emer Campbell (NCCMA)

Rick Webster (Ecosurveys)

Clayton Sharpe (CPS Environmental)

Jack Smart (MDBA)

Andrea Keleher (DEPI)

Tim Hoogwerf (NCCMA)

Genevieve Smith (NCCMA)

Anna Chatfield (NCCMA)

Chris Corr (NCCMA)

Pam Beattie (NCCMA)

Sharada Ramamurthy (DEPI)

Stephen Nicol (DEPI)

Paul Lacy (GMW)

Peter Foster (Parks Victoria)

Angela Gaynor (Parks Victoria)

This document captures the latest information relevant to the above aspects of the Guttrum Forest 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

Guttrum Forest supports a diversity of vegetation, which can be described at a number of scales.

Landscape components

The Landscape Logic approach includes broad habitat types and how they are influenced by their position in the landscape. Within Guttrum Forest, the habitat types include wetlands (permanent and semi-permanent) and River Red Gum forest (with flood dependent and flood tolerant understorey) (see diagram below) (Ecological Associates 2013).

Guttrum Forest contains the only permanent wetland habitat – a small billabong to the east of Reed Bed Swamp that is over 5m deep. Semi-permanent wetland habitat is provided in Guttrum Forest through Reed Bed Swamp, Little Reed Bed Swamp and Guttrum Swamp (Ecological Associates 2013).

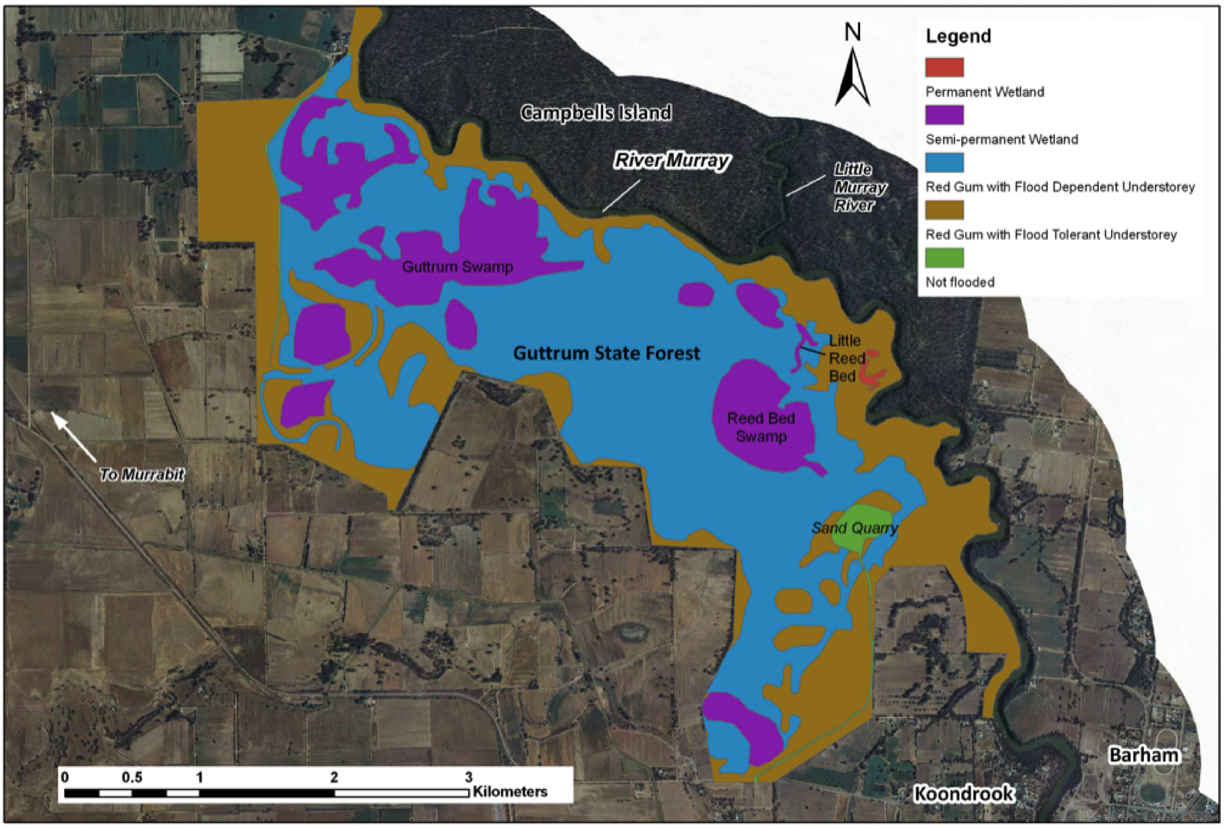

Figure 1. Guttrum Forest water regime classes (Ecological Associates 2013)

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 the Guttrum Forest, 8 EVCs have been recorded. These are shown in the below table and illustrated in Figure 3. .

Table 1. Ecological Vegetation Classes (EVCs) present in Guttrum Forest

Ecological Vegetation Class	Bioregional Conservation Status	Extent (ha)
Floodway Pond Herbland / Riverine Swamp Forest Complex (EVC 945)	Depleted	162
Grassy Riverine Forest (EVC 106)	Depleted	105
Riverine Grassy Woodland (EVC 295)	Vulnerable	166
Riverine Swamp Forest (EVC 814)	Depleted	684
Sedgy Riverine Forest (EVC 816)	Depleted	112
Spike-sedge Wetland (EVC 819)	Vulnerable	14
Floodplain Wetland Aggregate (EVC 172) including:Tall Marsh (EVC 821)	Least Concern	30
Floodplain Riparian Woodland (EVC 56)	Depleted	0*

Source: Ecological Associates (2013) *EVC was present at Guttrum Forest along the Murray River, but may have been too small an area for mapping to detect (K. Bennetts, pers. comm. August 1014).

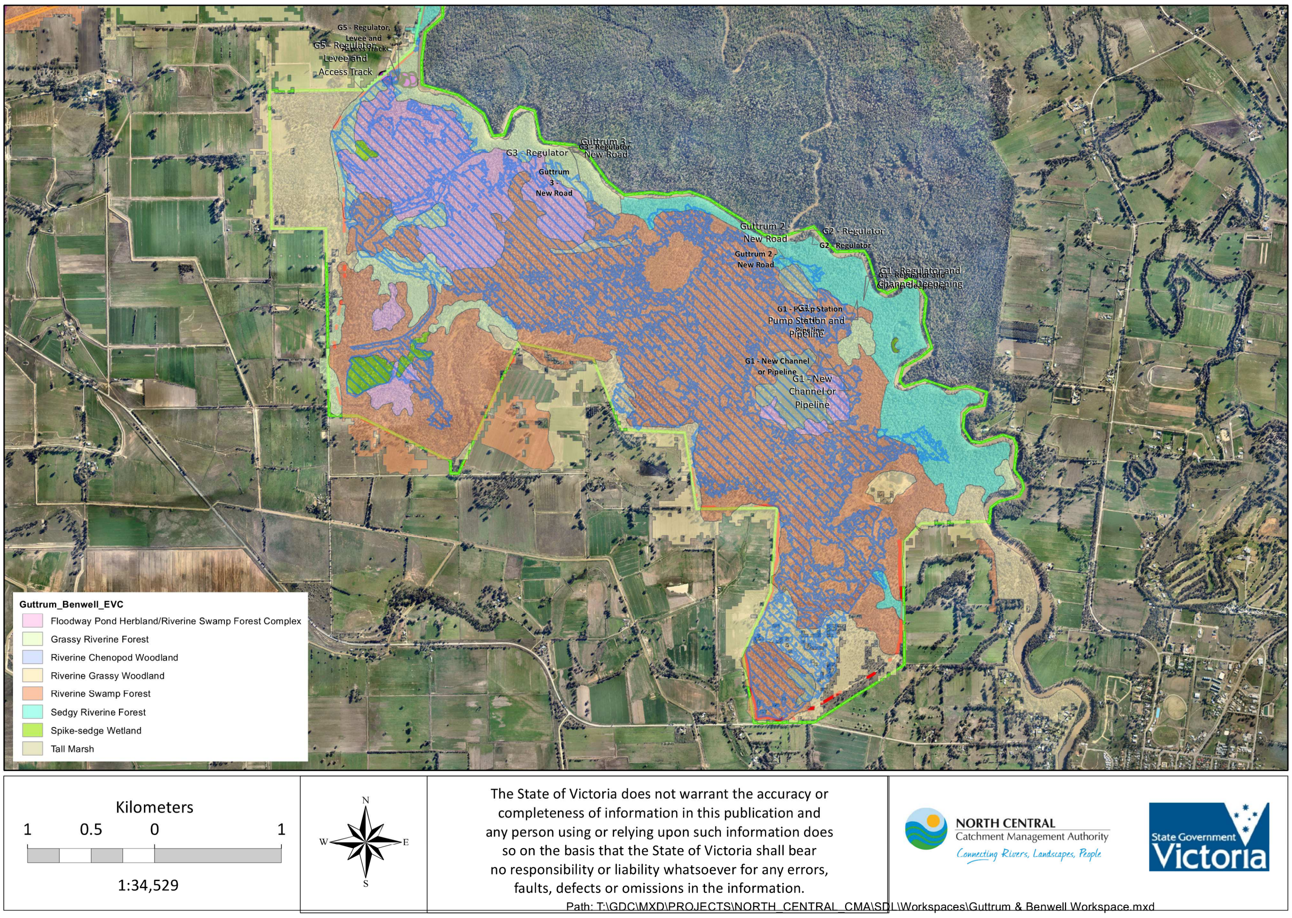

Figure 2. Ecological Vegetation Classes

Species

More than 75 species of native flora have been recorded in Guttrum and Benwell Forests in a single survey, including 20 rare or threatened species of which 19 were listed under the FFG Act (1988) (Biosis 2014). It is expected that many more species will be recorded in the forest during future investigations, similar to those species identified in the nearby Gunbower Forest (Bennetts 2014).

Flora species of conservation significance recorded in the Guttrum and Benwell Forests are shown below.

Table 2. Species of conservation significance recorded in the Guttrum and Benwell Forests

Flora species	**Status**		
	FFG	**EPBC**	**VROTS**
Branching groundsel (*Senecio cunninghamii* var. *cunninghamii*)			Rare
Flat-top saltbush (*Atriplex lindleyi* subsp. *lindleyi*)			Poorly known
Mealy saltbush (*Atriplex pseudocamanulata*)			Rare
Native peppercress (*Lepidium pseudohyssopifolium*)			Poorly known
Smooth elachanth (*Elachanthus glaber*)			Rare

Flora species	Status		
	FFG	EPBC	VROTS
Smooth minuria (*Minuria integerrima*)			Rare
Stiff groundsel (*Senecio behrianus*)	Listed as threatened	Endangered	Endangered

Source: North Central CMA (2014a)

FFG – Flora and Fauna Guarantee Act 1988, EPBC – Commonwealth Environment Protection and Biodiversity Conservation Act 1999, VROTS –Victorian Rare or Threatened Species Advisory Lists

2.2 Birds

The Guttrum Forest provides habitat for native birds including terrestrial and waterbird species. The Reed Bed Swamp in Guttrum Forest is a regionally significant colonial waterbird breeding site, of similar importance to the Little Gunbower Wetland Complex (Ecological Associates 2013). It (historically) provides extensive, closed beds of *Typha* sp. and *Juncus ingens*, together with open water and marsh vegetation, which provides habitat for a wide range of birds including (Ecological Associates 2013):

- Great crested grebe
- Darter
- Cattle egret
- Australasian bittern
- Glossy ibis
- Swamp harrier
- Peregrine falcon
- Azure kingfisher
- White-browed scrubwren
- Black-chinned honeyeater
- Painted honeyeater.

Breeding events involving thousands of waterbirds have been recorded at Reed Bed Swamp, including the Eastern Great Egret –protected under international migratory bird agreements (JAMBA and CAMBA).

Regular colonies of waterbirds have been reported in Guttrum Forest including Little Pied Cormorant, Little Black Cormorant, Great Cormorant, Nankeen Night Heron, Australian White Ibis, Great Egret, Intermediate Egret and more rarely, Little Egret (Ecological Associates 2013).

Guttrum Forest also provides habitat for the conservation significant Grey-crowned babbler which nests in River Red Gum at the western edge of Guttrum Forest. Several bird species of conservation significance occur across Guttrum Forest and are summarised here (from Atlas of Victoria Wildlife).

Table 3. Bird species of conservation significance present in the Guttrum Forest

Bird species	Status		
	FFG	EPBC	VROTS
Australasian bittern (*Botaurus poiciloptilus*)	Listed as threatened	Endangered	Endangered
Azure kingfisher (*Alcedo azurea*)			Near threatened
Brown treecreeper – south eastern subspecies (*Climacteris picumnus victoriae*)			Near threatened
Eastern great egret (*Ardea modesta*)			Vulnerable
Grey-crowned babbler (*Pomatostomus temporalis*)	Listed as threatened		Endangered
Intermediate egret (*Ardea intermedia*)	Listed as threatened		Endangered
Little egret (*Egretta garzetta*)	Listed as threatened		Endangered
Nankeen night heron (*Nycticorax caledonicus*)			Near threatened
Pied cormorant (*Phalacrocorax varius*)			Near threatened
Royal spoonbill (*Platalea regia*)			Near threatened
White-bellied sea eagle (*Haliaeetus leucogaster*)	Listed as threatened		Vulnerable

Source: North Central CMA (2014)

FFG – Flora and Fauna Guarantee Act 1988, EPBC – Commonwealth Environment Protection and Biodiversity Conservation Act 1999, VROTS –Victorian Rare or Threatened Species Advisory Lists

2.3 Native fish

Information on native fish within or using the Guttrum Forest floodplain and wetlands is limited. Three species of conservation significance are expected to use the area – Murray cod, Golden perch and Silver perch (Ecological Associates 2013).

While fish survey data is unavailable, it is possible that a similar fish community exists in these forests to that which has been recorded for Gunbower Forest (see below). This is due to the similar habitat availability (wetlands within River Red Gum forest floodplain), adjacent waterway (River Murray) and the relatively close proximity of these forest systems to each other. Confirmation of the validity of this assumption is required by fish ecologists.

Table 4. Possible native fish species at Guttrum Forest (based on those known and expected to occur at Gunbower Forest including the River Murray)

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

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. Prior to the natural flood event in 2010-12, the Guttrum Forest experienced inadequate, flooding compared to natural (with some unknown volumes likely to have been supplied through natural flooding in 2000 and 2003-2005 (K. Bennetts, pers. comm. August 2014). It was not possible to deliver environmental water to these sites due to a lack of appropriate infrastructure. Encroachment of terrestrial vegetation into areas formerly occupied by flood dependent species occurred during this period. While field data is limited, it is assumed that similar to other forests with inadequate flooding, the condition of the Guttrum Forest declined during the last drought period.

SKM (2007) noted that EVCs generally within the forest were degraded and stressed, represented through a loss of tree health and encroachment of terrestrial and dry tolerant species. Species dependent on regular flooding were absent from the Red Gum Flood Dependent Understory (FDU), with patches of dominant gums exhibiting signs of water stress. The extent of the Red Gum FDU and semi-permanent wetlands was considered to be retracting. Encroachment of terrestrial species into wetland areas was noted.

The dry climatic conditions for ten years prior to 2010-11 are expected to have reduced floodplain productivity and access to food and habitat for native fauna. This 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).

Ecological processes required to sustain native fish populations, such as connectivity to the floodplain for breeding and recruitment, is also likely to have been hindered (Ecological Associates 2010).

3.2 Post 2010-11

In 2010-11, the Guttrum Forest received extensive inundation from high River Murray flows. It is expected that the condition of the vegetation community improved as a result of the natural flooding.

The latest vegetation assessment (Bennetts 2014) found Guttrum Forest supports considerable areas of floodplain forest with relatively intact understorey, rare and threatened species and stands of large old trees. However the structure of the forest ecosystem has been altered and degraded in some parts through a number of disturbances – river regulation, timber harvesting, cattle grazing, weed invasion and quarrying. The current condition is summarised below (Bennetts 2014):

- Wetlands are impacted by cattle grazing, with some wetland vegetation trampled or physically uprooted and pugging evident. The more palatable wetland flora are absent e.g. River Swamp Wallaby Grass. River Red Gum saplings have encroached on the wetland areas and resulted in less open water habitat. Medic (Medicago spp.) is one of the most abundance weed species, forming mono-specific patches in the wetlands and reducing the biodiversity in these locations. Perennial emergent macrophytes are absent from Reed Swamp and elsewhere in Guttrum Forest are limited to a small stand of Juncus ingens in Little Reed Swamp (Ecological Associates 2013).

- Large areas of River Red Gum forest are dominated by small (i.e. < 50 cm diameter at breast height (DBH)) trees due to long-term forestry practices – progressive removal of the tallest and straightest trees, ringbarking the irregular trees and thinning regrowth. Most of the mature trees show signs of drought stress in their canopies (e.g. epicormic growth) and their ongoing health may be impacted by competition from the surrounding dense stands of regrowth. Some mature trees have recently died – potentially in response to the Millenium drought post long-term river regulation. In the south-west corner of Guttrum Forest (near Murrabit Road), numerous River Red Gums have died – presumably from drowning following extended ponding of water against the boundary levee.
- Between the wetlands and elevated River Red Gum woodland, are large forest areas with relatively intact understories that support characteristic, delicate and rare and threatened species.
- The old sand quarries are significantly disturbed and even though they currently retain water, they have limited ecological value.

A more detailed condition assessment is being undertaken across the forest and results will soon be available.

The flooding response from waterbirds after 2010-12 is unknown, however is expected to have been limited, primarily due to the loss of wetland habitat within the forests.

3.3 Ongoing expected flooding deficit

Similar to the nearby Gunbower Forest, the Guttrum 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 these forests has changed substantially because of the regulation and diversion of River Murray flows, resulting in a reduction in the frequency and duration of flooding (see below). Recent modelling (Ecological Associates 2013) demonstrates that, under current river operations, intervention is needed to maintain functioning floodplain ecosystems within the Guttrum Forest (Ecological Associates 2013).

Table 5. Evaluation of mean daily flow series from Barham 1895-2009

Flow threshold exceeded (ML/d)	Natural conditions		Benchmark conditions (including The Living Murray works)		Basin Plan (2750GL)	
	Median frequency (events/100yrs)	Median duration (days)	Median frequency (events/100yrs)	Median duration (days)	Median frequency (events/100yrs)	Median duration (days)
>15GL/day	100	175	80	75	91	115
>25GL/day	82	100	45	75	60	85
>33GL/day	25	40	8	49	9	49

Source: Ecological Associates 2013 (actual figures may vary slightly due to graph interpretation)

According to Ecological Associates (2013) and Gippel (2014), flows that inundate the semi-permanent wetlands now occur in 61% of years rather than the 90% of years that would have occurred naturally and last for 1 to 4 months (interquartile range at 21,000 ML/d) instead of 3 to 6 months. The reduction in flood duration and frequency and the longer periods between events has made wetland habitat less persistent and reliable. Perennial emergent macrophytes are absent from Reed Swamp and elsewhere in Guttrum Forest are limited to a small stand of *Juncus ingens* in Little Reed Swamp. Red gum has encroached on the wetland areas in the Guttrum Forest (Ecological Associates 2013).

Flows that inundate the River Red Gum forest with flood dependent understorey now occur in 37% of years rather than the recommended 70% of years that is modelled under natural conditions (Gippel 2014). Typical events last for 1 to 3 months instead of 2 to 5 months (interquartile range at 27,000 ML/d). The reduced flooding frequency and duration has reduced plant productivity so that wetland, canopy and understorey vegetation has less frequent and shorter growing periods and provides less food resources and physical habitat for fauna. The brief and less frequent flooding has reduced habitat opportunities, breeding events for wetland fauna including waterbirds, foraging and nursery habitat opportunities for riverine fish and contributions of carbon to the river channel food web (Ecological Associates 2013). This decline in overall condition is expected to continue under future regulated river conditions.

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:

Guttrum Forest vision:

To maintain and improve the Guttrum Forest by restoring a more natural water regime that supports a variety of aquatic habitats and a range of native flora and fauna species.

Management goal for Guttrum Forest Environmental Works Project:

Reinstate a more natural water regime that protects and enhances the ecological values within the Guttrum Forest.

Two levels of objectives and targets have been developed (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 Guttrum Forest project are based on the key values of the site (in line with the Victorian Waterway Management Strategy) including its:

- mosaic of habitat (e.g. foraging areas) required for macro/micro invertebrates, frogs, fish and waterbirds across multiple feeding guilds.
- regionally significant colonial nesting waterbird breeding site – Reed Bed in Guttrum Forest.
- ability to support native frog, native fish and waterbird breeding.
- ability to support species listed under international agreements (JAMBA, CAMBA), the *Environmental Protection Biodiversity Conservation Act* (1999) and the *Flora and Fauna Guarantee Act* (1988).
- ability to encourage recruitment of channel specialist native fish such as Murray Cod through floodwater inputs to the River Murray (Mallen-Cooper et al. 2014).

The objectives also take into consideration the:

- Hydrological changes in the system – the current and projected (under the Basin Plan) deficit in the water regime compared to natural inundation. Refer to previous section 'Ongoing expected flooding deficit'.
- Current condition and trajectory of each value and therefore whether intervention is required. Refer to previous section.
- Inter-dependencies within the Guttrum Forest site and between local forest floodplains (e.g. Benwell Forest, Campbells Island). For example, the success of colonial nesting waterbird breeding in Guttrum Forest's Reed Bed Swamp is dependent in part on the availability and security of foraging areas. Therefore objectives around colonial waterbird breeding in this part of Guttrum Forest is inter-linked with the objectives in the surrounding forest around inundating River Red Gum to provide foraging areas for waterbirds.

The overarching ecological objectives for the Guttrum Forest project and the justification for each are shown below.

Table 6. Overarching ecological objectives and their justifications for Guttrum Forest

Overarching objective	Justification
Improve the health of semi-permanent wetlands	▪ Provides a mosaic of habitat (e.g. marshland, herbland, open water and reed bed plant communities) for aquatic and amphibious plants to reproduce, which provide food for waterbirds (Ecological Associates 2013). ▪ Provides food and habitat for micro/macro invertebrates, frogs and small fish (which provide food resources for waterbirds e.g. large wading birds and piscivores). ▪ Receding flood water in summer provides habitat for migratory wading birds that pick over invertebrates in drying mud (Ecological Associates 2013). ▪ Maintains the health and distribution of the existing River Red Gum population, which provide nesting, feeding and breeding habitat for fauna, as well as organic inputs to the wetland (North Central CMA 2012). ▪ Ensures viable seed bank and invertebrate egg bank is maintained (North Central CMA 2012). ▪ Wet/dry cycle consolidates soils, allows sedimentation processes to occur, mineralises organic matter, supports microbial and planktonic productivity and overall biodiversity in the long-term (North Central CMA 2012; Ecological Associates 2013). ▪ Wetland vegetation provides shelter, nesting habitat and nesting materials for breeding waterbirds. E.g. dense macrophyte beds are important for cryptic waterbirds like Australasian bittern, purple swamp hen and black-tailed native hen. Dense reed beds provide nesting habitat for swamp harrier and growling grass frog. Marshy areas with semi-emergent vegetation are important to grebes and dabbling ducks e.g. Great crested grebe and Australasian grebe. Fringing red gum forest provides habitat for colonial nesting waterbirds to build platform nests (Ecological Associates 2013).
Healthy wetland bird community across Guttrum Forest 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 Guttrum Forest including those residing/breeding in the forest and those residing/breeding in nearby areas, which use these forests as part of their 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). ▪ Reed Bed Swamp is known to support large waterbird breeding events (thousands of waterbirds), including colonial nesting species. ▪ The other wetlands are expected to support a variety of waterbird breeding events. ▪ Provision of appropriate habitat will support recruitment of waterbirds at a landscape scale.
Healthy River Red Gum communities	▪ Provides food and habitat for micro/macro invertebrates (which are food resources for frogs, fish and waterbirds). ▪ The recently flooded understorey provides seeds, fruit and forage for granivores such as finches, cockatoos, galah, lorikeet and budgerigar, the frugivorous emu and herbivorous swamp wallaby (Ecological Associates 2013).

Overarching objective	Justification
	▪ Flood dependent understorey potentially reduced in extent prior to 2010, due to terrestrial encroachment. ▪ The trees directly support nectivorous and omnivorous birds such as honeyeaters and wattlebird (Ecological Associates 2013). ▪ 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 was observed as still recovering from the drought in some locations during recent field observations (K. Bennetts pers. com July 2014).
Promote recruitment of the local River Murray channel specialist native fish community^ by increasing opportunities to access productive floodplain outflows from Guttrum Forest.	▪ Provides organic inputs from the floodplain to the waterways, promoting instream productivity (North Central CMA 2014a). ▪ Supports recruitment of channel specialist fish through improved instream productivity i.e. higher survival of larvae as floodwaters (high in phytoplankton and zooplankton) recede back into channels (Mallen-Cooper et al. 2014). ▪ Recruitment occurs when floodplains are inundated, which increases productivity and larval survival. Likely applies to all fish species to some degree (Mallen-Cooper et al. 2014). ▪ Improved access to food resources from the floodplain will enhance the health and potentially the resilience of channel specialist fish species.

^ Mainly large bodied native fish that spawn within channel habitats (such as Murray Cod, Golden Perch and Silver Perch).

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

Table 7. Ecological objectives and targets for the Guttrum Forest Environmental Works Project

Objectives (by 2040)	Targets (by 2040)	Applicable values
SEMI-PERMANENT WETLANDS		
▪ Overarching: Improve the health of semi-permanent wetlands	▪ S1 (Overarching): >95% of semi-permanent wetlands with a water regime that maximises healthy condition. ▪ S2: At least 75% of wetland transects with 'moderate to excellent' vegetation condition as defined by the TLM wetland and floodplain condition assessment categories.	▪ Rare freshwater meadow with diverse habitats ▪ Nationally vulnerable Growling Grass Frog. ▪ Waterbird feeding and breeding habitat.
▪ Achieve an appropriate cover and diversity of species characteristic of the Plant Functional Groups found in the semi-permanent wetlands.	▪ S3: Plant Functional Groups 1-7 have >50% of total cover occupied by at least 2/3 of all species possible within these Plant Functional Groups. (See Monitoring & Evaluation Plan for further details).	
▪ Reduce River Red Gum encroachment in semi-permanent wetland areas.	▪ S4: River Red Gum encroachment is absent.	
▪ Provide suitable habitat for the threatened (EPBC listed) Growling grass frog.	▪ S5: Presence of habitat suitable for the EPBC listed Growling grass frog. i.e. water with diverse habitat including emergent, submerged and floating vegetation within the September to March breeding period in at least 7 years in 10 e.g. Reed Bed Swamp, Southwest Benwell Swamp. (See Monitoring & Evaluation Plan for further details).	
▪ Maintain and where possible increase the current diversity of threatened species.	▪ S6: >50% of threatened species previously recorded observed. (See Monitoring & Evaluation Plan for further details).	
▪ Reduce the area of high threat weed species.	▪ S7: High threat exotic plants absent in >90% of total cover.	
NATIVE BIRDS		
▪ Overarching: Healthy wetland bird community across Guttrum Forest through improved access to food and habitat that promotes breeding and recruitment	▪ B1 (Overarching): Successful colonial waterbird breeding in at least 3 years in 10 (for a range of species – egrets, cormorants, herons). ▪ B2: Successful waterfowl breeding in at least 7 years in 10.	▪ Bird species of conservation significance e.g. EPBC listed Australasian Bittern

Objectives (by 2040)	Targets (by 2040)	Applicable values
▪ Support a suite of waterbirds including waterfowl, colonial waterbirds and other wetland dependent species.	▪ B3: >50% of all waterbird species expected to occur observed over a ten-year period.	▪ Waterbird feeding and breeding habitat, particularly colonial waterbird nesting sites.
▪ Provide foraging and breeding areas for colonial nesting waterbirds in Guttrum Forest (Reed Bed Swamp) and foraging areas for waterbirds potentially elsewhere (e.g. lower Gunbower Forest).	▪ B4: >60% of the floodplain inundated for colonial waterbird foraging in 8 years in 10.	
▪ Provide suitable habitat for the threatened (EPBC listed) Australasian Bittern in the Guttrum Forest.	▪ B5: Presence of water in swamps with emergent vegetation e.g. Reed Bed Swamp, such as *Typha spp*. (bullrush), *Phragmites spp.* (reeds) and *Eleocharis spp*. (sedges) in at least 7 years out of 10.	
▪ Maintain and where possible increase the current diversity of threatened wetland bird species.	▪ B6: >50% of the wetland bird species of conservation significance recorded observed over a ten-year period.	
RIVER RED GUM FOREST		
▪ Overarching: Healthy River Red Gum communities.	▪ R1 (Overarching): >80% of River Red Gum forest with flood dependent understorey with a water regime that maximises healthy condition. ▪ R2: Range of age classes exist for River Red Gums in at least 75% of surveyed areas.	▪ FFG Act listed River Red Gum Grassy Woodland ecological community.
▪ Achieve an appropriate cover and diversity of species characteristic of the Plant Functional Groups found in the River Red Gum forest understorey.	▪ R3: 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. (See Monitoring & Evaluation Plan for further details).	
▪ Maximise the proportion of trees with healthy canopy condition in the River Red Gum forests.	▪ R4: >75% of surveyed trees with 'healthy' canopy condition - crown condition index score of 4 or greater.	

Objectives (by 2040)	Targets (by 2040)	Applicable values
▪ Maintain and where possible increase the current diversity of threatened flora species.	▪ R5: >50% of threatened flora species previously recorded observed.	
▪ Reduce the area of high threat weed species.	▪ R6: High threat exotic plants absent in >90% of total cover.	
NATIVE FISH		
▪ Overarching: Promote recruitment of the local River Murray channel specialist native fish community by increasing opportunities to access productive floodplain outflows from Guttrum Forest.	▪ F1: Commonly occurring large-bodied, channel specialist native fish species (Murray Cod and Golden Perch) occur every year in local River Murray surveys and include a range of age and size classes.	▪ Diverse fish community similar to that recorded around Gunbower Forest expected. ▪ EPBC listed Murray Cod in the River Murray.

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 8. Indicative hydrological requirements to achieve the Guttrum Forest Environmental Works Project objectives

Ecological objective		Hydrological Objectives										
		Recommended number of events in 10 years			Tolerable interval between events once wetland is dry (months)			Duration of ponding (months)			Preferred timing of inflows	Depth (m)
		Min	Opt	Max	Min	Opt	Max	Min	Opt	Max		
Improve the health of semi-permanent wetlands)		6	9	10	1	6	36	3	6	8	Winter/ spring	Often <50cm. At Full Supply Level Guttrum Swamp is >0.7m and Reed Bed Swamp is 0.85m.
Healthy bird community across Benwell Forest through improved access to food and habitat that promotes breeding and recruitment	Egrets	3	4	5	12	18	24	10	12	12	Late winter/spring/early summer	Not critical but maintain depth during breeding and have gradual changes
	General waterbirds (not colonial nesting species)	3	5	10	12	18	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.
Healthy River Red Gum communities		6	7	8	-	-	36	4	4	7	Winter/ spring	Not critical for adult River Red Gums. Varies for understorey. Some understorey sp. prefer shallow depths <10cm during active growth but can tolerate deeper immersion for short periods.
Promote recruitment of the local River Murray channel specialist native fish community by increasing opportunities to access productive floodplain outflows from Guttrum Forest.		6	7	8	-	-	36	4	4	7	Outflows to River Murray in spring/summer after temperature and flow cued spawning occurs in the channel.	Sharp drop in water level required to provide a fish exit cue in late spring/summer for any fish that have entered the floodplain. Hypothesis: 0.3m over 48 hrs. This will also promote organic matter export.

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.

Semi-permanent wetlands (Overarching objective: Improve the health of semi-permanent wetlands)

According to recent surveys (Bennetts 2014; Biosis & Bennetts 2014), semi-permanent wetlands in Guttrum Forest primarily consist of Floodway Pond Herbland/Riverine Swamp Forest Complex (EVC 945) with smaller areas of Spike-sedge Wetland (EVC 819) and Tall Marsh (EVC 821). The water regime for this objective therefore reflects that required by the dominant wetland EVC, which is similar to that required by the less extensive wetland EVCs as shown below (Fitzsimons et al. 2011).

See Appendix 1 for further details on wetland water requirements.

Table 9. Hydrological requirements of wetland EVCs in Guttrum Forest

Ecological Vegetation Class	Natural flood frequency	Critical interval between events (years)	Minimum duration (months)
Floodway Pond Herbland/Riverine Swamp Forest (EVC 945)	6-10 in 10	3	3-8
Spike-sedge wetland (EVC 819)	5-10 in 10	4	1-4
Tall Marsh (EVC 821)	6-10 in 10	2	6-11

Source: Fitzsimons et al. 2011

Waterbirds (Overarching objective: Healthy wetland bird community across Guttrum Forest through improved access to food and habitat that promotes breeding and recruitment)

This objective includes two sets of hydrological requirements – those needed for Egrets (an indicator species used to represent the water requirements of the broader group of colonial nesting waterbirds) and those needed for non-colonial waterbirds.

Achieving successful colonial waterbird breeding events requires a specific water regime in addition to that required by the general waterbird community. Egrets (Great Egret (*Ardea alba*), Intermediate Egrets (*Ardea intermedia*) and Little Egrets (*Egretta garzetta*)) are known to be sensitive to flooding conditions when breeding. For example, they require the longest flood duration of any waterbird in these forests. It is assumed that implementing an operating strategy that leads to successful breeding of egrets, will also enable other waterbird species to breed successfully. This is based on information obtained through a waterbird breeding requirement workshop, which found providing conditions suitable for colonial species will also provide suitable breeding conditions for a wide range of other species such as ducks, grebes, swamphens and herons (North Central CMA 2009).

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

Appendix 1 includes details on the water regime required for general waterbirds.

River Red Gum communities (Overarching objective: Healthy River Red Gum communities)

The River Red Gum forest with flood dependent understorey across both Guttrum and Benwell Forests is predominantly Riverine Swamp Forest (EVC 814). In Benwell Forest, a substantial portion of the eastern floodplain is Grassy Riverine Forest (106) (Bennetts 2014), with Riverine Swamp Forest dominating the western portion. The water regime has therefore been based on the Riverine Swamp Forest EVC. The optimum duration of ponding has been chosen to reflect that suitable for both the Riverine Swamp Forest and Grassy Riverine Forest EVCs.

Table 10. Hydrological requirements of the dominant River Red Gum EVC in Guttrum Forest

Ecological Vegetation Class	Natural flood frequency	Critical interval between events (years)	Minimum duration (months)
Riverine Swamp Forest (EVC 814)	6-8 in 10	3	4-7

Source: Fitzsimons et al. 2011

Note: Given the forest has experienced stress from the drought and is still recovering, there will be a gradual build up to this water regime as recommended by an expert vegetation ecologist (Bennetts, K. pers. comm. August 2014).

Native fish (Overarching objective: Promote recruitment of the local River Murray channel specialist native fish community by increasing opportunities to access productive floodplain outflows from Guttrum Forest.)

Native channel fish access to productive floodplain outflows (containing organic matter) from the Guttrum Forest floodplain is provided through broad inundation of the River Red Gum forests. The hydrological requirements for this objective therefore reflect that defined for River Red Gum forest with flood dependent understorey (Riverine Swamp Forest EVC 814). See Appendix 1 for further details on native fish requirements.

In general, the only channel species that require a rise in flow or a flood to spawn are the flow-cued spawners, golden perch and silver perch. All other species reliably spawn each year in response to rising temperatures in spring and summer (Mallen-Cooper et al. 2013).

This means that to maximise the contribution of floodplain outflows to in-channel recruitment for species such as golden perch, the outflows should occur, where possible, after variable channel flows that trigger spawning. For other species (e.g. Murray Cod), the floodplain outflows should occur in spring/summer after migration and temperature cued spawning has occurred.

6. PROPOSED WATER REGIME

The water regime for the Guttrum Forest has been based on consideration of:

- The relationship between objectives – for example, healthy wetland birds are partly provided through inundation of the semi-permanent wetland habitat. Colonial nesting waterbird breeding is partly reliant on large foraging areas provided through inundated River Red Gum forests. Access of channel fish to floodplain waters depends on the inundation of broad areas of River Red Gum floodplain that can then drain into the River Murray.
- Risk management – in terms of broader floodplain watering, the water regime is conservative to manage any risks associated with re-introducing regular watering to a forest that has experienced a flooding deficit for an extended period.

Therefore the water regime for the Guttrum Forest may be defined for two scenarios as below.

<u>Scenario 1 –River Red Gum floodplain:</u>

- Frequency: 8 years in 10
- Duration of inundation: 4 months (to be adapted depending on monitoring results)
- Timing: Winter/spring

<u>Scenario 2 – Semi-permanent wetland watering:</u>

- Frequency: 9 years in 10
- Duration of inundation: 6 months
- Timing: Winter/spring, with drying (drawdown of water level) in late summer/autumn.
- Depth: fluctuate over time, inundate to Full Supply Level in some years.

Note: if a substantial bird breeding event occurs (determined on an event by event basis), then ongoing environmental water deliveries (top-ups) may be required and will be provided as necessary. Detailed monitoring and advice from specialist ecologists will be used to determine the water requirements of each colony.

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Appendix 1: Literature review of hydrological requirements

Watering risks to be managed

Avoid delivery that supplies shallow water over summer months, which may result in displacement of wetland flora through **excessive River Red Gum recruitment** (Ecological Associates 2010). Alternatively, ensure water is available for follow-up flooding to drown red gum saplings.

Several **aquatic weeds** have the potential to expand their distributions into Guttrum 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 with the potential to invade 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) in the irrigation channel water may enter Guttrum Forest during water delivery events. To **avoid fish being stranded** in Guttrum 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 riverine 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 (and may develop anoxic conditions at depth) (Ecological Associates 2010). Avoid delivering environmental water when there is a combination of lower than normal flow in the River Murray and higher than average temperatures. For environmental watering post long, dry periods in Guttrum Forest, deliver the flow when there is moderate to high River Murray 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, duration and depth

The only permanent wetland across the forest has a relatively high inflow threshold, but is more than 5m deep and would rarely, if ever, dry out under natural conditions. Inflows to the billabong commence at flows exceeding 30,000 ML/d which, under natural conditions, was exceeded in approximately 50% of years for a duration of 1 to 3 months (interquartile range). Between inflow events water would be gradually lost to evaporation and seepage and the water level would fall (Ecological Associates 2013).

Timing

If semi-emergent and submerged aquatic macrophytes are to be promoted in the wetland, the timing of flooding is important. 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).

Semi-permanent wetlands

Flood frequency and duration

Ecological Associates (2013) noted that water would normally be present in the semi-permanent wetlands of the Guttrum and Benwell Forests, but they are shallow and would dry out from time to time.

The semi-permanent wetlands across the two systems share a similar hydrology. Inflows commence between 17,000 to 23,000 ML/d, and under natural conditions occur approximately 9 out of 10 years with events lasting 3 to 6 months (interquartile range at 21,000 ML/d). The wetlands retain water on the flood recession to a depth of 0.5 to 0.7 m and would usually remain flooded during summer. The wetlands would often dry out in autumn but in wet years may remain flooded until the following winter. Reed Bed Swamp retains water to a greater depth of 0.85 m and is more likely to remain flooded throughout the year (Ecological Associates 2013).

Similar to the semi-permanent wetlands within Gunbower Island, these semi-permanent wetlands require a drying phase at least every two years to maintain their biological diversity (Ecological Associates 2010).

Example aquatic herbs that may be found in these wetlands include Swamp Lily (*Ottelia ovalifolia*) and Clove strip (*Ludwigia peploides* subsp. *montevidensis*). Swamp Lily is found where flooding lasts 2-6 months and Clove strip occurs where floods last 8-10 months (Ward 1996).

SKM (2007) suggested the semi-permanent wetlands should remain full for at least the length of the wetland plant growing season (spring through to the end of summer for submerged and emergent plants), so they can complete their lifecycle by flowering and contributing to the seed bank. Preferably, semi-permanent wetlands would remain full until the following growing season.

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 need to 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) 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). Ecological Associates (2013) also found these species within the Guttrum and Benwell forest understorey – *Carex tereticaulis*, *Juncus usitatus* combined with *Phragmites australis*, *Typha domingensis* and *Juncus ingens* in local depressions and seasonal, submerged aquatic macrophytes including *Eleocharis acuta* and *Althernanthera denticulata*. 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

Red gum with flood-dependent understorey occurs in Guttrum Forest in areas that have a low flooding threshold but do not retain deep water when flood water recedes. At Guttrum Forest flooding commences at flows exceeding 20,000 ML/d. Flooding of the Red Gum Forest with flood dependent understorey is largely complete at flows of 26,000 ML/d. Under natural conditions the forest would have been flooded in approximately 8 years out of 10 for 2 to 5 months (interquartile range at 23,000 ML/d) with flooding typically occurring between June and December.

The minimum duration of flooding for this vegetation type 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).
- *Carex tereticaulis* tolerates flooding of 1-4 months in northern Victoria, but optimum duration is 2 months (Roberts and Marston 2000).
- *Phragmites australis* does not require flooding to survive, only adequate water. On the banks of the River Murray in South Australia, *Phragmites* occurs where flooding occurs for 80-225 days per year, not necessarily consecutive days (Blanch et al. 1999).
- *Typha domingensis* grows where the water regime ranges from permanently wet to seasonally or periodically dry. It can tolerate dry conditions for short periods (3-4 months in summer-autumn) once

the growing season is over, without loss of vigour. The rhizome can survive dry conditions for even longer, possibly a few years, if protected from desiccation by being deep (0.5 m) within heavy clay. On the banks of the River Murray, South Australia, *Typha domingensis* is found in permanently flooded or moist sites where flooding occurs for 360-365 days per year (Roberts and Marston 2000).

- *Juncus ingens* occurs in northern Victoria, where flooding is in winter–spring and lasts for 6-11 months. However, the optimum duration is 9 months (Ward 1996).

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).
- *Carex tereticaulis* tolerates flooding to 10cm in northern Victoria (Roberts and Marston 2000).
- *Phragmites australis* - British studies suggest *Phragmites* tolerates a maximum depth of 0.75 to 1.5 m, and suggests this may be deeper in warmer climates. The plant is tolerant of being overtopped in floods, although prolonged immersion will kill stems. It is also tolerant of fluctuating water levels, and can survive dry conditions. Growth is most vigorous when the water is only a few centimetres deep, and on the banks of the River Murray in South Australia, *Phragmites* occurs where depth is less than 60 cm (Roberts and Marston 2000).
- *Typha domingensis* will grow in areas where water is not too deep (ie < 2 m). On the banks of the River Murray, South Australia, *Typha domingensis* is found mainly in water depths of 20-60 cm (Roberts and Marston 2000).
- *Juncus ingens* in northern Victoria, occurs in depths of up to 1.5 m (Ward 1996).

Native fish (in channel access to floodplain water exiting the forest)

Overview

Describing the hydrological requirements of native fish depends in part on the habitat preference of each species (e.g. channel only, channel and floodplain wetland, off-channel wetland only).

This section focuses on the *requirements of channel specialist native fish.* This mainly includes the large bodied native fish that spawn within channel habitats (such as Murray Cod, Golden Perch and Silver Perch).

The hydrological requirements of native fish that require connectivity with and use of floodplain wetlands have not been included here as (from a fish perspective) the Guttrum Forest project primarily aims to supply channel fish with productive floodwater inputs that may promote in-channel recruitment. The Guttrum Forest does not have any permanent wetland areas to provide long lasting native fish habitat.

Flow requirements for in-channel recruitment

The flow requirements for recruitment in channel environments, varies among different types of fish (Mallen-Cooper et al. 2013):

- Low-flow channel recruitment (generalists) - Recruitment occurs within channel habitats at low stable flows. Presently only applies to generalist species which, apart from freshwater catfish and olive perchlet, remain common in regulated rivers in the Murray-Darling Basin. The basis of low-flow channel recruitment is that slow-flowing streams with dense plankton enhance survival of fish larvae. The evidence for low-flow channel recruitment was evident in the last drought where the generalist small-bodied species remained abundant in the River Murray. There is also evidence for low-flow recruitment of a range of fish species from the more arid inland river systems (Ebner et al. 2009; Kerezsy et al. 2011).
- Variable flow channel recruitment (channel specialists) - Recruitment occurs when there is variation of within-channel flows. Applies to golden perch, silver perch, and possibly Murray cod and trout cod. In the River Murray variable flow channel recruitment is known to occur for Golden perch and Silver perch and may be related to increased productivity associated with inundated riverine banks and benches (Mallen-Cooper and Stuart 2003; Zampatti and Leigh 2013). In the Darling River golden perch can spawn during low variable flows (Balcombe et al. 2006; Ebner et al. 2009). These perch species are commonly referred to as flow recruitment specialists (Lake 1967a; Gehrke 1997) as it is generally observed that pulses are needed to generate a spawning response in these species (Mallen-Cooper and Stuart 2003; King et al. 2009). Adult fish develop ova in response to increasing water temperatures (Lake 1967b; Leigh and Zampatti 2011) but can delay spawning, or not spawn at all, if conditions are unsuitable (Leigh and Zampatti 2011) (Baumgartner 2013).

Temperature requirements for in-channel recruitment

In general, the only species that require a rise in flow or a flood to spawn are the flow-cued spawners, golden perch and silver perch. All other species reliably spawn each year in response to rising temperatures in spring and summer (Mallen-Cooper et al. 2013).

This means that to maximise the contribution of floodplain water inputs to in-channel recruitment for species such as golden perch, the floodplain outflows should occur, where possible, after variable channel flows that trigger spawning. For other species, the floodplain outputs should occur in spring/summer after temperature cued spawning has occurred.

Golden Perch

Golden Perch (and Silver Perch) spawn in spring and early summer, in response to rising water temperature and rising flow (Lake 1967, King et al. 2007). Spawning mainly occurs in flowing water habitats in the main channel of rivers and eggs and larvae drift downstream (King et al. 2003, and King et al. 2007). Strong recruitment of these two species is linked to rising flows in spring (Mallen-Cooper and Stuart 2003; Ecological Associates 2010). The River Murray at Torrumbarry Weir is a stronghold for Silver Perch and to a lesser degree Golden Perch where adults and juveniles migrate each year in response to rising flows and water temperatures (Mallen-Cooper 1999).

Golden Perch spawning is associated with high flow events (Reynolds 1983; Hutchinson et al. 2008) and backwater inundation, but recruitment is also evident following a period of zero flow. It exhibits typical flood-induced recruitment, but also opportunistic spawning related to intermittent flooding and dry periods (Balcombe et al. 2006). Golden Perch is regarded as a flood spawner since it tends to spawn and recruit following flow rises, and major spawning occurs when floodplains become inundated (Young et al. 2003; King et al. 2009).

Zampatti and Leigh (2013) found successful spawning and recruitment of Golden Perch occurred during a small but prolonged within-channel increase in discharge in spring/ summer. Most Golden Perch spawned on the ascending limb of the second flow peak of one September to December event, however a few spawned during a small decrease in discharge between two flow peaks. Spawning occurred during a rise and fall in the hydrograph. Hence, some variation in the magnitude of flows rather than a sustained increase in flow may be important to stimulate spawning in Golden Perch. Flows delivered in late spring through summer of >15,000 ML/day when temperatures have reached at least 20◦C may promote spawning and recruitment of golden perch and increase population resilience (Zampatti & Leigh 2013).

During spring migration it is possible that movement is directed to specific spawning areas. Evidence for this comes from the movement of fish to distinct reaches within the river. Long distance movements generally occurred between September and December (O'Connor et al. 2005).

Silver Perch

Rogers & Ralph (2011) found the Silver Perch spawning period is from November to January, but is flexible and depends on rising water levels and temperatures. An increase of depth as little as 15cm, in a pond environment can induce spawning (Lake, 1967a). Spawning activity has been found to significantly increase during a flood (Lintermans 2009). Silver Perch migrate upstream to areas behind the peak of a flood, or do so coinciding with a slight rise in water levels and water temperatures (Allen et al. 2003; Lintermans 2007).

Silver Perch is typically regarded as a flood spawner since it tends to spawn and recruit following rises in flow; major spawning occurs when floodplains become inundated (Young et al. 2003).

Murray Cod

Murray Cod spawn around October to December (Humphries 2005; King et al. 2009). A rising spring flow is needed to initiate movement and courtship (Ivor Stuart pers. comm. April 2014). The greatest amount of movement of adult Murray cod has been correlated with peak flows (Koehn & Nicol 1998; Hutchinson et al. 2008).

However, there can also be considerable variation in migration within and between populations; for example, Murray cod can migrate in stable flow and not all Murray cod in a population may migrate. In anabranches Murray cod can have a different pattern again, migrating to spawning areas in autumn or winter rather than spring (Saddlier et al. 2008; Mallen-Cooper et al. 2013).

Murray cod and Trout cod are known to spawn over a predictable temporal period in response to increasing temperature irrespective of flow (Rowland 1983; Humphries 2005). Provision of flow increases may not be required as a spawning trigger for these species but could be used to maximize breeding opportunities by inundating more spawning habitat (Baumgartner et al. 2013).

Floodwater contributions to recruitment

According to Mallen-Cooper et al. (2014) recruitment of fish is dependent on the survival of larvae, which have a naturally high mortality. Inundated floodplains are very productive with high densities of phytoplankton and zooplankton that provide food of appropriate size and density for fish larvae. For the fish species that spawn within channel habitats, such as Murray cod, golden perch and silver perch, high survival of larvae may occur as floodwaters recede back into channels. This would be an indirect use of the floodplain by channel specialists and it may occur at a small scale of 10s of kilometres or in large floods over scales of 100s of kilometres. The body of research at present indicates that the channel specialists, which are mostly the large-bodied fish species, can spawn and recruit in absence of floods, especially where there are flowing water habitats without barriers to fish passage, but it is likely that floods significantly enhance recruitment.

Waterbirds

Overview

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 is the basis of 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).

Flood frequency

Waterbirds generally

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).

Recurrent flooding is considered to be an important factor in building food resources within the forests prior to a managed bird breeding event. A large flood event in the year preceding a managed bird breeding event is highly recommended as this will ensure permanent and semi-permanent wetlands have been refreshed and are productive. Wetlands that are already inundated will provide a source population of wetland vegetation and native fish allowing other areas within the forest to be quickly recolonised. Therefore in planning a managed bird breeding event, it would be desirable to implement a moderate to large watering event in the preceding year (North Central CMA 2009).

Duration

Egrets

For slow breeders such as Eastern Great Egrets a minimum inundation period of 10 months is required for successful breeding (7 month time lag followed by 3 months for egg laying, hatching and fledging) (Scott 1997, Kingsford and Auld 2005; North Central CMA 2009). See below for further details.

Waterbirds generally

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 Guttrum Forest and their different breeding timeframes (North Central CMA 2009).

Table 11. Waterbirds typical of Guttrum Forest and their different breeding timeframes (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, 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).

Colonial stick-nesting waterbird breeding is dependent on areas of living River Red Gum that are flooded for at least four months (Briggs et al. 1997).

Interval between floods

Waterbirds generally

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).

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

Waterbirds generally

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 Guttrum 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 Benwell Forest, Koondrook-Perricoota Forest, Gunbower Forest, Campbells Island 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.
- Irrigation season – colonial waterbirds have been observed to feed in irrigated farm land such as pasture. Success of a breeding event is highly dependant upon a good food resource for the birds. Therefore a large area of irrigated land may contribute to a successful breeding event (North Central CMA 2009).

Depth

Egrets

The depth of flooding is not a directly important variable for ensuring a bird breeding event. However it is an indicator of the extent of flooding and the length of time that the floodwaters will remain. The deeper the water the more insurance there is against dropping water levels and hence the greater chance of breeding success. Ecologists have recommended that as long as the depth of inundation is maintained, depth of flooding is not a critical variable (North Central CMA 2009).

Nearly all colonial nesting waterbirds are vulnerable to sudden drops in water level beneath nesting sites or in foraging areas - this can result in waterbirds abandoning their nests and young before they fledge (Kingsford 1998, Kingsford and Norman 2002; North Central CMA 2009). In the Barmah-Millewa Forest, stick nesting colonial waterbirds (e.g. Australian Darter, Great Egret, Great, Little Pied and Little Black Cormorants, Intermediate Egret, Little Egret, Nankeen Night Heron, and White-necked Heron), which generally nest in trees, declined due to decreased nest security associated with water receding too early, and low food availability (Leslie 2001).

Past observations have shown that birds are sensitive to reductions in area of inundation around their breeding sites, even when this relates to minimal change in depth under nests (North Central CMA 2009).

Past observations of breeding events has also demonstrated that waterbirds are more sensitive to drops in water level and contractions in inundated area early in the breeding cycle (August - October). A drop in water level and contraction of inundated area is most likely an indicator to the birds that food resources might decline and not be sufficient to complete the breeding event. Therefore this is probably a survival adaption where the birds are more likely to abandon young when they have not invested a lot of energy into breeding. Where laying has been staggered this may result in younger birds being abandoned. A gradual decline in area inundated of the broader forest would be acceptable later on in the season (November – February). The risk of abandonment is reduced later in the breeding cycle as it is more likely to be worth their while persisting (Scott, 1997).

A slow reduction in area inundated within the wider forest can be managed providing a) water levels are maintained under nests b) food resources are still available in core feeding wetlands c) it provides the opportunity to expose additional food resources.

The challenge for bird breeding operating scenarios is to define the acceptable level of draw down. This will need to take into account the relationship between inflow and inundation extent as well as seepage and evaporative losses across the forests.

Rapid rises in water level at the initiation of the flood event are not as critical. However once breeding has begun, rapid rises in water levels that will flood nests should be avoided.

Small increases and decreases in the area of inundation outside of the breeding colonies (i.e. in feeding grounds), during a flooding event is not considered to be problematic. Small changes in the water depth of a wetland that results in the wetting and drying of wetland sediments is considered beneficial as it has the potential to increase the food resource and stimulate native fish breeding.

A short increase in inflows during November could also be desirable under some circumstances as this will assist in building confidence within egrets to commit to breeding (North Central CMA 2009).

Piscivorous (fish eating) waterbird breeding success, of egrets for example, will be enhanced by the availability of prey in shallow water as water levels recede (Ecological Associates 2010).

Waterbirds generally

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);

- 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; and
- nearly all colonial nesting waterbirds are vulnerable to sudden drops in water level beneath nesting sites or in foraging areas as discussed above.

In Barmah Forest, a predicted colonial bird breeding event occurred because of the suitable constant low-level flooding through the traditional breeding sites, despite the otherwise drought conditions in the region. Although the higher level transfers were concluded by early December 2002, appropriate ponding levels were maintained by supplying targeted low flows into early February until the colony of predominantly Australian White Ibis and Royal Spoonbill successfully fledged (O'Connor & Ward 2003; Ward 2005). Although targeted water management activities have achieved some good waterbird breeding results over the past decade in Barmah Forest, other breeding attempts have been known to fail due to premature flood subsidence or lack of appropriate flooding (O'Connor & Ward 2003; Webster 2004).

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 the Guttrum Forest will likely increase waterbird species diversity and numbers able to forage in wetlands.