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Department of Sustainability, Environment, Water, Population and Communities





Barmah Forest

Ramsar Site

Ecological Character Description

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The steering committee was comprised of the following:
- Leah Beesley; Department of Sustainability and Environment
- Tamara Boyd; Parks Victoria
- Lyndell Davis; DSEWPaC
- John Foster; DSEWPaC
- Janet Holmes; Department of Sustainability and Environment
- Richard Loyn; Department of Sustainability and Environment
- Shar Ramamurthy; Department of Sustainability and Environment
- Keith Ward; Goulburn-Broken Catchment Management Authority
- Kane Weeks; Parks Victoria.

Introductory Notes
This Ecological Character Description (ECD Publication) has been prepared in accordance with the *National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands (National Framework)* (Department of the Environment, Water, Heritage and the Arts, 2008).

The Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) prohibits actions that are likely to have a significant impact on the ecological character of a Ramsar wetland unless the Commonwealth Environment Minister has approved the taking of the action, or some other provision in the EPBC Act allows the action to be taken. The information in this ECD Publication does not indicate any commitment to a particular course of action, policy position or decision. Further, it does not provide assessment of any particular action within the meaning of the EPBC Act, nor replace the role of the Minister or his delegate in making an informed decision to approve an action.

The *Water Act 2007* requires that in preparing the [Murray-Darling] Basin Plan, the Murray-Darling Basin Authority (MDBA) must take into account Ecological Character Descriptions of declared Ramsar wetlands prepared in accordance with the National Framework.

This ECD Publication is provided without prejudice to any final decision by the Administrative Authority for Ramsar in Australia on change in ecological character in accordance with the requirements of Article 3.2 of the Ramsar Convention.

Cover photos (left to right):
Aerial photo of Barmah Forest – Jim Mollison (DSEWPaC), Barmah Forest – Bruce Gray (DSEWPaC), Barmah Forest – Trevor J Lerino (DSEWPaC), Barmah Forest – Jim Mollison (DSEWPaC), Superb Parrot – Kirsty Wilkes (DSEWPaC).

Table of Contents

Glossary....iv
List of Abbreviations vi
Executive Summary....vii
1. Introduction 1
1.1 Site details....2
1.2 Statement of purpose....3
1.3 Relevant treaties, legislation and regulations 5
1.4 Method 9
2. General Description of the Barmah Forest Ramsar Site 10
2.1 Location....10
2.2 Land tenure 10
2.3 Wetland types 11
2.4 Ramsar criteria....14
2.4.1 Criteria under which the site was designated....14
2.4.2 Assessment based on current Ramsar criteria 15
3. Critical Components and Processes 21
3.1 Identifying critical components and processes 21
3.2 Supporting components and processes 23
3.2.1 Climate 23
3.2.2 Geomorphic setting 25
3.2.3 Water quality 26
3.2.4 Other wetland fauna 28
3.3 Critical components and processes....29
3.3.1 Hydrology 30
3.3.2 Wetland vegetation....35
3.3.3 Fish....41
3.3.4 Wetland birds 43
4 Ecosystem services....45
4.1 Overview of benefits and services 45
4.2 Identifying critical ecosystem services and benefits 45
4.3 Critical services....47
4.3.1 Supports a diversity of wetland types....47
4.3.2 Supports biodiversity....49
4.3.3 Provides physical habitat for wetland bird breeding and feeding....50
4.3.4 Supports threatened species 56
4.3.5 Maintains ecological connectivity for spawning and recruitment of native fish 57
4.3.6 Organic carbon cycling....58
4.4 Conceptual models 60
4.1 Wet phase (filling and inundated state)....60
4.2 Dry phase (drying and dry state)....62
5. Limits of acceptable change....63
5.1 Process for setting Limits of Acceptable Change (LAC)....63
5.2 LAC for the Barmah Forest Ramsar site....64
6. Threats to Ecological Character 71
6.1 Water resource use....73
6.2 Climate change 73
6.3 Altered fire regimes....74
6.4 Invasive species....74
6.5 Human disturbance....74
6.6 Summary of threats....75
7. Current Ecological Character and Changes Since Designation....76
7.1 Changes in land use 76
7.2 Changes in critical components, processes and services 76
8. Knowledge Gaps 81
9. Monitoring....82
10. Communication and Education Messages 83
References 84
Appendix A: Methods....92
A.1 Approach 92
A.2 Consultant Team 93
Appendix B: Waterbirds....95
Appendix C: Aquatic mammals, reptiles and frogs....97
Appendix D: Fish predicted and recorded within the Ramsar site 98

Glossary

Definitions of words associated with ecological character descriptions (DEWHA 2008 and references cited within).

Benefits	Benefits/services are defined in accordance with the Millennium Ecosystem Assessment definition of ecosystem services as "the benefits that people receive from ecosystems" (Ramsar Convention 2005, Resolution IX.1 Annex A). See also "Ecosystem Services".
Biogeographic region	A scientifically rigorous determination of regions as established using biological and physical parameters such as climate, soil type, vegetation cover, etc. (Ramsar Convention 2005).
Biological diversity	The variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species (genetic diversity), between species (species diversity), of ecosystems (ecosystem diversity) and of ecological processes. This definition is largely based on the one contained in Article 2 of the Convention on Biological Diversity (Ramsar Convention 2005).
Blackwater	Tannin stained, low oxygen water as a result of the microbial breakdown of organic matter.
Change in ecological character	The human-induced adverse alteration of any ecosystem component, process, and/or ecosystem benefit/service (Ramsar Convention 2005, Resolution IX.1 Annex A).
Community	An assemblage of organisms characterised by a distinctive combination of species occupying a common environment and interacting with one another (ANZECC and ARMCANZ 2000).
Community Composition	All the types of taxa present in a community (ANZECC and ARMCANZ 2000).
Conceptual model	Wetland conceptual models express ideas about components and processes deemed important for wetland ecosystems (Gross 2003).
Contracting Parties	Countries that are Member States to the Ramsar Convention on Wetlands; 160 as at August 2010. Membership in the Convention is open to all states that are members of the United Nations, one of the United Nations specialised agencies, or the International Atomic Energy Agency, or is a Party to the Statute of the International Court of Justice.
Critical stage	Stage of the life cycle of wetland-dependent species. Critical stages being those activities (breeding, migration stopovers, moulting etc.) which, if interrupted or prevented from occurring, may threaten long-term conservation of the species (Ramsar Convention 2005).
Ecological character	The combination of the ecosystem components, processes and benefits/services that characterise the wetland at a given point in time.
Ecosystems	The complex of living communities (including human communities) and non-living environment (Ecosystem Components) interacting (through Ecological Processes) as a functional unit which provides inter alia a variety of benefits to people (Ecosystem Services) (Millennium Ecosystem Assessment 2005).
Ecosystem components	The physical, chemical and biological parts of a wetland (from large scale to very small scale, for example habitat, species and genes) (Millennium Ecosystem Assessment 2005).
Ecosystem processes	The changes or reactions which occur naturally within wetland systems. They may be physical, chemical or biological (Ramsar Convention 1996, Resolution VI.1 Annex A). They include all those processes that occur between organisms and within and between populations and communities, including interactions with the non-living environment that result in existing ecosystems and bring about changes in ecosystems over time.
Ecosystem services	The benefits that people receive or obtain from an ecosystem. The components of ecosystem services are provisioning (e.g. food and water), regulating (e.g. flood control), cultural (e.g. spiritual, recreational) and supporting (e.g. nutrient cycling, ecological value) (Millennium Ecosystem Assessment 2005). See also "Benefits".
Essential elements	A component or process that has an essential influence on the critical components, processes or services (CPS) of the wetland. Should the essential element cease, reduce or be lost, it would result in a detrimental impact on one or more critical CPS. Critical CPS may depend in part or fully on essential elements; however, an essential element is not in itself critical for defining the ecological character of the site.
Fluvial geomorphology	The study of water-shaped landforms.

Indigenous species	A species that originates and occurs naturally in a particular country (Ramsar Convention 2005).
Limits of Acceptable Change	The variation that is considered acceptable in a particular component or process of the ecological character of the wetland without indicating change in ecological character which may lead to a reduction or loss of the criteria for which the site was Ramsar listed (modified from definition adopted by Phillips 2006).
List of Wetlands of International Importance ("Ramsar List")	The list of wetlands which have been designated by the Ramsar Contracting Party in which they reside as internationally important, according to one or more of the criteria that have been adopted by the Conference of the Parties.
Ramsar	City in Iran, on the shores of the Caspian Sea, where the Convention on Wetlands was signed on 2 February 1971; thus the Convention's short title "Ramsar Convention on Wetlands".
Ramsar Criteria	Criteria for Identifying Wetlands of International Importance, used by Contracting Parties and advisory bodies to identify wetlands as qualifying for the Ramsar List on the basis of representativeness or uniqueness or of biodiversity values.
Ramsar Convention	Convention on Wetlands of International Importance especially as Waterfowl Habitat. Ramsar (Iran), 2 February 1971. UN Treaty Series No. 14583. As amended by the Paris Protocol, 3 December 1982, and Regina Amendments, 28 May 1987. The abbreviated names "Convention on Wetlands (Ramsar, Iran, 1971)" or "Ramsar Convention" are more commonly used.
Ramsar Information Sheet (RIS)	The form upon which Contracting Parties record relevant data on proposed Wetlands of International Importance for inclusion in the Ramsar Database; covers identifying details like geographical coordinates and surface area, criteria for inclusion in the Ramsar List and wetland types present, hydrological, ecological and socioeconomic issues (among others), ownership and jurisdictions, and conservation measures taken and needed.
Ramsar List	The List of Wetlands of International Importance.
Ramsar Sites	Wetlands designated by the Contracting Parties for inclusion in the List of Wetlands of International Importance because they meet one or more of the Ramsar Criteria.
Waterbirds	"Birds ecologically dependent on wetlands" (Article 1.2). This definition thus includes any wetland bird species. However, at the broad level of taxonomic order, it includes especially: • penguins: *Sphenisciformes*; • divers: *Gaviiformes*; • grebes: *Podicipediformes*; • wetland pelicans, cormorants, darters and allies: *Pelecaniformes*; • herons, bitterns, storks, ibises and spoonbills: *Ciconiiformes*; • flamingos: *Phoenicopteriformes*; • screamers, swans, geese and ducks (wildfowl): *Anseriformes*; • wetland related raptors: *Accipitriformes* and *Falconiformes*; • wetland related cranes, rails and allies: *Gruiformes*; • Hoatzin: *Opisthocomiformes*; • wetland related jacanas, waders (or shorebirds), gulls, skimmers and terns: *Charadriiformes*; • coucals*: Cuculiformes*; and • wetland related owls: *Strigiformes*.
Waterfowl	Waterbirds of the order Anseriformes, especially members of the family Anatidae, which includes ducks, geese and swans.
Wetlands	Areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres (Ramsar Convention 1987).
Wetland types	As defined by the Ramsar Convention's wetland classification system [http://www.ramsar.org/cda/ramsar/display/main/main.jsp?zn=ramsar&cp=1-26-76%5E21235_4000_0__].

List of Abbreviations

ANZECC	Australian and New Zealand Environment and Conservation Council
ARI	Arthur Rylah Institute
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
AWSG	Australasian Waders Studies Group
CAMBA	China Australia Migratory Bird Agreement
CMA	Catchment Management Authority
CMS	The Convention on the Conservation of Migratory Species of Wild Animals (also known as CMS or Bonn Convention)
CPS	Components, processes and services
DEWHA	Department of Environment, Water, Heritage and the Arts (Commonwealth) (now DSEWPaC)
DSE	Department of Sustainability and Environment (Victoria)
DPI	Department of Primary Industries (Victoria)
DSEWPaC	Department of Sustainability, Environment, Water, Population and Communities (Commonwealth) (formerly DEWHA)
ECD	Ecological Character Description
EPA	Environment Protection Authority
EPBC Act	Environment Protection and Biodiversity Conservation Act, 1999 (Commonwealth)
EPBC Regulations	Environment Protection and Biodiversity Conservation Regulations, 2000 (Commonwealth)
GBCMA	Goulburn Broken Catchment Management Authority
IUCN	International Union for Conservation of Nature
JAMBA	Japan Australia Migratory Bird Agreement
LAC	Limits of Acceptable Change
RAOU	Royal Australasian Ornithologists Union
MDBA	Murray-Darling Basin Authority
MDBC	Murray-Darling Basin Commission
NCCMA	North Central Catchment Management Authority
ROKAMBA	Republic of Korea Australia Migratory Bird Agreement
VWSG	Victorian Waders Studies Group

Executive Summary

This Ecological Character Description (ECD) represents the second ECD prepared for the Barmah Forest Ramsar site. The first ECD (DSE 2008) was prepared in 2005 using the 'Framework for describing the ecological character of Ramsar wetlands' (DSE 2005) which pre-dated the current National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands (DEWHA 2008). This second ECD updates the description of ecological character in line with the current national framework.

The Barmah Forest Ramsar site is located in northern Victoria and consists of the section of the Murray River floodplain within Victoria (i.e. south of the main river channel) between the downstream end of the Ulupna Island and Barmah Township. It is an area of river red gum (*Eucalyptus camaldulensis*) forest, subject to periodic inundation. The forest features a variety of permanent and temporary wetlands, including lakes, swamps, lagoons and flooded forest. These wetlands provide habitat for a large number of bird species. It was originally nominated as a "Wetland of International Importance" under the Ramsar Convention in 1982.

The Barmah Forest Ramsar site met the following six criteria under conditions at the time of listing. However, it is now considered that the evidence is insufficient to claim that the site met Criterion 5 at that time:

Criterion 1: Barmah Forest is part of the largest complex of tree-dominated floodplain wetlands in southern Australia. Barmah Forest, together with Millewa Forests (on the NSW side of the Murray River) is nationally the largest continuous stand of river red gum forest (MDBC 2007). The size and intact nature of this forested floodplain makes it clearly one of the best representatives of the wetland type Xf (freshwater tree-dominated wetlands) in the bioregion. In addition, the site forms an extensive area of intact floodplain and is one of the few such areas with native vegetation in the bioregion.

> **Criterion 2:** Barmah Forest is a significant site in terms of supporting at least seven threatened wetland dependent species, listed at the national and/or international scale. These include Australasian bittern (*Botaurus poiciloptilus*), superb parrot (*Polytelis swainsonii*), Mueller daisy (*Brachyscome muelleroides*), swamp wallaby grass (*Amphibromus fluitans*), silver perch (*Bidyanus bidyanus*), Murray cod (*Maccullochella peelii*) and trout cod (*Maccullochella macquariensis*).
>
> **Criterion 3:** Barmah Forest supports at least 553 native species of flora and 273 fauna (considerably more than some comparable sites in the bioregion). In addition, the site is bioregionally significant with respect to moira grass (*Pseudoraphis spinescens*), containing the largest expanses of this species in the Murray-Darling Basin.
>
> **Criterion 4:** The Barmah Forest Ramsar site supports breeding of waterbirds, frogs, native fish and turtles during times of inundation. The site periodically supports thousands of colonial nesting waterbirds and is considered a drought refuge for waterbirds and native fish.
>
> **Criterion 5:** There are only two confirmed records of more than 20 000 waterbirds from within the site. While it is the opinion of local experts that total counts of colonial nesting waterbirds, waterfowl and other solitary nesters would number greater than 20 000 during floodplain inundation, there are insufficient quantitative waterbird abundance data to justify the claim that the site met this criterion at the time of listing. This criterion should be reassessed when further data are available.
>
> **Criterion 8:** The site provides migratory routes between habitat in the Murray River, anabranches and floodplains and is considered important for recruitment of native fish (King et al. 2007).

Central to a description of the ecological character of a Ramsar site is the identification and description of critical components, processes and services, benchmarked to the time of listing. Limits of Acceptable Change (LACs) are developed for each of the identified critical components, process and services and an assessment of changes since listing, with respect to the LACs undertaken. A summary of the components, processes and services critical to the ecological character of the Barmah Forest Ramsar site, together with the LACs and assessment of current conditions is provided in Table E1.

Additional explanatory notes on LACs

Limits of Acceptable Change are a tool by which ecological change can be measured. However, ECDs are not management plans and LACs do not constitute a management regime for the Ramsar site.

Exceeding or not meeting LACs does not necessarily indicate that there has been a change in ecological character within the meaning of the Ramsar Convention. However, exceeding or not meeting LACs may require investigation to determine whether there has been a change in ecological character.

In reading the ECD and the LACs, it should be recognised that the hydrology of many catchments in the Murray-Darling Basin is highly regulated, despite many of the wetlands forming under natural hydrological regimes that were more variable and less predictable. Many of the Ramsar wetlands of the Murray-Darling Basin were listed at a time when the rivers were highly regulated and water over allocated, with the character of these sites reflecting the prevailing conditions. When listed under the Ramsar Convention, many sites were already on a long-term trend of ecological decline.

While the best available information has been used to prepare this ECD and define LACs for the site, a comprehensive understanding of site character may not be possible as in many cases only limited information and data is available for these purposes. The LACs may not accurately represent the variability of the critical components, processes, benefits or services under the management regime and natural conditions that prevailed at the time the site was listed as a Ramsar wetland.

Users should exercise their own skill and care with respect to their use of the information in this ECD and carefully evaluate the suitability of the information for their own purposes.

LACs can be updated as new information becomes available to ensure they more accurately reflect the natural variability (or normal range for artificial sites) of critical components, processes, benefits or services of the Ramsar wetland.

Table E1: Summary of critical components, process and services, LACs and current conditions.

Critical components processes and services	Limit of Acceptable Change	Current conditions
Hydrology: • Inundation of the site is driven largely by flows within the Murray River. • The hydrology of the site is highly regulated and seasonality of low and moderate flow is determined largely by irrigation needs. • Large scale floods that inundate the forest are generally the result of catchment scale rainfall events. • Groundwater may be important for maintaining tree health, but remains a knowledge gap.	*Minimum of 10 400 megalitres a day (Murray River at Yarrawonga) no less than 7 years in any 10 year period, with a mean duration no less than 100 days; and a maximum interval of 4 years between the flow threshold.* *Minimum of 16 000 megalitres a day (Murray River at Yarrawonga) no less than 7 years in any 10 year period, with a mean duration no less than 90 days; and a maximum interval of 4 years between the flow threshold.* *Minimum of 35 000 megalitres a day (Murray River at Yarrawonga) no less than 10 years in any 20 year period, with a mean duration no less than 60 days; and a maximum interval of 10 years between the flow threshold.* *Minimum of 60 000 megalitres a day (Murray River at Yarrawonga) no less than 12 years in any 50 year period, with a mean duration no less than 21 days; and a maximum interval of 12 years between the flow threshold.*	There is evidence that there has been a decline in small and medium floods in the past decade as a result of water use, prolonged drought and potential effects of climate change. The hydrology LACs for small (in channel) and medium (overbank) flows have been exceeded.
Vegetation: • The two critical wetland vegetation categories are: river red gum forests, floodplain marshes. • Approximately 85 percent of the site is covered in inundation dependent river red gum forest (21,461 hectares), river red gum woodland (2736 hectares) and black box woodland (114 hectares). • River red gum forest is the dominant vegetation community, comprising 75 percent of the site.	*Extent of river red gum-dominated vegetation to be no less than:* • *19 350 hectares of river red gum forest* • *2400 hectares of river red gum woodland* *River red gum condition to be "moderate" (according to the method of Cunningham et al. 2009) or better for at least 80 percent of forest.*	No recent mapping of forest extent is available, but mapping of ecological vegetation classes (EVCs) in 2005 indicated little evidence of widespread loss of long-lived trees. Cunningham et al. (2009) indicated that 95 percent of trees were in moderate or better condition in 2009.
	Extent of floodplain marshes to be no less than: • *1350 hectares moira grass* • *450 hectares of giant rush*	No recent quantitative assessment, but extent of giant rush has expanded at the expense of moira grass and it is possible the LAC for moira grass has been exceeded.

Critical components processes and services	Limit of Acceptable Change	Current conditions
• Floodplain marshes include moira grass (*Pseudoraphis spinescens*) plains (regionally significant), giant rush (*Juncus ingens*) beds, common reed (*Phragmites australis*) beds, moist grasslands, herblands and semi-permanent marshes. • Supports two nationally threatened wetland flora species: Mueller daisy (*Brachyscome muelleroides*) and swamp wallaby-grass (*Amphibromus fluitans*).	*Presence of Mueller daisy (Brachyscome muelleroides) and swamp wallaby-grass (Amphibromus fluitans) in permanent and intermittent wetlands within the site.*	Mueller daisy was recorded as recently as 2004 (Lucas 2010) and swamp wallaby-grass as recently as 2005 (DSE unpublished).
Fish: • Data deficient. • Seventeen native species of fish have been recorded from within the site. • Results from surveys indicate that abundance varies considerably and that invasive species generally comprise 10 to 30 percent of the total abundance and up to 70 percent of biomass. • Supports three native threatened fish species: silver perch (*Bidyanus bidyanus*), Murray cod (*Maccullochella peelii*) and trout cod (*Maccullochella macquariensis*).	*Presence of the following species in no less than two in five annual surveys:* • *Australian smelt (Retropinna semoni)* • *Carp gudgeons (Hypseleotris spp.)* • *Dwarf flat-headed gudgeon (Philypnodon macrostomus)* • *Flat-headed gudgeon (Philypnodon grandiceps)* • *Unspecked hardyhead (Craterocephalus stercusmuscarum fulvus)* • *Murray-Darling rainbowfish (Melanotaenia fluviatilis).*	In surveys from 2007 to 2009, all of these species were recorded in the Barmah Forest (Rouke and Tonkin 2009).
	Presence of Murray cod, trout cod and silver perch in three out of five of annual surveys.	In surveys from 2007 to 2009, all of these species were recorded in the Barmah Forest (Rouke and Tonkin 2009).
Wetland birds: • Sixty species of wetland bird have been recorded from the site. This includes seven species listed under international migratory agreements and two threatened species: • superb parrot (*Polytelis swainsonii*) and Australasian bittern (*Botaurus poiciloptilus*). • Over 100 000 birds have been recorded in the site during times of flood. • The site is significant for supporting the breeding of colonial nesting waterbirds and contains a significant breeding population of superb parrots.	*Successful breeding (80 percent chicks fledged) of colonial nesting waterbirds in at least five years in ten.* *Thousands of colonial nesting birds in no less than two years in ten.*	In the ten-year period January 2000 to December 2009, there were two large breeding events of colonial nesting waterbirds with thousands of birds recorded, as well as several smaller events. In addition, thousands of waterbirds bred successfully in 2010/2011.
	Presence of the Australasian bittern when reed beds are inundated.	Australasian bittern was recorded in 2010/2011 and suspected of breeding.
	Presence of superb parrot and evidence of breeding annually.	Superb parrot nesting recorded in 2005/2006 (Webster 2007).

Critical components processes and services	Limit of Acceptable Change	Current conditions
Diversity of wetland types: The site supports part of the largest remaining river red gum forest in Australia and provides a mosaic of vegetated wetland habitats.	This critical service is linked to changes in the frequency and duration of wetland wetting and drying as well as changes in the extent and condition of wetland vegetation. Therefore no direct LAC has been developed and instead the critical service will be assessed indirectly through changes in the Average Recurrence Interval and duration of specific flow events, extent and condition of river red gum forests and woodlands and extent of floodplain marshes. *See LACs for hydrology and vegetation.*	
Biodiversity: The site supports the regionally significant moira grass vegetation community and a significant number of plant and animal species.	This critical service relates not only to species richness but also to the presence and extent of moira grasslands within the site. A LAC based on a total species census is not sensible in terms of assessment and it is likely that some species that use the site have yet to be recorded. As such, surrogates in terms of fish, vegetation and waterbirds will be used to assess against this service. *See LACs for wetland birds, fish and vegetation.*	
Physical habitat: Barmah Forest provides habitat for feeding and breeding of wetland birds.	This critical service is linked to changes in the frequency and duration of wetland wetting and drying as well as changes in extent and condition of wetland vegetation. In addition, wetland bird abundance can be used as a surrogate measure. Therefore no direct LAC has been developed and instead the critical service will be assessed indirectly through changes in the Average Recurrence Interval and duration of specific flow events, extent and condition of river red gum forests and woodlands, extent of floodplain marshes and abundance of wetland birds. *See LACs for hydrology, vegetation and wetland birds.*	
Threatened species: The Ramsar site supports seven species listed under the EPBC Act and/or the IUCN Red List.	This critical service is indicated by the presence of threatened species at the site. Therefore no direct LAC has been developed and instead the critical service will be assessed through presence of threatened species. *See LACs for wetland birds, fish and vegetation.*	
Ecological connectivity: The site provides important migratory routes between riverine, wetland and floodplain habitats for fish spawning and recruitment.	The site maintains connectivity between the river and floodplain wetlands and channels for fish spawning and recruitment. This service is maintained by hydrology and can also be indicated by the species richness and abundance of native fish. Therefore no direct LAC has been developed and instead the critical service will be assessed indirectly through changes in hydrology and native fish populations. *See LACs for hydrology and fish.*	
Organic carbon cycling: As part of a major floodplain system, the site is important for the cycling of nutrients, particularly carbon both on the floodplain and as a source of organic carbon to receiving waterways.	This service is provided by the uptake of carbon by vegetation, the deposition of organic matter (coarse woody debris and litter) on the floodplain and the mobilisation of particular and dissolved organic carbon to receiving river systems with flood return waters. This service is maintained by vegetation extent, forest structure and hydrology. Therefore no direct LAC has been developed and instead the critical service will be assessed indirectly through changes in hydrology and floodplain forest extent. *See LACs for hydrology and vegetation.*	

Assessment of changes since designation in 1982 for the Barmah Forest Ramsar site is hampered by a lack of baseline data from around the time of listing. This is particularly so for biotic critical components, processes and services. There is some evidence that tree health has declined in the forests in the period from 2003 to 2010 (Cunningham et al. 2009) and the extent of moira grass has declined since the time of listing. An assessment of current conditions with respect to LACs indicates that some of the LACs for hydrology have been exceeded. However, whether these changes are a result of sustained change or the effects of the recent sustained drought (2000 to 2010) is unknown. It is likely due to a combination of a number of factors that include water resource development, climate change and shorter term climatic cycles.

In addition to changes in components, process and services, there have been a number of important changes in land use and management since listing. From April 2010, the Ramsar site (formally comprised of State Forest and Crown Land) was reserved as national park under the Victorian *Parks and Crown Land Legislation Amendment (River Red Gum) Act 2010.* These alterations to land tenure have resulted in major land use changes including a restriction of logging activities in the area.

Threats to the ecological character of the site have been identified as:

- Water resource development (decreased frequency and duration of inundation; altered seasonality of inundation), leading to:
    - Reduced health and extent of river red gum forests and floodplain marshes.
    - Altered vegetation community composition.
    - Decreased habitat for fauna feeding and breeding.
    - Absence or disruption of bird, fish and frog breeding events.
- Altered fire regimes (increased frequency and intensity of fires), leading to:
    - Death of mature river red gums.
    - Adverse changes to forest structure.
    - Loss or degradation of habitat.
- Climate change (increased temperatures and decreased rainfall) which has exacerbated the effects of water resource development and altered fire regimes.
- Invasive species (weeds, introduced fish), which have caused:
    - Increased predation or competition with native flora and fauna.
    - Increased risk of destructive wildfire through increased understorey biomass.
- Human disturbance (recreation), which can lead to:
    - Loss or degradation of habitat through unauthorised firewood collection.
    - Soil and riparian zone degradation by off road vehicles or watercraft.
    - Increased risk of destructive wildfire.

There are a number of knowledge gaps associated with the ecological character of the Barmah Forest Ramsar site. The majority of these relate to conditions at the time of listing in 1982. Monitoring to address these knowledge gaps and assess against LACs has been recommended.

1. Introduction

This ECD represents the second ECD prepared for the Barmah Forest Ramsar site. The first ECD (DSE 2008) was prepared in 2005 using the 'Framework for describing the ecological character of Ramsar wetlands' (DSE 2005) which pre-dated the current National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands (DEWHA 2008). This second ECD updates the description of ecological character in line with the current national framework.

1.1 Site details

The Barmah Forest Ramsar site is located in northern Victoria and consists of the section of the Murray River floodplain within Victoria (south of the main river channel) between the downstream end of the Ulupna Island and Barmah Township. It is an area of river red gum (*Eucalyptus camaldulensis*) forest that is subject to periodic inundation. The forest features a variety of permanent and temporary wetlands, including lakes, swamps, lagoons and flooded forest. These wetlands provide habitat for a large number of bird species. The site was originally nominated as a "Wetland of International Importance" under the Ramsar Convention in 1982. Details for this Ramsar wetland are provided in Table 1.

Table 1: Site details for the Barmah Forest Ramsar site.

Site Name	Barmah Forest
Location in coordinates	Latitude: 35° 50' S to 36° 01' S Longitude: 144° 56' E to 145° 20' E
General location of the site	The Barmah Forest Ramsar site is located on the Murray River floodplain in the State of Victoria, approximately 225 kilometres north of Melbourne. Bioregion – Drainage Division 4: Murray-Darling (Australia's River Basins Australian Water Resources Council 1987).
Area	28 515 hectares
Date of Ramsar site designation	Designated on 15/12/1982
Ramsar Criteria met by wetland	Ramsar criteria 1, 2, 3, 4, and 8
Management authority for the site	At the time of listing, the site was managed by what is currently called DSE State Forests and Parks Victoria. In April 2010, the area was designated as a National Park and is currently managed by Parks Victoria.
Date the ECD applies	1982
Status of Description	This represents the second ECD for the site, updating DSE 2008.
Date of Compilation	June 2011
Name(s) of compiler(s)	Jennifer Hale and Rhonda Butcher on behalf of DSEWPaC.
References to the Ramsar Information Sheet (RIS)	RIS compiled by Parks Victoria in 1999.
References to Management Plan(s)	Department of Sustainability and Environment, 2003, Barmah Forest Ramsar Site: Strategic Management Plan, Victoria.

1.2 Statement of purpose

As a contracting party to the Ramsar Convention, Australia is obliged to promote the conservation of listed sites, promote the wise use of wetlands and report any changes to the ecological character of those sites. Wise use is defined as “the maintenance of their ecological character, achieved through the implementation of ecosystem approaches, within the context of sustainable development” (Ramsar 2005). Thus, understanding and describing the ‘ecological character’ of a Ramsar site is fundamental to promoting its conservation and being able to detect changes.

The Ramsar Convention has defined “ecological character” and “change in ecological character” as (Ramsar 2005):

“Ecological character is the combination of the ecosystem components, processes and benefits/services that characterise the wetlands at a given point in time”: and

“…change in ecological character is the human induced adverse alteration of any ecosystem component, process and or ecosystem benefit/service.”

The EPBC Act lists Ramsar wetlands as matters of national environmental significance. Actions which have or are likely to have a significant impact on the ecological character of a Ramsar wetland are required to be referred, assessed and approved under the EPBC Act. The EPBC Regulations (2000) also provide for Ramsar management principles which guide the development of management plans by site managers.

In order to detect change, it is necessary to establish a benchmark for management and planning purposes. An ECD forms the foundation on which a site management plan and associated monitoring and evaluation activities are based. It also forms the basis for the assessment of actions which are likely to impact on the Ramsar site.

The ECD provides details on the interactions between ecological components, processes and functions to give a comprehensive description of ecological character. This information supplements the Ramsar Information Sheet (RIS) which is prepared at the time of designation. It conforms to the *National Framework and Guidance for Describing the Ecological Character of Australia’s Ramsar Wetlands. Module 2 of Australian National Guidelines for Ramsar Wetlands: Implementing the Ramsar Convention in Australia* (DEWHA 2008) which was developed by the Australian and state/territory governments.

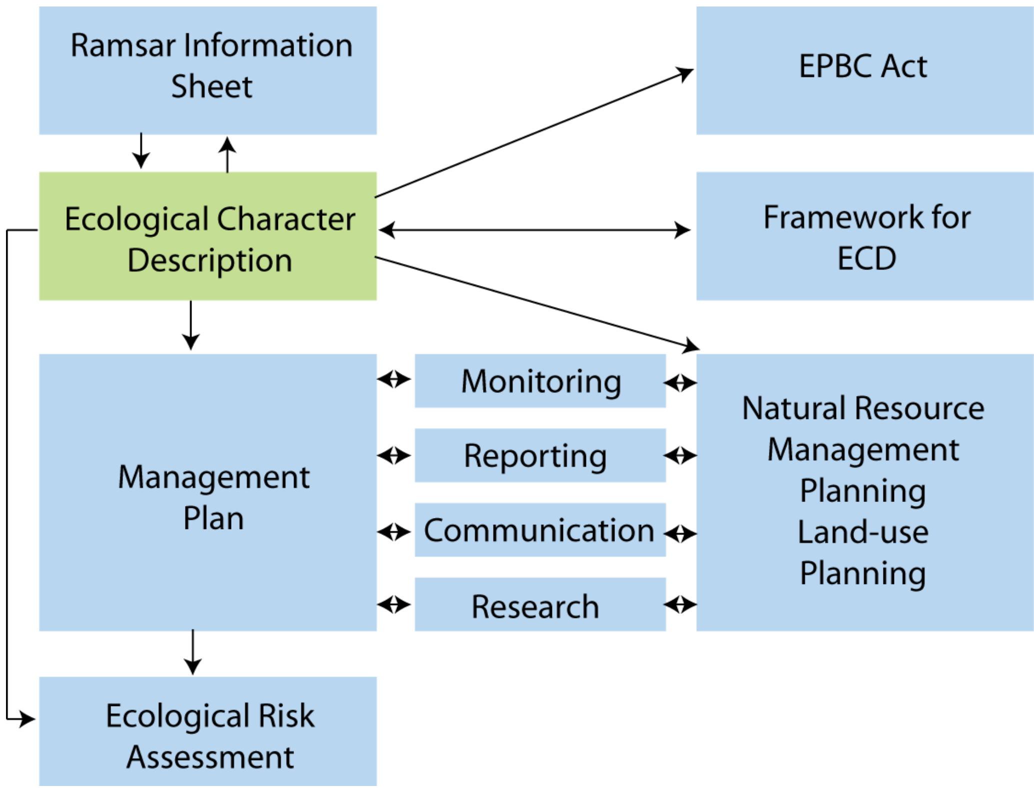

Figure 1: The ecological character description in the context of other requirements for the management of Ramsar sites (adapted from DEWHA 2008).

<u>The National Framework</u>
The framework emphasises the importance of describing and quantifying the ecosystem components, processes and benefits/services of the wetland and the relationship between them. It is also important that information is provided on the benchmarks or ecologically significant limits of acceptable change that would indicate when the ecological character has or is likely to change.

McGrath (2006) detailed the general aims of an ECD as follows:

1. To assist in implementing Australia's obligations under the Ramsar Convention, as stated in Schedule 6 (managing wetlands of international importance) of the *Environment Protection and Biodiversity Conservation Regulations* 2000 (Commonwealth):
    a) To describe and maintain the ecological character of declared Ramsar wetlands in Australia; and
    b) To formulate and implement planning that promotes:
        i) Conservation of the wetland; and
        ii) Wise and sustainable use of the wetland for the benefit of humanity in a way that is compatible with maintenance of the natural properties of the ecosystem.
2. To assist in fulfilling Australia's obligation under the Ramsar Convention to arrange to be informed at the earliest possible time if the ecological character of any wetland in its territory and included in the Ramsar List has changed, is changing or is likely to change as the result of technological developments, pollution or other human interference.
3. To supplement the description of the ecological character contained in the RIS submitted under the Ramsar Convention for each listed wetland and, collectively, to form an official record of the ecological character of the site.
4. To assist the administration of the EPBC Act, particularly:

a) To determine whether an action has, will have or is likely to have a significant impact on a declared Ramsar wetland in contravention of sections 16 and 17B of the EPBC Act; or

b) To assess the impacts that actions referred to the Minister under Part 7 of the EPBC Act have had, will have or are likely to have on a declared Ramsar wetland.

5. To assist any person considering taking an action that may impact on a declared Ramsar wetland whether to refer the action to the Minister under Part 7 of the EPBC Act for assessment and approval.

6. To inform members of the public who are interested generally in declared Ramsar wetlands to understand and value the wetlands.

1.3 Relevant treaties, legislation and regulations

This section provides a brief listing of the legislation and policy that is relevant to the description of the ecological character of the Ramsar site. There is a significant amount of legislation, particularly at the state/local level, relevant to the management of the site, which is documented more fully in the management plan for the site and as such is not repeated here.

International

Ramsar Convention

The Convention on Wetlands of International Importance, otherwise known as the Ramsar Convention, was signed in Ramsar Iran in 1971 and came into force in 1975. It provides the framework for local, regional and national actions, and international cooperation, for promoting the conservation and wise use of wetlands. Wetlands of International Importance are selected on the basis of their international significance in terms of ecology, botany, zoology, limnology and/or hydrology.

Migratory bird bilateral agreements and conventions

Australia is party to a number of bilateral agreements, initiatives and conventions for the conservation of migratory birds, which are relevant to the Barmah Forest Ramsar site. The bilateral agreements are:

- *Japan-Australia Migratory Bird Agreement (JAMBA)* – The agreement between the Government of Australia and the Government of Japan for the Protection of Migratory Birds in Danger of Extinction and their Environment, 1974;
- *China-Australia Migratory Bird Agreement (CAMBA)* – The agreement between the Government of Australia and the Government of the People's Republic of China for the Protection of Migratory Birds and their Environment 1986;
- *Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA)* – The agreement between the Government of Australia and the Republic of Korea for the Protection of Migratory Birds and their Environment, 2006; and
- *The Bonn Convention on Migratory Species (CMS)* – The Bonn Convention adopts a framework in which countries with jurisdiction over any part of the range of a particular species co-operate to prevent migratory species becoming endangered. For Australian purposes, many of the species are migratory birds.

National legislation, plans and programs

EPBC Act

The EPBC Act regulates actions that will have or are likely to have a significant impact on any matter of national environmental significance, which includes the ecological character of a Ramsar wetland (EPBC Act s16(1)). An action that will have or is likely to have a significant impact on a Ramsar wetland will require an environmental assessment and approval under the EPBC Act. An ‘action’ includes a project, a development, an undertaking or an activity or series of activities (http://www.environment.gov.au/epbc/index.html).

The EPBC Act establishes a framework for managing Ramsar wetlands, through the Australian Ramsar Management Principles (EPBC Act s335), which are set out in Schedule 6 of the EPBC Regulations. These principles are intended to promote national standards of management, planning, environmental impact assessment, community involvement and monitoring, for all of Australia's Ramsar wetlands in a way that is consistent with Australia's obligations under the Ramsar Convention.

The EPBC Act protects some species that occur in wetlands. For example, species listed under international treaties (JAMBA, CAMBA, ROKAMBA and CMS) are included in the List of Migratory Species under the EPBC Act. Threatened species and communities listed under the EPBC Act may also occur (or potentially occur) in the Ramsar site. Some species listed as threatened under state/territory legislation are not listed as threatened under the EPBC Act, usually because they are not threatened at the national (often equivalent to whole-of-population) level. The EPBC Regulations also cover matters relevant to the preparation of management plans, the environmental assessment of actions that may affect the site and the community consultation process.

Native Title Act 1993
This Act provides for the recognition and protection of native title. It establishes ways in which future dealing affecting native title may proceed and sets standards for such dealing. It establishes a mechanism for determining claims to native title. It provides for, or permits, the validation of past Acts, and intermediate period Acts, that are invalidated because of the existence of native title.

Water Act 2007
This Act provides for the management of the water resources of the Murray-Darling Basin, and to make provision for other matters of national interest in relation to water and water information, and for related purposes.

The Living Murray (TLM)
TLM instigated one of Australia's most significant river restoration programs. It aims to achieve a healthy working Murray River system for the benefit of all Australians, which includes returning water to the river's environment. TLM program was established in 2002 in response to strong evidence showing the declining health of the Murray River system. It is a partnership of the Australian, New South Wales, Victorian, South Australian and Australian Capital Territory governments.

The Basin Plan
The Basin Plan is a strategic plan for the integrated and sustainable management of water resources in the Murray-Darling Basin. It provides a framework for setting environmentally sustainable limits on the amount of surface water and groundwater that can be taken from the Basin. In addition it identifies, and seeks to protect and restore, key environmental assets which are essential to the life of the rivers, their surrounding landscapes and the cultural values of the communities which depend on those water resources. The Basin Plan takes into account the impact of this protection and restoration on individual communities, industries, regions and the wider economy (http://www.mdba.gov.au/what-we-do/basin-plan).

Victorian state policy and legislation

*Crown Land (Reserves) Act 197*8
This Act provides the framework for the administration and management of Crown land reserves including nature conservation reserves. The Act also deals with the making of regulations, committees of management and leasing and licensing.

The Environment Protection Act 1970
This Act establishes the Environment Protection Authority and makes provision for the Authority's powers, duties and functions. These relate to improving the air, land and water environments by managing waters, control of noise and control of pollution. State Environment Protection Policies (SEPPs) are subordinate legislation made under the

provisions of the Act. SEPP (Waters of Victoria) sets water quality objectives to protect the beneficial uses of inland waters.

Fisheries Act 1995
The Fisheries Act provides a framework for the regulation, management and conservation of Victorian fisheries. It deals with commercial and recreational licences, fish culture, noxious aquatic species, research and development, the declaration and management of fisheries reserves; and the preparation of management plans for individual fisheries, declared noxious aquatic species and fisheries reserves.

Flora and Fauna Guarantee Act 1988
The Act provides a legislative and administrative framework for the conservation of biodiversity in Victoria. The Act provides for the listing of threatened taxa, communities and potentially threatening processes. It requires the preparation of action statements for listed species, communities and potentially threatening processes and sets out the process for implementing interim conservation orders to protect critical habitats. The Act also seeks to provide programs for community education in the conservation of flora and fauna and to encourage co-operative management of flora and fauna.

Forests Act 1958
This Act protects and manages Victoria's State Forests and provides licensing requirements for the harvesting of those forests. Administered by the Secretary of the Department of Sustainability and Environment and subject to the supervision of the Minister for Environment, the Act states that working plans shall be established for state forests and allows the Minister to proclaim unoccupied Crown land to be a protected forest. The Act manages 'burning off' procedures, the use of fire, saw mills and the cutting of trees.

National Parks Act 1975
This Act makes provision for the preservation and protection of the natural environment including wilderness areas and remote and natural areas. This includes the protection and preservation of indigenous flora and fauna and of features of scenic or archaeological, ecological, geological, historic or other scientific interest in those parks. It allows for the study of ecology, geology, botany, zoology and other sciences relating to the conservation of the natural environment in those parks, and for the responsible management of the land in those parks.

Water Act 1989
The Water Act establishes rights and obligations in relation to water resources and provides mechanisms for the allocation of water resources. This includes the consideration of environmental water needs of rivers and wetlands as well as for human uses such as urban water supply and irrigation.

Wildlife Act 1975
The Wildlife Act 1975 ensures procedures are in place to protect and conserve Victoria's wildlife and prevent any taxa of wildlife from becoming extinct. The Act also provides for the establishment of State Game Reserves. Regulations under the Act ensure that the consumptive use or other interactions with flora and fauna in Victoria does not threaten the sustainability of wild populations, while facilitating cultural and recreational pursuits in a humane, safe, ethical and sustainable manner.

Catchment and Land Protection Act 1994
This Act sets up a framework for the integrated management and protection of catchments. It establishes processes to encourage and support community participation in the management of land and water resources and provides for a system of controls for noxious weeds and pest animals.

Aboriginal Heritage Act 2006
This Act provides for the protection and management of Victoria’s Aboriginal heritage. It establishes the Victorian Aboriginal Heritage Council to advise the Minister in the management of cultural heritage and registered Aboriginal parties. The Act also deals with

cultural heritage management plans, cultural heritage permits and agreements. The Act also includes enforcement provisions and processes for handling dispute resolution. This includes the review of certain decisions through the Victorian Civil and Administrative Tribunal (VCAT).

<u>Securing our natural future: A white paper for land and biodiversity at a time of climate change (November 2009)</u>
The Land and Biodiversity White Paper is a long-term, strategic framework to secure the health of Victoria's land, water and biodiversity in the face of ongoing pressures and a changing climate over the next fifty years. The framework for action is based on three inter-related elements:

- Building ecosystem resilience across Victoria,
- Managing flagship areas to maintain ecosystem services, and
- Improving connectivity in areas identified as biolinks.

<u>The Northern Region Sustainable Water Strategy (Northern Region SWS) 2010</u>
The Northern Region SWS aims to identify and understand threats to water availability and quality over the next 50 years, and outlines policies and actions to manage the consequences of prolonged drought and climate change.

1.4 Method

The method used to develop the ECD for the Barmah Forest Ramsar site is based on the twelve-step approach provided in the *National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands* (DEWHA 2008) illustrated in Figure 2. A more detailed description of each of the steps and outputs required is provided in the source document. This ECD was developed primarily through a desktop assessment and is based on existing data and information. A steering committee was formed to provide input and comment on the ECD.

1. Introduction to the description
Site details, purpose of the description, relevant legislation

2. Describe the site
Site location, climate, maps and images, tenure, criteria and wetland types

3. Identify and describe the critical components, processes, benefits and services
3.1 Identify all possible components, processes, benefits and services
3.2 Identify the critical components, processes benefits and services responsible for determining the ecological character of the site
3.3 Describe each of the critical components, processes, benefits & services

4. Develop a conceptual model of the wetland
Depict the critical components & processes of the wetland and their interactions

5. Set limits of acceptable change (LAC)
Determine LAC for critical components, processes and services

6. Identify threats to the ecological character of the site
Identify the actual or likely threats to the site

7. Describe changes to ecological character
Describe changes to the ecological character since the time of listing
Include information on the current condition of the site

8. Summarise knowledge gaps
Use information from Steps 3 - 7 to identify knowledge gaps

9. Identify site monitoring needs
Use information from Steps 3 - 8 to identify monitoring needs

10. Identify communication and education messages
Identify any communication & education messages highlighted during the development process

11. Compile the description of ecological character

12. Prepare or update the Ramsar Information Sheet
Submit as a companion document to the ecological character description

Figure 2: Twelve step process for developing an ECD (adapted from DEWHA 2008).

2. General Description of the Barmah Forest Ramsar Site

2.1 Location

The Barmah Forest Ramsar site is located in northern Victoria, within the Murray-Darling Drainage Division (bioregion). The site covers approximately 28 515 hectares and lies within the Moira Shire local government area. The site is 255 kilometres north of Melbourne and approximately 22 kilometres north east of the town of Echuca (population in 2006: 12 400) (Figure 3).

The Barmah Forest Ramsar site is within the Murray-Darling Basin, which covers over one million square kilometres and comprises 14 percent of the continent. The forest is located on the floodplain of the Murray River, the longest river in Australia.

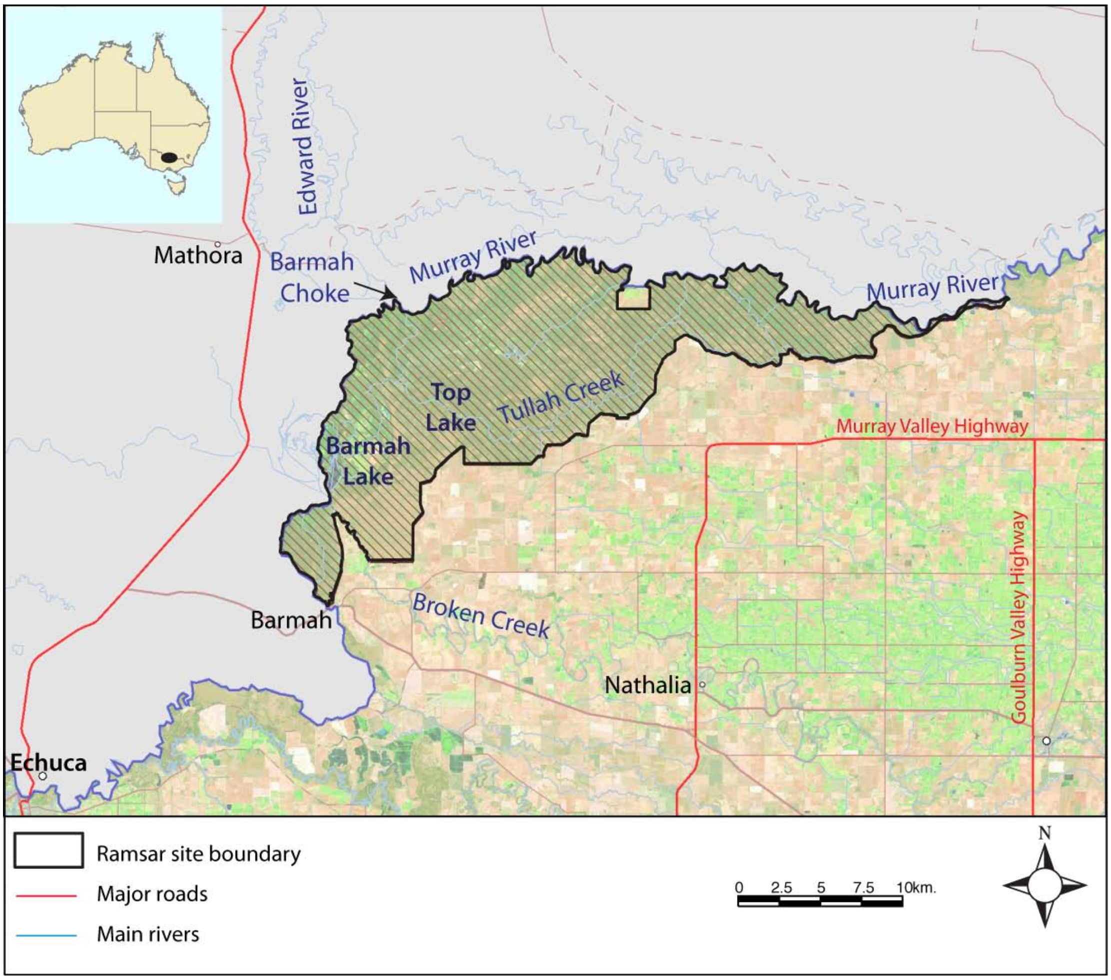

Figure 3: Location of the Barmah Forest Ramsar site (data provided by DSE).

2.2 Land tenure

At the time of listing (1982), the Barmah Forest Ramsar site was a declared State Forest managed for the purposes of timber production and harvesting (DCE 1992). In 1987, 7900 hectares of the site were declared State Park (with primary objectives for conservation), 280 hectares were declared as Reference Areas and approximately 20 000 hectares remained as State Forest. In April 2010, the entire site was declared a National Park by the Victorian Government to protect and enhance the river red gum forests (Parks Victoria 2010).

2.3 Wetland types

According to the Ramsar wetland classification, there are five wetland types within the Barmah Forest Ramsar site. In order of dominance, these are:

- Xf - Freshwater, tree-dominated wetlands;
- Ts - Seasonal/intermittent freshwater marshes/pools on inorganic soils;
- P - Seasonal/intermittent freshwater lakes (over eight hectares);
- M - Permanent rivers/streams/creeks; and
- N - Seasonal/intermittent/irregular rivers/streams/creeks.

Victorian wetlands have been mapped and classified according to the system developed by Corrick and Norman (1980), which for inland wetland systems can be approximated to Ramsar wetland types (Table 2 and Figure 4). It should be noted that the wetland classification adopted in Victoria defines "permanent" as wetlands that hold water for at least 12 months, although they can have periods of drying, especially during prolonged drought. With respect to Barmah Forest, the "permanent" wetlands at the time of listing are probably better described as semi-permanent, holding water for extended periods of time but occasionally drying, and so best equate to type P (intermittent freshwater lakes) although there may be smaller areas of permanent water.

Table 2: Extent (hectares) of wetland types within the Barmah Forest Ramsar site mapped under Victorian inland wetland system (data provided by DSE).

Ramsar wetland type	Equivalent Victorian wetland type (subcategory)	Extent (hectares)	Examples
Xf – Freshwater, tree-dominated wetlands	Freshwater meadow, shallow freshwater marsh, deep freshwater marsh (river red gum)	23 300	Majority of Barmah Forest – river red gum forest and woodland
Ts – Seasonal/intermittent freshwater marshes/pools on inorganic soils	Shallow freshwater marsh (herb)	960	Duck Hole Plain Little Rushy Swamp
	Deep freshwater marsh (reed)	972	Reedy Lake, Boals Deadwood
P – Seasonal/intermittent freshwater lakes (over eight hectares)	Permanent open freshwater (shallow; open)	166	Barmah Lake Hut Lake
M – Permanent rivers/streams/creeks	No equivalent type	Not applicable	Gulf Creek, Smiths Creek
N – Seasonal/intermittent/irregular rivers/streams/creeks	No equivalent type	Not applicable	Tullah Creek, Black Engine Creek

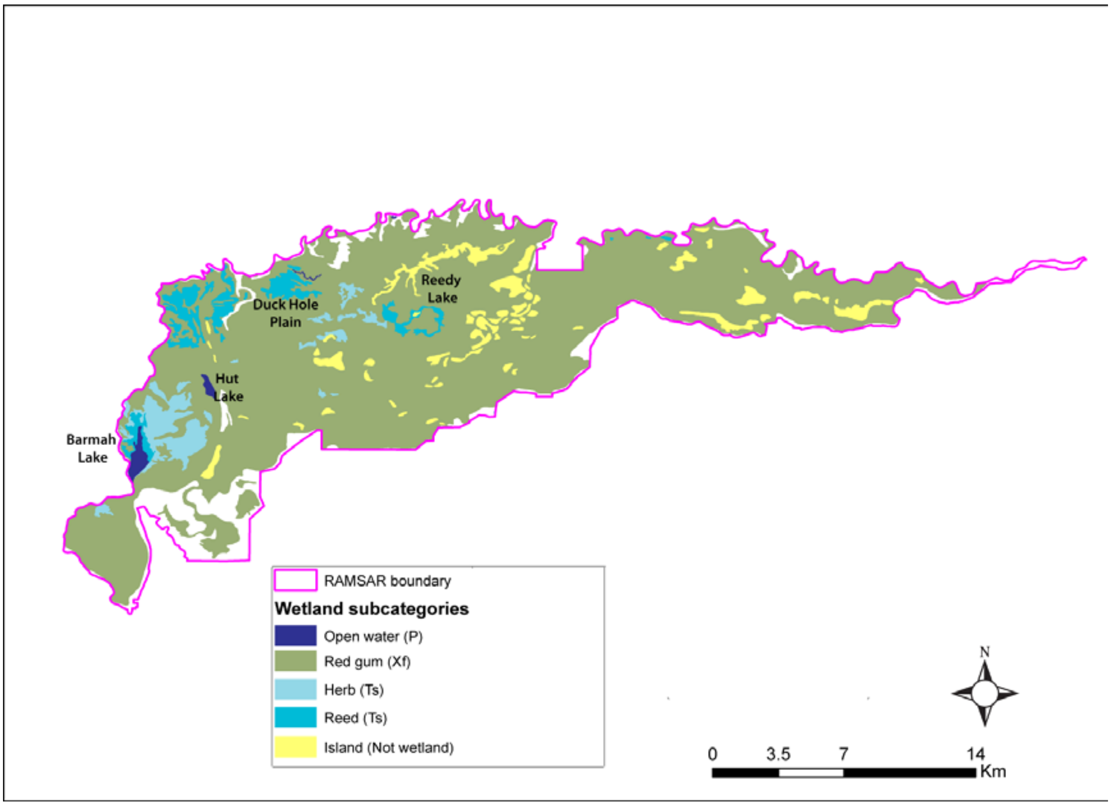

Figure 4: Wetland types in the Barmah Forest Ramsar site (adapted from data provided by DSE).

Examples of wetland types are provided in Figures 5, 6 and 7.

Figure 5: Example of wetland type Xf (freshwater tree dominated) (photo DSEWPaC – J. Mollison; 2010).

Figure 6: Example of wetland type Ts (seasonal / intermittent freshwater marsh) (photo DSEWPaC – B. Gray; 2006).

Figure 7: Example of wetland type P (intermittent freshwater lakes) – Hut Lake (photo DSEWPaC – J. Baker; 2006).

2.4 Ramsar criteria

2.4.1 Criteria under which the site was designated

At the time that Barmah Forest was first nominated as a Wetland of International Importance, the criteria for identifying wetlands of international importance were the "Cagliari criteria", adopted at the first conference of contracting parties in Cagliari in 1980. The original nomination documentation for the Barmah Forest Ramsar site considered that the site met three of these criteria as shown in (Table 3). However, no specific justification for these criteria was provided.

Table 3: Criteria for Identifying Wetlands of International Importance as at listing date, 1982. Criteria for which Barmah Forest was listed are highlighted in green.

Basis	Number	Description
Criteria for waterfowl	1a	It regularly supports 10,000 ducks, geese and swans; or 10,000 coots or 20,000 waders.
	1b	It regularly supports 1% of the individuals in a population of one species or subspecies of waterfowl.
	1c	It regularly supports 1% of the breeding pairs in a population of one species or subspecies of waterfowl.
Criteria based on plants and animals	2a	It supports an appreciable number of rare, vulnerable or endangered species or subspecies of plant or animal.
	2b	It is of special value for maintaining the genetic and ecological diversity of a region because of the quality and peculiarities of its flora and fauna.
	2c	It is of special value as the habitat of plants or animals at a critical stage of their biological cycle.
	2d	It is of special value for one or more endemic plant or animal species or communities.
Criterion based on representative wetlands	3	It is a particularly good example of a specific type of wetland characteristic of its region.

The 1999 RIS (Parks Victoria 1999) assessed the site against the eight criteria adopted at the Fourth Conference of Contracting Parties in Montreux in 1990, four of which were considered to be met. Justifications for the criteria (as contained in the 1999 RIS) were as follows:

Criterion 1: A wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.
The Barmah-Millewa forest is a good example of, and the largest, river red gum (*Eucalyptus camaldulenis)* forest in the state.

Criterion 3: A wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.
Barmah is of special value for maintaining the genetic and ecological diversity of the region because of its size, variety of communities and its high productivity. Barmah Forest also has the most extensive areas of moira grasslands in Victoria. The forest is an important breeding area for ibis in some years; up to 100 000 ibis nested in the Barmah Area during the 1973-75 flood.

Criterion 5: A wetland should be considered internationally important if it regularly supports 20 000 or more waterbirds.
After flood periods, Barmah Forest is one of Victoria's largest waterfowl breeding areas, supporting ducks (particularly black duck and maned duck), great cormorants, little black cormorants, little pied cormorants, white-faced herons, pacific herons and rufous night herons, yellow-billed spoonbills, crakes and rails.

Criterion 6: A wetland should be considered internationally important if it regularly supports one percent of the individuals in a population of one species or subspecies of waterbird.
During 1979-80, 1000 sacred ibis (3.0 percent of the State population) and 1700 straw-necked ibis (2.2 percent of the State population) nested in Barmah Forest.

2.4.2 Assessment based on current Ramsar criteria

There have been a number of developments in the past two decades that influence the application of the Ramsar criteria to wetland sites. This includes:

- Refinements and revisions of the Ramsar criteria since 1999. A ninth criterion was added at the 9th Ramsar Conference in Uganda in 2005.
- Revision of population estimates for waterbirds (Wetlands International 2006; Bamford et al. 2008), which influences the application of criterion six.
- A decision with respect to the appropriate bioregionalisation for aquatic systems in Australia, which for inland systems is now based on drainage divisions and for marine systems the interim marine classification and regionalisation for Australia (IMCRA). This affects the application of Criterion One and Criterion Three.
- Updates to threatened species listings, which affects Criterion Two.

Therefore an assessment of the Barmah Forest Ramsar site against the current nine Ramsar criteria has been undertaken (Table 4). In deciding if the site qualifies under criteria five and six (regularly supports one percent of the individuals in a population of one species of waterbird), an approach consistent with the Ramsar Convention has been adopted (Text Box 1). This represents an assessment of the conditions at the time of listing with respect to the current criteria.

Regularly (Criteria 5 & 6) – as in supports regularly – a wetland regularly supports a population of a given size if:

i. the requisite number of birds is known to have occurred in two thirds of the seasons for which adequate data are available, the total number of seasons being not less than three; or
ii. the mean of the maxima of those seasons in which the site is internationally important, taken over at least five years, amounts to the required level (means based on three or four years may be quoted in provisional assessments only).

In establishing long-term 'use' of a site by birds, natural variability in population levels should be considered especially in relation to the ecological needs of the populations present. Thus in some situations (e.g., sites of importance as drought or cold weather refuges or temporary wetlands in semi-arid or arid areas - which may be quite variable in extent between years), the simple arithmetical average number of birds using a site over several years may not adequately reflect the true ecological importance of the site. In these instances, a site may be of crucial importance at certain times ('ecological bottlenecks'), but hold lesser numbers at other times. In such situations, there is a need for interpretation of data from an appropriate time period in order to ensure that the importance of sites is accurately assessed.

In some instances, however, for species occurring in very remote areas or which are particularly rare, or where there are particular constraints on national capacity to undertake surveys, areas may be considered suitable on the basis of fewer counts. For some countries or sites where there is very little information, single counts can help establish the relative importance of the site for a species.

Text Box 1: Definition of "regularly supports" (Ramsar 2009).

Table 4: Criteria for Identifying Wetlands of International Importance (adopted by the 6th (1996) and 9th (2005) Meetings of the Conference of the Contracting Parties). Criteria for which the Barmah Forest Ramsar site qualified at the time of designation are highlighted in green.

Number	Basis	Description
Group A. Sites containing representative, rare or unique wetland types		
Criterion 1		A wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.
Group B. Sites of international importance for conserving biological diversity		
Criterion 2	Species and ecological communities	A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.
Criterion 3	Species and ecological communities	A wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.
Criterion 4	Species and ecological communities	A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.
Criterion 5	Waterbirds	A wetland should be considered internationally important if it regularly supports 20 000 or more waterbirds.
Criterion 6	Waterbirds	A wetland should be considered internationally important if it regularly supports one percent of the individuals in a population of one species or subspecies of waterbird.
Criterion 7	Fish	A wetland should be considered internationally important if it supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity.
Criterion 8	Fish	A wetland should be considered internationally important if it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.
Criterion 9	Other taxa	A wetland should be considered internationally important if it regularly supports one percent of the individuals in a population of one species or subspecies of wetland-dependent non-avian animal species.

An assessment against each of the criteria for the Barmah Forest Ramsar site is as follows:

Criterion 1: The application of this criterion must now be considered in the context of the newly adopted bioregionalisation for aquatic systems, which is based on drainage divisions. The site lies within the Murray-Darling Drainage Division, which extends from Queensland, through New South Wales into Victoria and South Australia. There is no comprehensive inventory of Ramsar wetland types across this bioregion. However, there is strong evidence that the Barmah Forest Ramsar site contains both representative and rare wetland types in a bioregional context.

Barmah Forest is part of the largest complex of tree-dominated floodplain wetlands in southern Australia. Barmah Forest, together with Millewa Forests (on the New South Wales side of the Murray River) is nationally the largest continuous stand of river red gum forest (MDBC 2007). Overall, it is representative of the structure, species composition and ecological character of this wetland type (ANCA 1996). The site also contains other wetland types that are rare within the bioregion, particularly types P (floodplain lake) and Ts (floodplain meadows and reed swamps) (ANCA 1996).

Advice from the Convention (Ramsar Convention 2009) indicates that this criterion should apply (in terms of representativeness) to the best examples of a wetland type in the appropriate bioregion. In this context, Barmah Forest is part of the largest complex of tree-dominated floodplain wetlands in southern Australia. Barmah Forest, together with Millewa Forests (on the New South Wales side of the Murray River) is nationally the largest continuous stand of river red gum forest (MDBC 2007). The size and intact nature of this forested floodplain makes it clearly one of the best representatives of the wetland type Xf in the bioregion.

In addition, this criterion can also be applied with respect to hydrological importance, if for instance the site: "plays a major role in the natural control, amelioration or prevention of flooding" or "is a major natural floodplain system" (Ramsar Convention 2009). The Barmah Forest Ramsar site clearly meets the latter of these options as it forms an extensive area of intact floodplain on the Murray River, and is one of the few such areas with native vegetation in the bioregion.

This criterion was met at the time of listing and continues to be met.

Criterion 2: In the Australian context, it is recommended that this criterion should only be applied with respect to nationally threatened species/communities, listed under the EPBC Act or the International Union for Conservation of Nature (IUCN) Red List. A number of threatened species listed at the national and/or international level have been recorded within the boundary of the Barmah Forest Ramsar site. However, central to the application of this criterion are the words "a wetland" and "supports". Guidance from the Ramsar Convention (Ramsar 2005) in applying the criteria indicates that the wetland must provide habitat for the species concerned. For this reason, terrestrial species such as the small scurf-pea (*Cullen parvum*) and mountain swainson-pea (*Swainsona recta*) have not been considered to contribute to the meeting of this criterion. In addition, there are records from 1937 to 1951 for the Macquarie perch (*Macquaria australasica*) but this species is considered to be locally extinct (King et al. 2007) and so is not considered with respect to this criterion.

There are eight wetland dependent threatened species that have been recorded within the Ramsar site post 1960 (Table 5). However, there is a very low degree of certainty that the site is important for the winged peppercress with only a single record from the site. The site is considered important for supporting seven threatened species:

- Australasian bittern (*Botaurus poiciloptilus*)
- Superb parrot (*Polytelis swainsonii*)
- Murray cod (*Maccullochella peelii*)
- Silver perch (*Bidyanus bidyanus*)
- Trout cod (*Maccullochella macquariensis*)
- Mueller daisy (*Brachyscome muelleroides*)
- Swamp wallaby grass (*Amphibromus fluitans*)

This criterion was met at the time of listing and continues to be met.

Table 5: Threatened species recorded in the Barmah Forest Ramsar site post 1960 (CE = critically endangered; E = endangered; V = vulnerable).

Species	Listing		Records	Strength of evidence
	IUCN	EPBC		
Australasian bittern *Botaurus poiciloptilus*	E	E	Recorded in Boals Deadwood in 1978, 1989, 2000 and 2001 (DSE unpublished) and on numerous occasions between 2003 and 2008 (Birds Australia unpublished).	Despite the cryptic nature of this species there are a number of records from within the site. There is a high degree of certainty that the site is important for this species.
Superb parrot *Polytelis swainsonii*	V	V	Records from within the site at the time of listing and recently (Webster 2007).	Barmah Forest contains the only known breeding site for superb parrot in Victoria (DSE 2003a). There is a high degree of certainty that the site is important for this species.
Murray cod *Maccullochella peelii*	CE	V	Present in streams and creeks within the forest 2002-03 (Jones and Stuart 2004); 2003-05 (Jones 2006) and 2005-06 (King et al. 2007).	There are records for both adults and juvenile from within the Ramsar site (Jones 2006; King et al. 2007). The site is important for this species with a high degree of certainty.
Silver perch *Bidyanus bidyanus*	V		Present in streams and creeks within the forest 2002-03 (Jones and Stuart 2004); 2003-05 (Jones 2006) and 2005-06 (King et al. 2007).	There are records for both adults and juvenile from within the Ramsar site (Jones 2006; King et al. 2007). The site is important for this species with a high degree of certainty.
Trout cod *Maccullochella macquariensis*	E	E	Present in streams and creeks within the forest 2002-03 (Jones and Stuart 2004); 2003-05 (Jones 2006) and 2005-06 (King et al. 2009).	Jones (2006) indicated that this species was relatively common in the streams and creeks within the Ramsar site. The site is important for this species with a high degree of certainty.
Mueller daisy *Brachyscome muelleroides*		V	Recorded in six locations in the forest from 1979 to 1980 and observed in large patches (Lucas 2010).	Multiple records and potentially a significant site for this species that has a restricted distribution. The site is important for this species with a high degree of certainty.
Swamp wallaby-grass *Amphibromus fluitans*		V	Present in the forest in numerous locations (DSE unpublished).	Present in both permanent wetlands and in the understorey of river red gum forest at a large number of locations within the Ramsar site. There is a high degree of certainty that the site is important for this species.
Winged peppercress *Lepidium monoplocoides*		E	Present in the forest in 2001 (DSE unpublished).	Single record only. There is a low degree of certainty that the site is important for this species.

Criterion 3: Guidance from the Ramsar Convention (Ramsar 2008) indicates that the application of this criterion should consider endemism and “hot-spots” of biodiversity. Although there is insufficient information at the bioregional scale to adequately assess this criterion, the site supports more species than the adjacent Gunbower Forest (553 native species of flora and 273 fauna at Barmah compared to 278 native species of flora and 150 native species of fauna at Gunbower; DSE unpublished). In addition, the site is bioregionally significant with respect to moira grass (*Pseudoraphis spinescens*), containing the most extensive expanses (swards) of this species in the Murray-Darling Basin (Jane Roberts, personal communication).

This criterion was met at the time of listing and continues to be met.

Criterion 4: The basic description of this criterion implies a number of common functions/roles that wetlands provide including supporting fauna during migration, providing drought refuge and supporting breeding and moulting in waterfowl. Although not considered to be met in the 1999 assessment, there is clear evidence for the site meeting this criterion, particularly with respect to supporting the breeding of waterbirds and native fish during periods of inundation and acting as a refuge in periods of drought.

Breeding records for colonial nesting waterbirds were presented in DSE (2008) with breeding recoded in 10 years in the 20 year period between 1961 and 1981. In more recent times, colonial waterbird breeding has been recorded in 1983, 1989, 1992, 2001/2 2002/3, 2005/6 and 2010/11 (DSE unpublished, O’Connor and Ward 2003, MDBC 2007, Rick Webster personal communication).

DSE (2008) made a case for the role of the site as a drought refuge, by indicating “reasonable” numbers (defined as counts over 100) of waterbirds within the site during the drought years of 1963-68, 1972-73 and 1982-1983. There are also records of greater than 100 birds within the forest during the prolonged drought of 2000 to 2010 (DSE unpublished, O’Connor and Ward 2003, MDBC 2007).

This criterion was met at the time of listing and continues to be met.

Criterion 5: The application of this criterion to the site is problematic. The site is dominated by wetlands with a high-dense canopy cover provided by the river red gums, so aerial surveys of bird numbers are unfeasible over the majority of the site. Moreover, ground-based surveys have a lower return per unit effort than in more open habitats and so it is difficult to gauge accurately the number of waterbirds present at any one time. This is especially true during times of flood, when waterbird numbers are greatest but site access is most constrained.

There are only two records of more than 20 000 waterbirds from within the site; Chesterfield et al. (1984) published an anecdotal report of 100 000 birds during the 1974 floods and there is a record of 55 000 waterbirds (28 000 adults and 27 000 chicks) from 2005/06 (MDBC 2007). This alone, does not meet the provisions of “regularly supports” as stated under the Ramsar Convention (Text Box 1).

In the opinion of local experts, total counts that include colonial nesting waterbirds as well as waterfowl and other solitary nesters would number greater than 20 000 during floodplain inundation (Keith Ward, GBCMA, personal communication; Richard Loyn, ARI, personal communication). Floods resulting in waterbird breeding on this scale have occurred in the Millewa Forest Group in 1994, 2000/01 and 2005 (Barmah Millewa Forum 2001; O’Connor et al. 2006). However, due to a lack of quantitative data, there is a low level of confidence that this criterion was met at the time of listing (despite claims in earlier documentation) or has been met subsequently.

This criterion is not considered to be met and should be re-assessed when further quantitative data are available.

Criterion 6: The application of this criterion suffers from the same problems as that described for Criterion Five above. The 1999 assessment for this criterion used Victorian populations as a benchmark. However, the correct benchmark is the national or international populations as provided in Wetlands International (2006). The one percent population threshold for Australian white ibis (*Threskiornis molucca*) and straw-necked ibis (*Threskiornis spinicollis*) is 10 000 birds in each case. There are only two records of numbers exceeding this (see above) which is insufficient to meet the requirements of "regularly supports (see Text Box 1).

There is anecdotal evidence that the site may regularly support greater than one percent of the population of Australasian bittern. The south-eastern Australian population estimate for this species is just 2000 and so the site need only regularly support 20 individuals to meet the criterion. Up to five breeding pairs of Australasian bittern have been recorded on a single occasion within the forest (Richard Loyn, ARI, personal communication). Given the cryptic nature of this species and the lack of surveys it is possible that the population within the entire site regularly exceeds 20 individuals, but there is insufficient evidence to state this with any certainty.

This criterion was not met at the time of listing and continues not to be met.

Criterion 7: This criterion is very difficult to apply. A site can potentially qualify based on the proportion of fish species present that are endemic to the site (must be greater than 10 percent) or by having a high degree of biodisparity in the fish community. While 22 species of native fish have been recorded (or are predicted to occur) within the site (which equates to approximately 50 percent of inland fish species in the bioregion), none are endemic to the site. There is no evidence that this site is more diverse with respect to fish than other wetlands in the Murray-Darling Basin and all of the fish present at the site have similar, inland water-life histories.

This criterion was not met at the time of listing and continues not to be met.

Criterion 8: Guidance from the Ramsar Convention indicates that this criterion is about providing a network of sites that maintain fish populations as they migrate during their lifecycle. The site provides migratory routes between habitat in the Murray River, anabranches and floodplains. Native fish of the Murray River main channel utilise anabranch and flood runner channels when they are available (Thoms et al. 2000). Native fish move into off-stream areas on rising flows, and make refuge movements into deeper waters during low flow periods. Many species spawn on the floodplains (Jones 2006). Tagged fish have been recorded moving large distances from the site (up to 300 kilometres upstream and 900 kilometres downstream), which is indicative of pre- and post-spawning behaviour (McKinnon 1997). River red gum forests make a significant contribution to instream nutrient accumulation and productivity through litterfall (Gawne et al. 2007) and provide important shelter in the form of coarse woody debris and shaded water (Jones and Stuart 2007).

This criterion was met at the time of listing and continues to be met.

Criterion 9: The application of this criterion relies on estimates of the total population of non-bird species. As with most sites in Australia, there are few population estimates for non-avian wetland dependent species in Australia. It is possible that Barmah Forest meets this criterion with respect to the swamp yabby (*Cherax* sp. C). This species is widely distributed across the Murray-Darling Basin of New South Wales and Victoria (Raadik and McCormack undated) and can occur in high densities within Barmah Forest (Edney et al. 2002). However, population estimates for the species are not known, nor are there quantitative records from within the Ramsar site. As such, it is unknown what proportion of the population of swamp yabby is supported by the Ramsar site.

This criterion was not met at the time of listing and continues not to be met.

3. Critical Components and Processes

3.1 Identifying critical components and processes

The basis of an ECD is the identification, description and where possible, quantification of the critical components, processes, benefits and services of the site at the time of listing. Wetlands are complex ecological systems and the complete list of physical, chemical and biological components and processes for even the simplest of wetlands would be extensive and difficult to conceptualise. It is not possible, or in fact desirable, to identify and characterise every organism and all the associated abiotic attributes that are affected by, or cause effect to, that organism to describe the ecological character of a system. This would result in volumes of data and theory but bring us no closer to understanding the system and how to best manage it. What is required is to identify the key components, the initial state of the systems and the basic rules that link the key components and cause changes in state (Holland 1998). Thus, we need to identify and characterise the key or critical components, processes, benefits and services that determine the character of the site. These are the aspects of the ecology of the wetland, which, if they were to be significantly altered, may result in a significant change in the system.

DEWHA (2008) suggest the minimum components, processes, benefits and services which should be included in an ECD are those:

- that are important determinants of the sites unique character;
- that are important for supporting the Ramsar or Directory of Important Wetlands Australia criteria under which the site was listed;
- for which change is reasonably likely to occur over short to medium time scales (less than 100 years); and/or
- that will cause significant negative consequences if change occurs.

In additional to critical components and processes are characteristics of the site which are not critical (that is, if they were to change they would not lead directly to a change in character) but are still important in the ecology of the system. These supporting components and processes may act as early warning indicators of a potential change in character and therefore should be considered in management planning for the site.

In identifying critical components and processes, the role that these components and processes play in the provision of critical ecosystem services should also be considered. To this end, the linkages between critical components, processes, benefits and services and the criteria under which the site was listed are illustrated conceptually in Figure 8. Note that cultural services such as recreation and tourism are not shown, but are underpinned by all critical components and processes and all other services. Each of the identified critical components and processes meet the four criteria provided by DEWHA (2008). More complete descriptions for components and process are provided below. The interactions between components and processes, the functions that they perform and the benefits and services that result are described in Section 4.

It should also be noted that the separation of components from processes is not straightforward. For example, aspects of geomorphology such as bathymetry and topography may be considered as components, while other aspects of geomorphology such as sediment transport and erosion could be considered processes. Similarly, the species composition of birds at a site may be considered a component, but feeding and breeding are processes. In the context of this ECD a separation of the ecology of wetlands into components and processes is an artificial boundary and does not add clarity to the description. As such, components and processes are considered together.

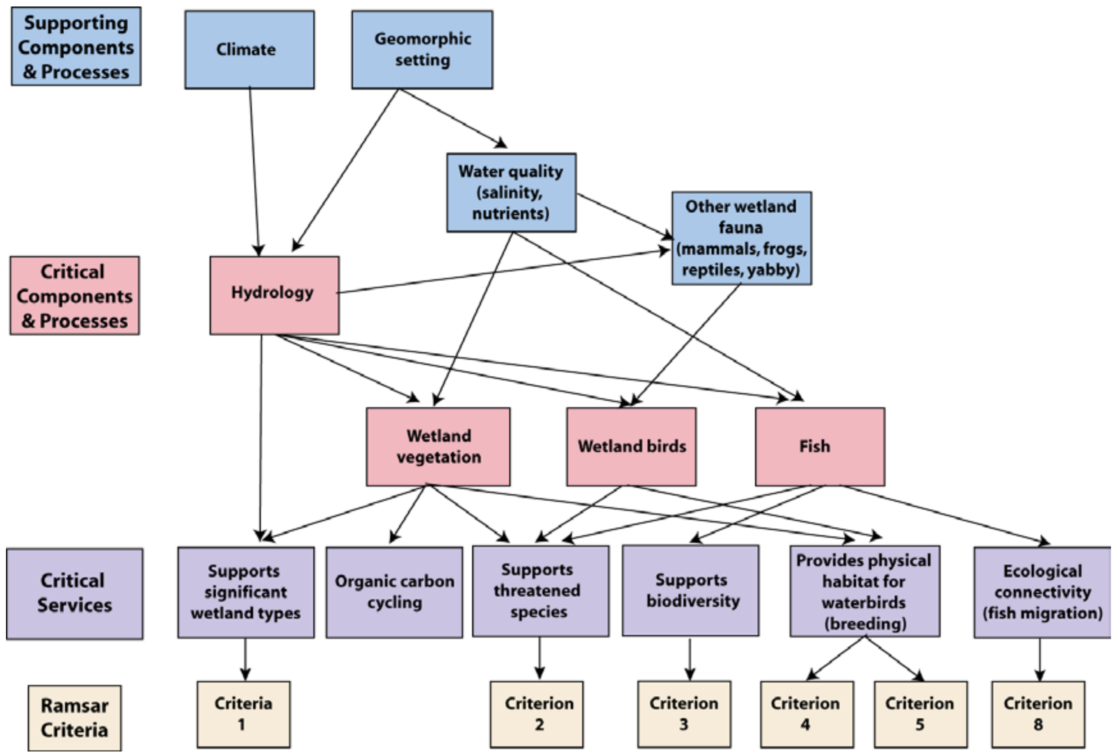

Figure 8: Simple conceptual model showing the key relationships between components and processes, benefits and services and the reasons for the site being listed as a Wetland of International Importance. Note that Criterion 5 is not met due to lack of quantitative evidence (see Section 2.4.2)

The identified critical components and processes for the Barmah Forest Ramsar site are:

- Hydrology;
- Wetland vegetation;
- Wetland birds; and
- Fish.

It should be noted that with respect to threatened species, only those for which the site comprises important habitat were considered to meet all four of the DEWHA (2008) criteria for determining critical components processes and services. In particular, species that have been recorded on a single occasion, or for which the site does not contain core habitat were not considered to be “important determinants of the sites unique character”. The threatened species that are identified as critical to the ecological character of the Barmah Forest Ramsar site are (see Table 5):

- Australasian bittern;
- Superb parrot;
- Murray cod;
- Silver perch;
- Trout cod;
- Mueller daisy; and
- Swamp wallaby grass.

3.2 Supporting components and processes

The components and process that are considered important in supporting the critical components, processes, benefits and services of the Barmah Forest Ramsar site are described briefly below and summarised in Table 6.

Table 6: Summary of supporting components and processes within the Barmah Forest Ramsar site.

Components and processes	Description
Climate	• Located in semi-arid climatic zone with hot dry summers and cold winters. • Rainfall occurs year round, but is higher in winter months. • On average evaporation exceeds rainfall. • Rainfall is highly variable.
Geomorphic setting	• On the floodplain of the Murray River. • Hydrology is controlled by the Barmah Choke, where the Murray River channel narrows considerably below Picnic Point and restricts and forces flows to overtop the bank and spill onto the floodplain. • Highly depositional environment with soils predominantly comprising silty-clays.
Water quality	• Water quality is influenced by river water quality and the length of time between floodplain inundation. • Salinity in the rivers and on the floodplain is generally low and fresh conditions prevail. • During inundation of the floodplain, nutrients are released from litter and organic debris on the forest floor. This is a natural processes, but if the duration of dry periods is long, organic matter can build up and upon re-wetting result in low dissolved oxygen concentrations.
Wetland fauna (other than birds and fish)	• Data deficient. • Three wetland-dependant mammal species. • Nine species of frogs. • Four water-dependent reptile species. • The swamp yabby (*Cherax* sp. C).

3.2.1 Climate

Barmah Forest is situated within the semi-arid/grassland climatic zone of south-eastern Australia (Bureau of Meteorology 2011). The general climatic pattern is hot, dry summers and cold winters. The three aspects of climate that most directly affect wetland ecology are rainfall (both local and in the catchment), temperature and (to a lesser extent in temperate systems) relative humidity. These all fundamentally affect wetland hydrology and the water budget. Note that the climate as described here is relevant to the time of listing; the issue of climate change is addressed under Threats (see Section 7).

Rainfall, on average, occurs year round with highest monthly median rainfall in June (41 millimetres) and lowest in February (15 millimetres). There is some degree of variability in rainfall, as evidenced by the 10^{th} and 90^{th} percentiles, which range from less than 1 millimetre per month to greater than 85 millimetres per month (Figure 9).

Annual average rainfall at Echuca is in the order of 450 millimetres per year. Once again, there is some degree of variability in annual rainfall, ranging from around 200 millimetres up to 900 millimetres in the 60 years of records from this site (Figure 10).

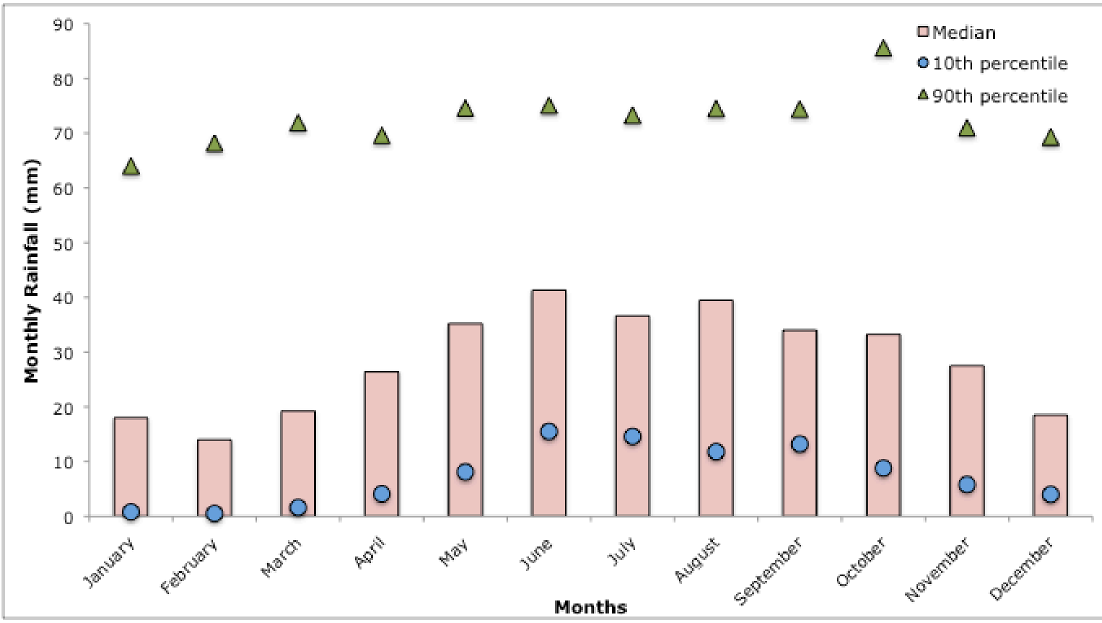

Figure 9: Median, 10th and 90th percentile monthly rainfall at Echuca (1859 – 2010; Bureau of Meteorology).

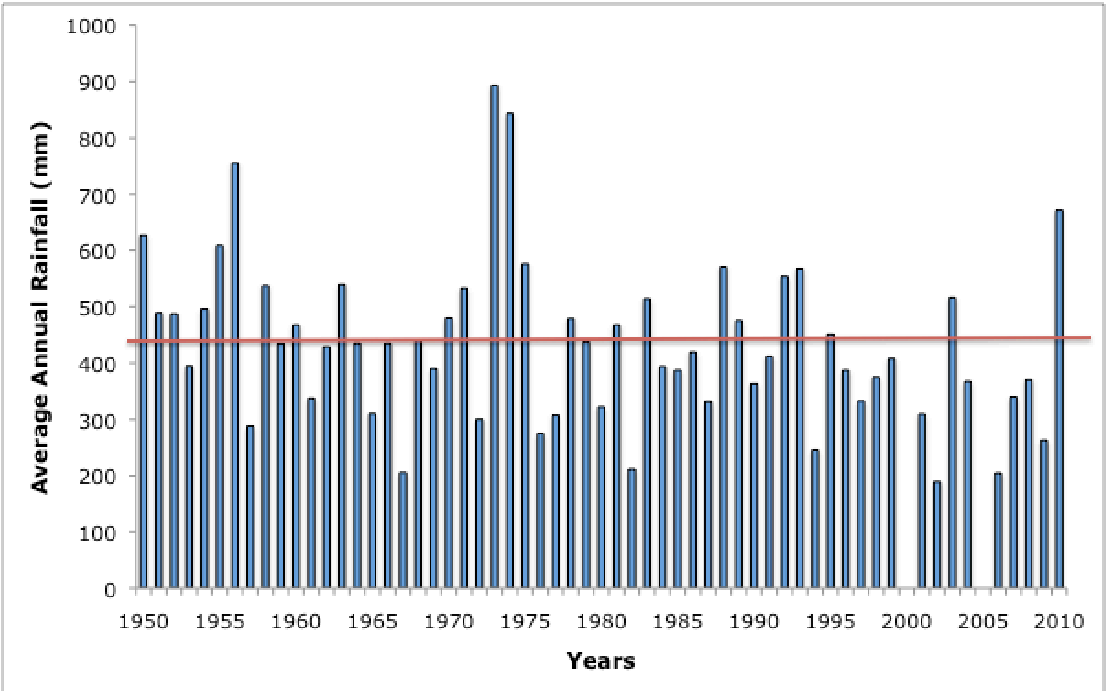

Figure 10: Average annual rainfall at Echuca (1950 – 2010; Bureau of Meteorology). Horizontal line shows long term average.

Temperatures range from cool to warm (Figure 11), with average summer maximum temperatures around 30 degrees Celsius and average minimum temperatures around 15 degrees Celsius. During winter, average maximum temperatures are considerably cooler (15 to 13 degrees Celsius) as are average minimum temperatures (four to five degrees Celsius). Average relative humidity ranges from 50 percent during summer to 90 percent during winter months. Combined with the relatively low winter temperatures, this results in rainfall exceeding evaporation during winter but the reverse situation for the remainder of the year.

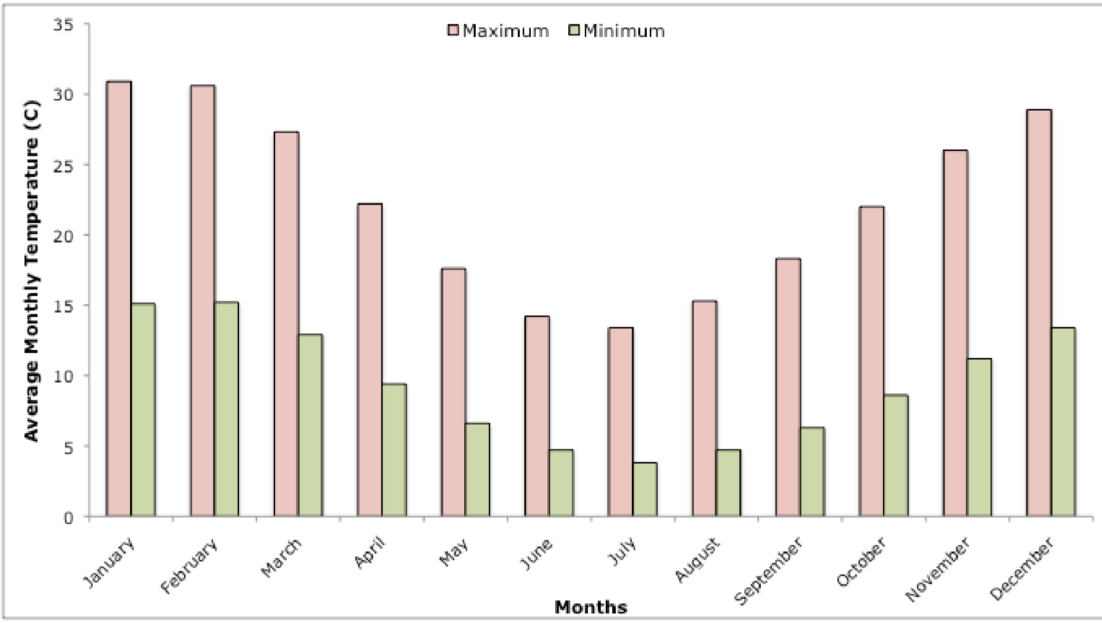

Figure 11: Average monthly maximum and minimum temperatures at Echuca (1881 – 2010; Bureau of Meteorology).

3.2.2 Geomorphic setting

The site is composed of Quaternary alluvial sediments on the floodplain of the Murray River. Quaternary geological and geomorphological processes have fundamentally shaped the character of Barmah Forest. These processes were responsible for the formation of extensive floodplains and ongoing patterns of wetting and drying that allow the maintenance of forests and wetlands in a semi-arid region. The general terrain of the site is extremely flat, with a regional east-west slope of some 0.2 metres per kilometre (Bacon et al. 1993). Alluvial formations are the dominant landscape features. Quaternary alluvial features include modern and ancestral river channels, floodplains, backplains, swamps, lakes and lunettes.

Historically the Murray River followed a course through what is now known as Green Gully, a depression that is approximately 20 kilometres north of Echuca. Following the uplift of the Cadell Fault block between 20 000 and 13 000 years ago, the river underwent various course changes in the area and for much of the past 10 000 years followed the course of the Bullatale Creek (Stone 2006). The current course from Picnic Point in a southerly direction and into the ancestral course of the Goulburn River occurred relatively recently in geological timescales (Stone 2006).

The section where the Murray cut through to the Goulburn channel (approximately the confluence with the Edwards River at Picnic Point to the confluence with Broken Creek at the town of Barmah) is today known as the Barmah Choke because of its limited capacity to carry flows (Rutherfurd 1990). Arguably the most significant geomorphic feature of the site, the Barmah Choke has a capacity of approximately one third of the channel upstream and acts like a partial dam, often forcing floodwater to 'back up' onto the floodplain, thereby inundating the forests and resulting in the triangular shape of the floodplain which supports the Barmah Forest (MDBC 2007).

Sediment across the floodplain is of alluvial origin and comprises fine grained silts, clays and sand, with up to 15% organic material in the upper soil profiles (Thoms 1995; Figure 12). The site is a highly depositional environment with high rates of sedimentation (Thoms 1995). Sedimentation is typically higher in summer than winter due to fluvial processes upstream.

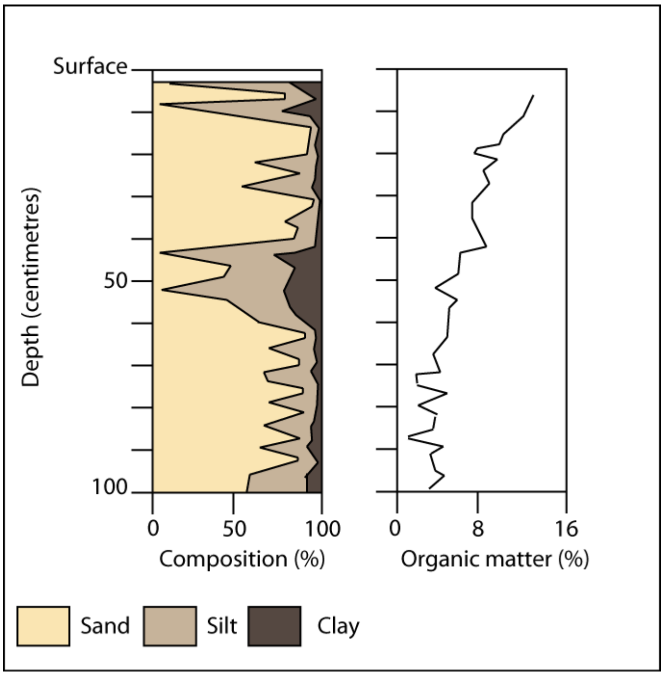

Figure 12: The textural character of soils on the Barmah Forest floodplain (adapted from Thoms 1995).

3.2.3 Water quality

Water quality within the Ramsar site is influenced both by the quality of water in river sources as well as floodplain interactions that occur during cycles of wetting and drying. Water quality in the main channel of the Murray River is generally fresh with salinity below 400 micro Siemens per centimetre from 1992 to 2008 (data from Victorian Water Resources Data Warehouse). Turbidity is moderate with a median value of 9.7 NTU and a ninetieth percentile of 27 NTU downstream of Yarrawonga Weir (Ecos Consulting 2002).

Water quality in permanent and frequently flooded wetlands on the floodplain can vary considerably between sites and over time, and is greatly influenced by floodplain inundation. Results of monitoring of Hut Lake and War Plain over a spring inundation event in 1993, illustrate the variability in water quality in response to inundation and drawdown (Figure 13). Turbidity ranged from 20 NTU to over 150 NTU, dropping following inundation and then rising as water levels receded. A boom in productivity (as indicated by chlorophyll-a concentrations and dissolved organic carbon) occurred in the months following inundation, as nutrients and carbon were released from floodplain inundation and taken up by phytoplankton. Salinity remained fresh throughout but varied between 80 and 150 micro Siemens per centimetre.

The flooding of ephemeral wetlands and floodplain surfaces may trigger blackwater events (Howitt et al. 2005). These are defined as flood events with elevated levels of dissolved organic carbon, sufficient to colour the water a deep brown. They are associated with reduced levels of dissolved oxygen in the water column both on the floodplain and in receiving channels. Wetlands act as micro organisms that consume litter on the floodplain surface upon wetting, using oxygen from the water column in the process. These events are natural and are considered important in maintaining productivity of river and floodplain environments (Junk et al. 1989). However, if there is a long period between flood events, organic matter builds up on the floodplain and dissolved oxygen concentrations can fall below the tolerances of fish and other aquatic fauna (Howitt et al. 2005).

There are recent examples of blackwater events from the Ramsar site, most notably in the floods of 2010, which inundated large areas of floodplain that had been dry for a decade. Water discharging from the forest was very low in dissolved oxygen (less than one milligram per litre) causing decreased oxygen concentrations in the Edwards and Murray Rivers (MDBA unpublished).

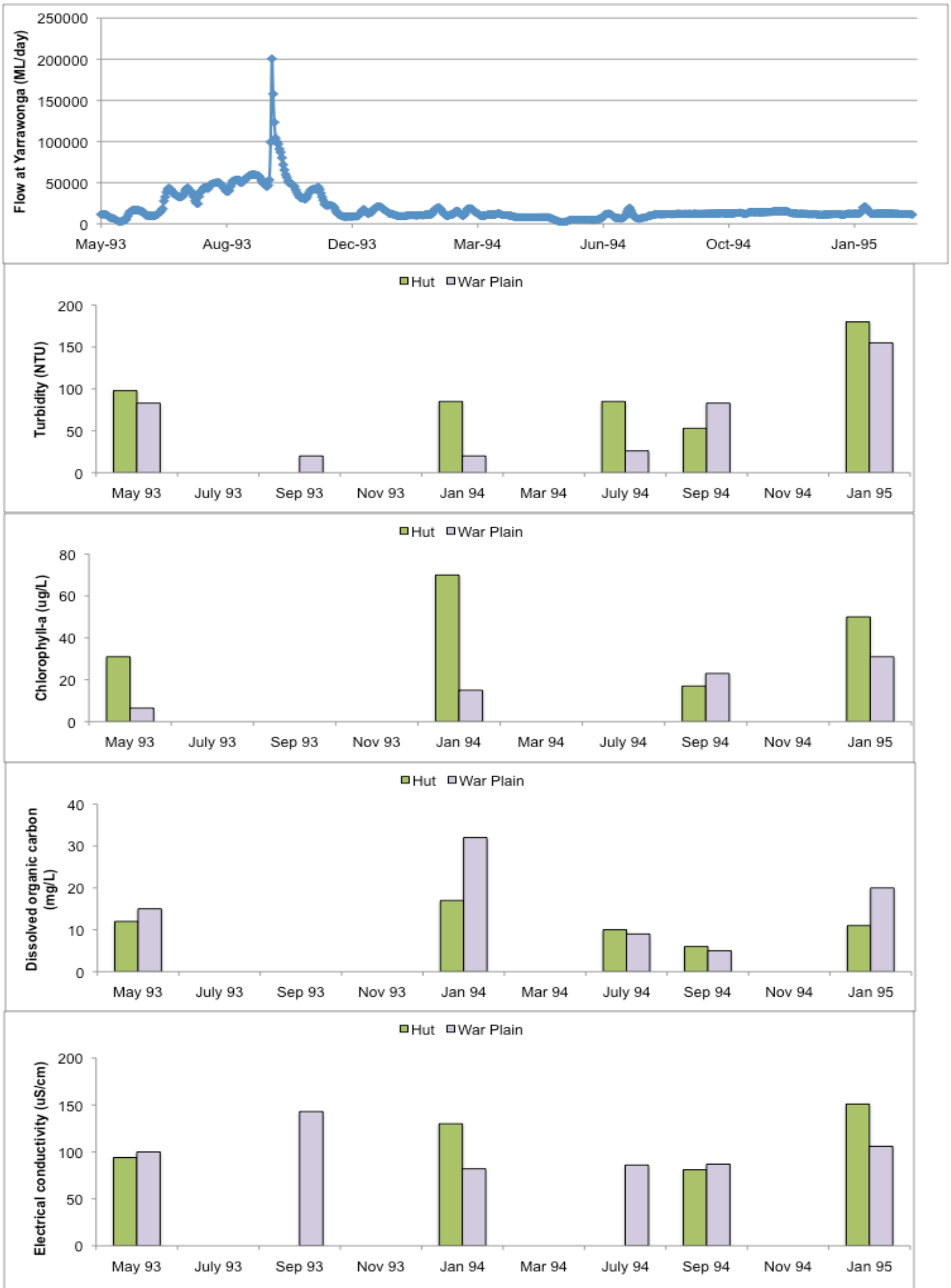

Figure 13: Water quality in Hut Lake and War Plain within the Barmah Forest Ramsar site May 1993 to January 1995 (data from the Victorian Water Resources Data Warehouse).

3.2.4 Other wetland fauna

There are records of three species of wetland-dependent mammals, four reptiles and nine frogs from within the Barmah Forest Ramsar site (Appendix C). The only quantitative data is for frogs, collected from 2000 to 2005/6 (Ward 2001; Ward 2006; Table 7). Frog breeding attempts were observed in well-vegetated wetlands that were actively flooding (rather than ponded sites) and were correlated with abundance of invertebrates and small fish.

Table 7: Summary of the results of frog monitoring from 2000 to 2006 (data from Ward 2001; 2002; 2003; 2004; 2006).

Year	Water regime	Species richness	Total abundance	Abundance per unit effort*
2000/1	Large natural flood.	9	4000	19.6
2001/2	Dry^ with some low level flooding.	5	1600	5.5
2002/3	Dry^ with some low level flooding.	6	2500	7.1
2003/4	Dry^ with some low level flooding.	7	6500	22
2005/6	Dry^ with some winter-spring flooding and environmental watering in spring-summer.	3	360	3.3

* As the number of sites and sampling events varied from year to year, the abundance per unit effort is the total number divided by the number of samples collected.
^ The term 'dry' refers to a year in which there was below average rainfall recorded for most months.

These data were collected two decades after the site was listed as a Ramsar site and it is not known whether the data represent conditions at the time of listing. However, it is the only information available and goes some way to describing the relationship between frog abundance (and species richness) and flooding of the forest. In addition to their inherent biodiversity values, frogs are important in terms of the ecological character of the site, given the role they play in the food chain supporting the identified critical components of fish and wetland birds.

The Barmah Forest Ramsar site also supports the swamp yabby (*Cherax* sp. C) a burrowing crayfish, that although widely distributed and locally abundant is poorly understood (Edney et al. 2002; Raadik and McCormack undated). There are no quantitative data for this species from the site or across its range but it is possible that the Barmah Forest Ramsar site supports greater than one percent of the population of this species (Keith Ward, GBCMA, personal communication).

3.3 Critical components and processes

The attributes and characteristics of each of the identified critical components and processes of the Barmah Forest Ramsar site are described below. Wherever possible, quantitative information is included. However, as with many ECDs, there are significant knowledge gaps (see Section 8). A summary of the critical components and processes within the Barmah Forest Ramsar site is provided in Table 8.

Table 8: Summary of critical components and processes within the Barmah Forest Ramsar site.

Component / process	Description
Hydrology	• Inundation of the site is driven largely by flows within the Murray River. • The hydrology of the site is highly regulated and seasonality of low and moderate flow is determined largely by irrigation needs. • Large scale floods that inundate the forest are generally the result of catchment scale rainfall events. • Groundwater may be important for maintaining tree health but remains a knowledge gap.
Wetland vegetation	• The two critical wetland vegetation categories are river red gum forests and floodplain marshes. • Approximately 85 percent of the site is covered in inundation dependent forest and woodland (river red gum and black box), which has a combined extent of over 24 000 hectares. • River red gum forest is the dominant vegetation community, comprising 75 percent of the site. • Floodplain marshes include moira grass (*Pseudoraphis spinescens*) plains (regionally significant), giant rush (*Juncus ingens*) beds, common reed (*Phragmites australis*) beds, moist grasslands, herblands and semi-permanent marshes. • Supports two nationally threatened wetland flora species: Mueller daisy (*Brachyscome muelleroides*) and swamp wallaby-grass (*Amphibromus fluitans*).
Fish	• Data deficient. • Seventeen native species of fish have been recorded from within the site. • Results from surveys indicate that abundance varies considerably and that invasive species generally comprise 10 to 30 percent of the total abundance and up to 70 percent of biomass. • Supports three native threatened fish species: silver perch (*Bidyanus bidyanus*), Murray cod (*Maccullochella peelii*) and trout cod (*Maccullochella macquariensis*).
Waterbirds	• Sixty species of wetland birds have been recorded from the site. This includes seven species listed under international migratory agreements and two threatened species: superb parrot (*Polytelis swainsonii*) and Australasian bittern (*Botaurus poiciloptilus*). • Over 100 000 birds have been recorded at the site during times of flood. • The site is significant for supporting breeding of colonial nesting waterbirds and contains a significant breeding population of the superb parrot.

3.3.1 Hydrology

The hydrology of the Barmah Forest Ramsar site is defined by flow in the Murray River. The hydrology of the Murray River and its tributaries was managed for water supply, flood mitigation, navigation and hydroelectricity production long before the Barmah Forest Ramsar site was designated as a Wetland of International Importance in 1982. River regulation began almost a century ago with a large number of dams, locks and weirs constructed between 1915 and 1974. Regulators were constructed on several streams within the Ramsar site in the 1930s and 1940s where they leave the Murray River (DSE 2008) and hydrology within the site has been regulated and managed since this time. The character of the site at the time of listing was strongly influenced by river regulation and the baseline for the hydrology of the site is this regulated regime. Hydrology is considered in terms of surface water and groundwater.

<u>Surface water</u>

Surface water inflows into the Barmah Forest Ramsar site are controlled by releases from Yarrawonga Weir, which is located approximately 200 kilometres upstream of the site. There are two types of surface water flows (MDBC 2005):

- In-channel flow, which features inundation of effluent streams, channels and floodplain depressions connected at pool level; and
- Overbank flow as water moves laterally from channels and spreads across the broader floodplain.

In-channel flow is controlled by the large number of water regulating structures within the forest. Their operation, to a large extent determines inundation extent, frequency and duration. The original procedures for regulator operation, developed in the 1950s and 1960s, were aimed at preventing loss of regulated flow into the forest, which can occur at low river flows of 6000 megalitres per day (Maunsell, 1992). Regulators are generally closed to exclude floodwaters from the forest at flows that do not exceed channel capacity (10 400 megalitres a day) during the irrigation season (August to May). This is so that the maximum volume of water can be delivered downstream for consumptive use. It also prevents unseasonal flooding in summer and autumn (DSE 2008).

When flows in the Murray River downstream of Yarrawonga exceed the capacity of the Barmah Choke (10 400 megalitres a day), the regulators are progressively opened to allow water to enter the forest. At flows between 10 400 and 16 000 megalitres a day, channels, swamps and other low lying areas, including about 16 percent of the forest, are inundated (Water Technology 2009). Larger floods of over 35 000 to 45 000 megalitres a day are required to inundate about 60 percent of the forest and it is only at flows of greater than 60 000 megalitres a day that inundation of most of the river red gum forest and substantial proportions of the black box communities occurs (Water Technology 2009).

Operation of the regulators influences the movement of water through the forest and given the number of regulators, there are many possible inundation scenarios depending on which ones are opened and closed and at what time. The results of modelled inundation scenarios (30 day steady inflows and all Victorian regulators open) provide an indication of flood extents in Barmah Forest under a number of flow thresholds (Figure 14). A comparison with inundation under a similar 30 day inundation scenario, but with all the New South Wales regulators open (Figure 15) highlights the significant effect of regulator operation. By opening Victorian regulators a large area in the centre of the Ramsar site is inundated at 13 000 megalitres a day, as opposed to 25 000 megalitres a day when the Victorian regulators are closed and those in New South Wales are open. As flows increase, the ability to control water movement diminishes. This is illustrated by the two modelled scenarios (Figures 14 and 15) which show very little difference in inundation above 35 000 megalitres a day.

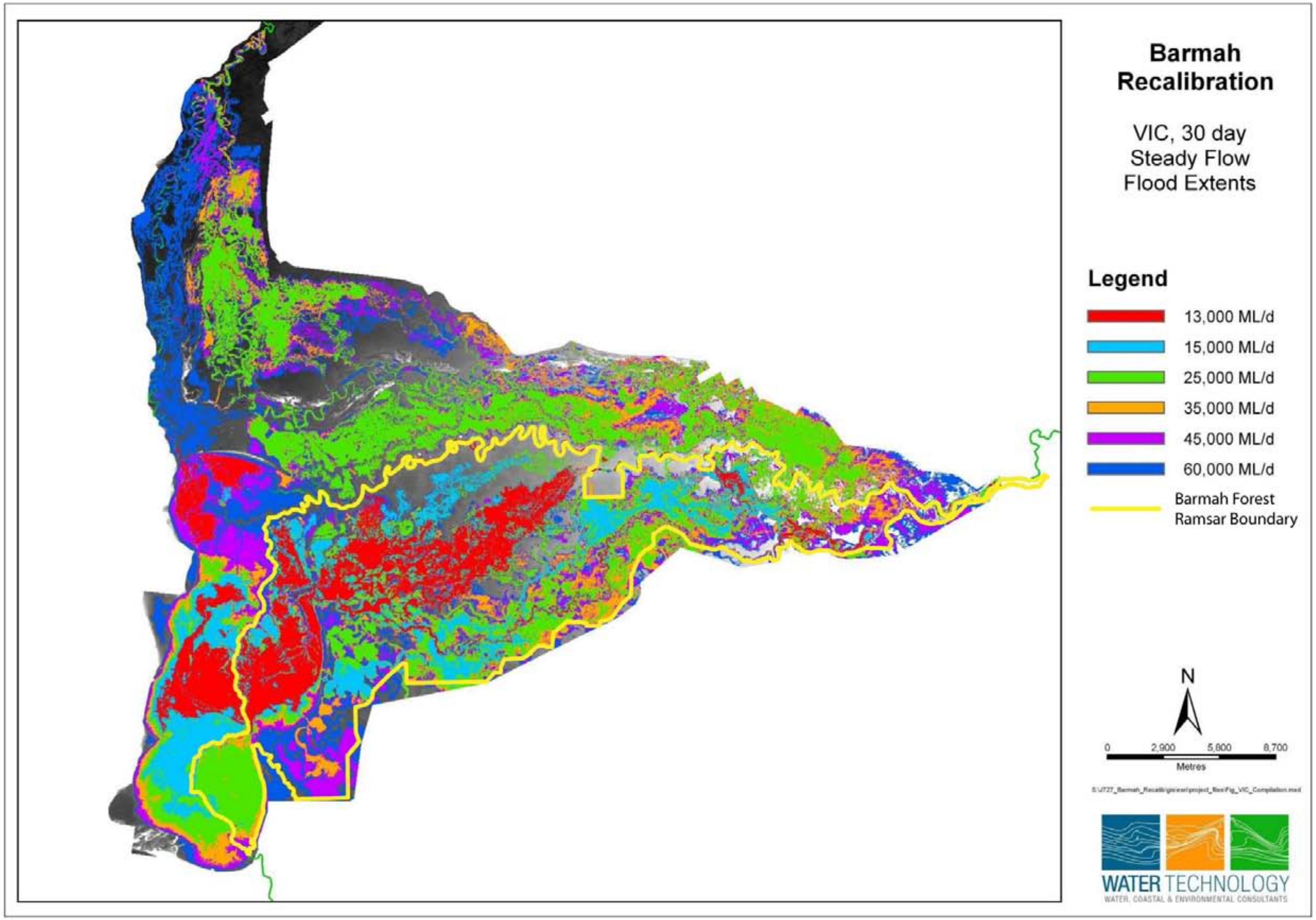

Figure 14: Inundation of Barmah Forest and Millewa Forest with Victorian regulators open (Water Technology 2009).

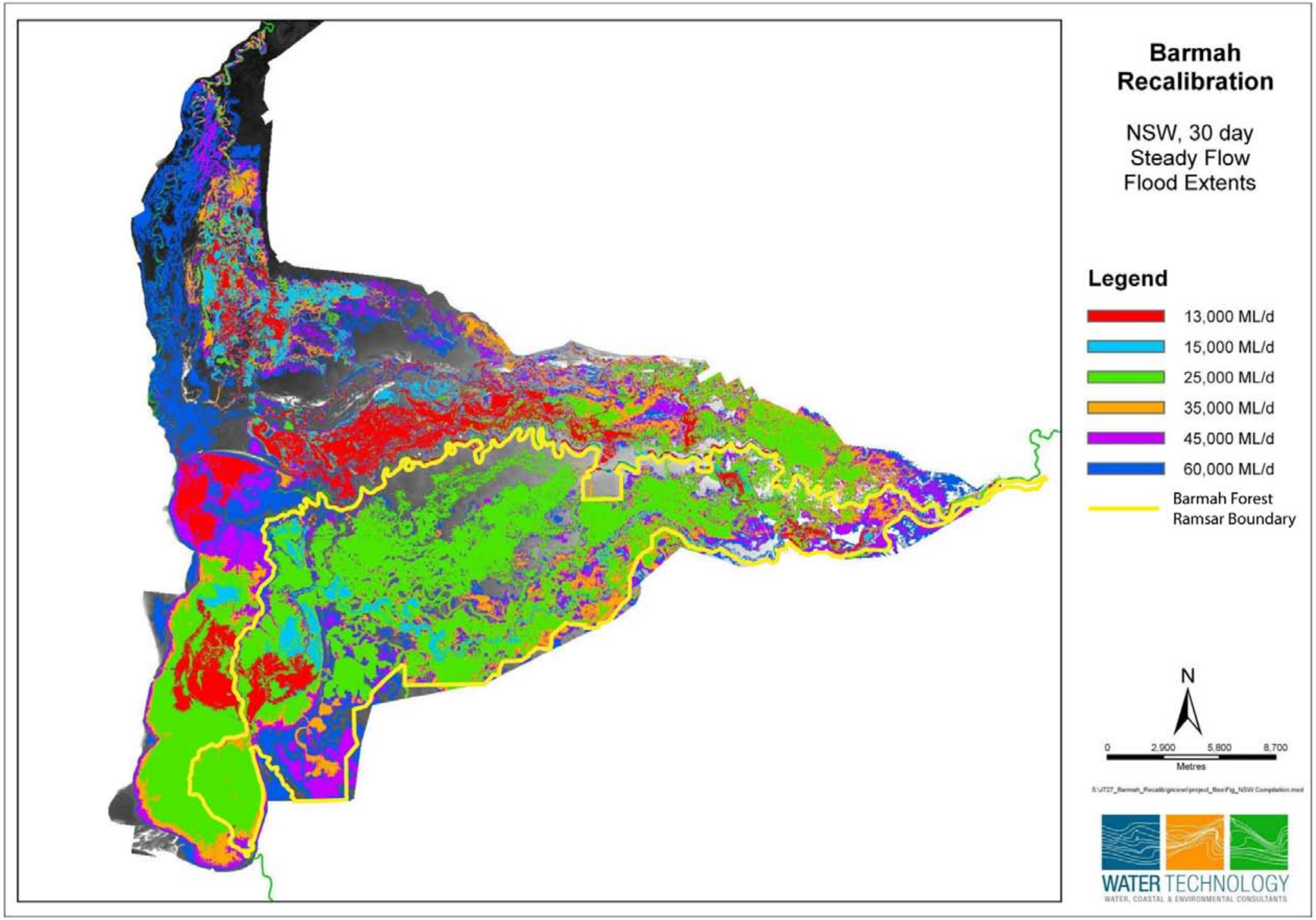

Figure 15: Inundation of Barmah Forest and Millewa Forest with NSW regulators open (Water Technology 2009).

Large flow events vary in frequency and duration and are largely driven by large rainfall events. Significant flood events occurred in 1964, 1969, 1973, 1974, 1975, 1981, 1991, 1992, 1993, 1996, 2000 and 2010 (Figure 16). Characterisation of the flow conditions at the time of listing is problematic as there has been a level of development both before and after listing and a highly variable natural flow regime which is difficult to describe adequately over short periods of time. Data are available for a model of Murray River flow from 1895 to 1984 based on water resource conditions in 1984 (Leitch 1989). This has been considered as broadly indicative of the time of listing, given that there is a 90 year record and that the model is based on conditions just two years post listing[1]. Average frequency and duration for significant flood thresholds in the forest based on modelled monthly flow from 1895 to 1984, are provided in Table 9.

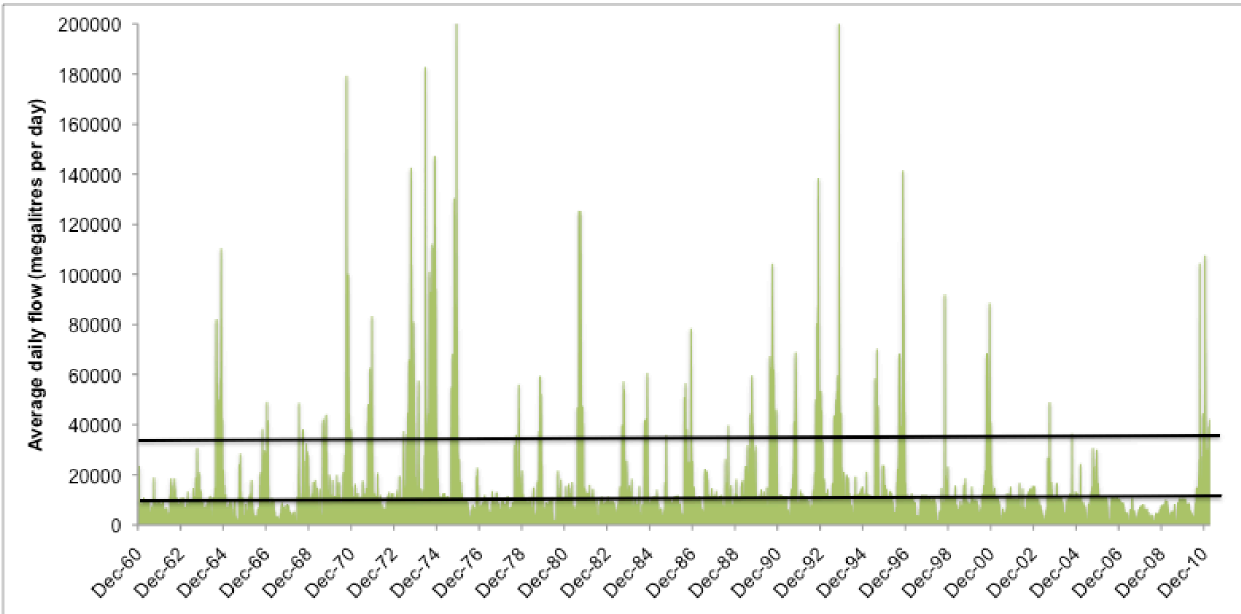

Figure 16: Average daily flow (megalitres per day) in the Murray River downstream of Yarrawonga from 1960 to 2011 (actual flow; data from the Victorian Water Resources Data Waterhouse). Lines show commence to flow level (10 400 megalitres per day) and threshold for broad scale inundation (35 000 megalitres per day).

Table 9: Modelled flood flow recurrence intervals at the Murray River downstream of Yarrawonga for specific flow events in Barmah Forest (adapted from Leitch 1989; extent of inundation from Water Technology 2009).

Flow (megalitres per day)	Average frequency (percent)	Average duration (months)	Longest dry period (months)	Inundation extent
10 400	78	3.6	45	All low lying areas and channels, floodplain marshes.
16 000[2]	70	3	45	Moira grass plains.
35 000	57	2.1	116	Sixty percent of river red gum forest and 30 percent of river red gum woodland.
60 000	25	0.7	201	Virtually all river red gum forest, a large proportion of river red gum woodland and some inundation of black box woodland.

[1] Note that the most recent major water storage relevant to the site at the time of listing was Dartmouth Dam, which was completed in 1979. The modelled data selected includes the effects of this structure which had been in place for a short time prior to the Ramsar site listing in 1982.
[2] Commence to fill threshold, up to 25 000 ML/day may be required to inundate to optimum depth.

Average daily flows from around the time of listing illustrate the typical seasonality (Figure 17). The lowest flows are recorded between May and August each year. This coincides with the period when water demand from downstream users (irrigators and urban water supplies) is lowest. There is a consistent flow of water between September and January/February of each year in line with irrigation demands.

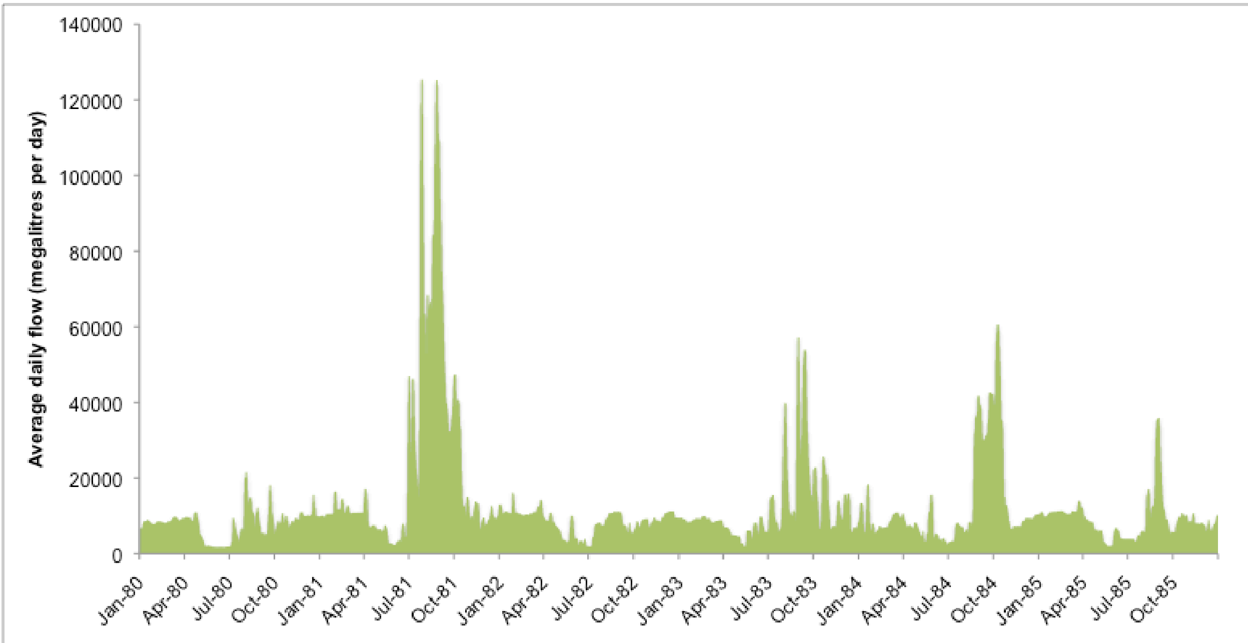

Figure 17 Average daily flow (megalitres per day) in the Murray River downstream of Yarrawonga from 1980 to 1985 (actual flow; data from the Victorian Water Resources Data Waterhouse).

<u>Groundwater</u>
The Barmah Forest Ramsar site is underlain by the following hydrogeological units (SKM unpublished in DSE 2008; Figure 18):

1. The Coonambidgal Formation, which dominates the surface geology and consists of relative shallow deposits of clay, sand and sandy clay. The Coonambidgal Formation formed from the deposits of recent streams and postdates the underlying Shepparton Formation.

2. The Shepparton Formation, which is between 80 and 120 metres thick. It consists of thin, irregular and discontinuous sand and gravel beds that vary from isolated ribbon-like bodies to semi-continuous sheets. The Upper Shepparton Formation is composed of low permeability clay and clayey silts with lenses of high permeability sands. The Lower Shepparton Formation sediments have sand layers of high permeability and may have good hydraulic connections with the underlying Calivil Formation.

3. Unconsolidated sediments around 120 metres below the surface from the Renmark Group (basal aquifer system in the Murray basin) and Calivil Formation (the Deep Lead aquifer system).

4. Palaeozoic age bedrock greater than 180 metres below the surface with transmissivity and yield an order of magnitude smaller than overlying unconsolidated aquifer systems.

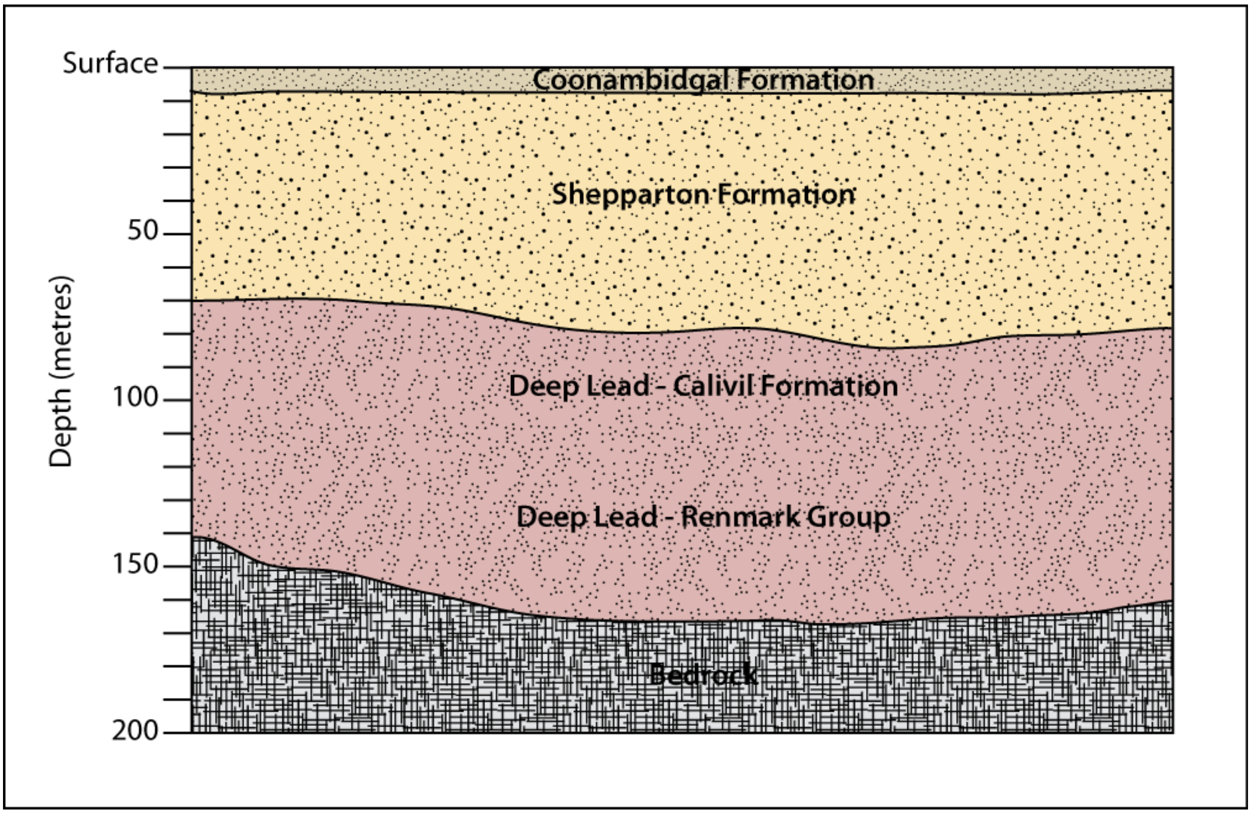

Figure 18: Cross section of hydrogeology in the region (adapted from Goulburn Murray Water 2006).

Groundwater is believed to be of secondary in importance to surface flows (MDBC 2007) with groundwater tables around the time of listing that were 11 to 14 metres below the surface in most areas (Rural Water Commission 1988 in DSE 2008). Groundwater levels more than ten metres below the surface are unlikely to support river red gums (DSE 2008). However, the perched water tables along the streams and rivers are closer to the surface and may be important for river red gum health.

Surface-groundwater connectivity along the Murray River is highly variable with both losing and gaining river reaches. Variation from reach to reach is likely to be due to a combination of river regulation, floodplain groundwater flow processes and the influence of irrigation development. However the direction of water movement is typically from the river to the groundwater aquifer.

3.3.2 Wetland vegetation

There are 553 native flora species that have been recorded within the Ramsar site. This includes a range of aquatic, floodplain and terrestrial species and two nationally threatened species:

- Mueller daisy (*Brachyscome muelleroides*); and
- Swamp wallaby-grass (*Amphibromus fluitans*).

There are two broad vegetation types within the site that are considered critical to the ecological character of the Barmah Forest Ramsar site (Figure 19):

- River red gum forests and woodlands (EVC group Riverine Grassy Woodlands or Forests, Table 11), which comprise the majority of the site and occupy the large areas of floodplain; and
- Floodplain marshes (EVC group Wetlands), which comprise a number of different communities that occur in low lying areas of the site and are subjected to more frequent inundation.

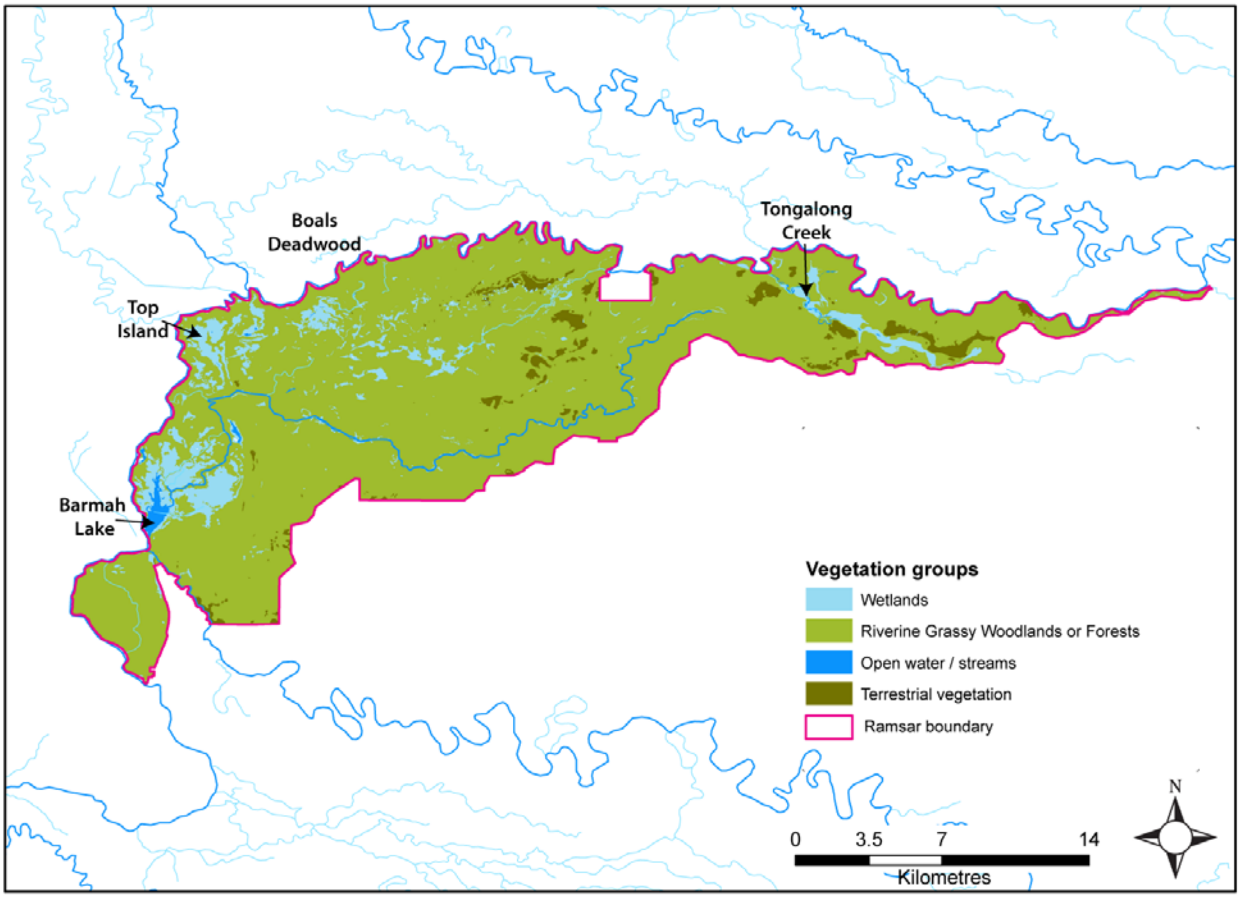

Figure 19: Broad vegetation groups within the Barmah-Millewa Forest (data supplied by DSE).

River red gum forests and woodlands
River red gum dominated forest and woodland communities are the characteristic feature of the Ramsar site. River red gum is the canopy dominant in all vegetation associations in which it occurs, and in many areas forms monospecific communities. Community structure and understorey composition vary with flood regime, which in turn is a product of geomorphic setting. The driest portions of the floodplain support black box woodland which grades into a river red gum woodland at its wetter end, with a sparse, shrubby understorey and groundcover of grasses and herbs with increasing soil moisture. Better-watered locations support a taller river red gum forest with an understorey of moisture-loving grasses, herbs and sedges (Roberts and Marston 2000).

The forest and woodland communities have been classified and described according to a number of different systems. Close to the time of listing, the forest and woodland extent and dominant understorey species were mapped and described (Chesterfield et al. 1984; Table 10). This estimated the total river red gum forest and woodland extent as approximately 24 000 hectares, with river red gum forest communities comprising around 75 percent of the total Ramsar site. There is a small amount (just over 100 hectares) of black box (*Eucalyptus largiflorens*) woodland at higher elevations and a small area of non-floodplain forest dominated by yellow box (*Eucalyptus melliodora*) and/or grey box (*Eucalyptus microcarpa*) (Bren and Gibbs 1986).

Table 10: Extent of river red gum forests and woodlands within the Barmah Forest Ramsar site (Chesterfield et al. 1984 as interpreted by MDBC 2005).

Structural type	Height (metres)	Dominant understorey species	Percentage of the site	Total area (hectares)
River red gum forest	33	Moira grass (*Pseudoraphis spinescens*).	13.8	21 461
	31	Disturbed areas of wallaby grasses now dominated by numerous introductions.	1.9	
	28	Terete culm-sedge (*Carex Tereticaulis*) in association with swamp wallaby grass (Amphibromus spp.) and Warrego summer grass (*Setaria jubiflora*).	21.7	
	28	Terete culm-sedge.	10.8	
	28	Common spike-rush (*Eleocharis acuta*) in association and mosaic with swamp wallaby grass and Warrego summer grass.	5.7	
	28	Warrego summer grass.	19.4	
	25	Wallaby grasses.	2.0	
River red gum woodland	22	Swamp wallaby and brown-back wallaby grass (*Austrodanthonia duttoniana*) in association and mosaic with common spike-rush.	9.6	2736
Black box woodland	18	Wallaby grasses, saloop (*Einadia hastate*), prickly salwort (*Salsola tragus*) and numerous introductions.	0.4	114

Current classification and mapping of vegetation communities in Victoria is by “Ecological Vegetation Classes” (EVCs). The EVCs that correlate with river red gum forests and woodlands are within the group “Riverine Grassy Woodlands or Forests” and there are a number of different classes that occur within the Ramsar site (Table 11). According to this mapping and classification there are 25 900 hectares of riverine forest and woodland across the site, with river red gum forest comprising 73 percent of the Ramsar site.

Table 11: Riverine Grassy Woodlands or Forests EVCs within the Barmah Forest Ramsar site (data supplied by DSE).

EVC	Description	Extent (hectares)
Riverine Swamp Forest	Open eucalypt (river red gum) forest to 25 metres tall with understorey dominated by obligate wetland species (or opportunistic annuals during sustained dry periods) and ranging from closed sedgeland or herbland to grassy-herbaceous or extremely sparse and with cover primarily leaf-litter, black water or exposed alluvium. Occupies low-lying areas subject to reasonably regular flooding, typically flood-prone lower river terraces and low-lying areas adjacent to floodways through or within riverine forest.	3584
Sedgy Riverine Forest	Eucalypt (river red gum) forest to 25 metres tall with understorey dominated by larger sedges. Understorey composition indicative of at least occasional shallow flooding and a tolerance of gaps between floods of several years. Typically on heavy soils which can become wet in winter.	5718
Grassy Riverine Forest	River red gum forest to 25 metres tall with a groundlayer dominated by graminoids. Occasional tall shrubs present. Occurs on the floodplain of major rivers, in a slightly elevated position where floods are infrequent, on deposited silts and sands, forming fertile alluvial soils.	1463
Forest complexes	Mixed forest communities (i.e. combinations of Riverine Swamp Forest, Sedgy Riverine Forest and Grassy Riverine Forest)	8022
Riverine Swampy	Eucalypt (river red gum and/or black box) woodland to 15 metres tall above a grassy to sedgy-herbaceous groundlayer, with species	854

EVC	Description	Extent (hectares)
Woodland	indicative of periodic waterlogging. Occupies areas subject to shallow inundation only from higher-level flooding on riverine flood plain. Soils are typically heavy, cracking mottled grey-brown clays/clay-loams	
Riverine Grassy Woodland	River red gum woodland to 20 metres tall with a groundlayer dominated by graminoids and sometimes lightly shrubby or with chenopod shrubs. Occurs on the floodplain of major rivers, in a slightly elevated position where floods are rare, on deposited silts and sands, forming fertile alluvial soils.	2442
Floodplain Riparian Woodland	An open eucalypt (river red gum with occasional yellow box) woodland or open forest to 20 metres tall over a medium to tall shrub layer with a ground layer consisting of amphibious and aquatic herbs and sedges. Occurs along the banks and floodplains of the larger meandering rivers and major creeks. Elevation and rainfall are relatively low and soils are fertile alluviums subject to periodic flooding and inundation.	370
Riverine woodland/forest complexes and mosaics	A mixture of the above together with areas of mixed forest and floodplain marsh communities.	3459

Condition of the forest communities at the time of listing is a knowledge gap. There is evidence that the forest was in less than optimum condition prior to the time of listing (Bren 1988; Leitch 1989). Condition assessments based on conditions in 2003 (some two decades after the site was listed as a Wetland of International Importance) indicated that 52 percent of the forest was in good condition and 43 percent was in moderate condition (Cunningham et al. 2009; Figure 20). Recent flooding history just prior to listing (major flood in 1981) and relative to the 2003 condition assessment (flood in 2000/01) indicate that the condition of forests at the time of listing is likely to have been equal to or better than that in 2003 (J. Roberts, floodplain vegetation expert, personal communication, May 2011).

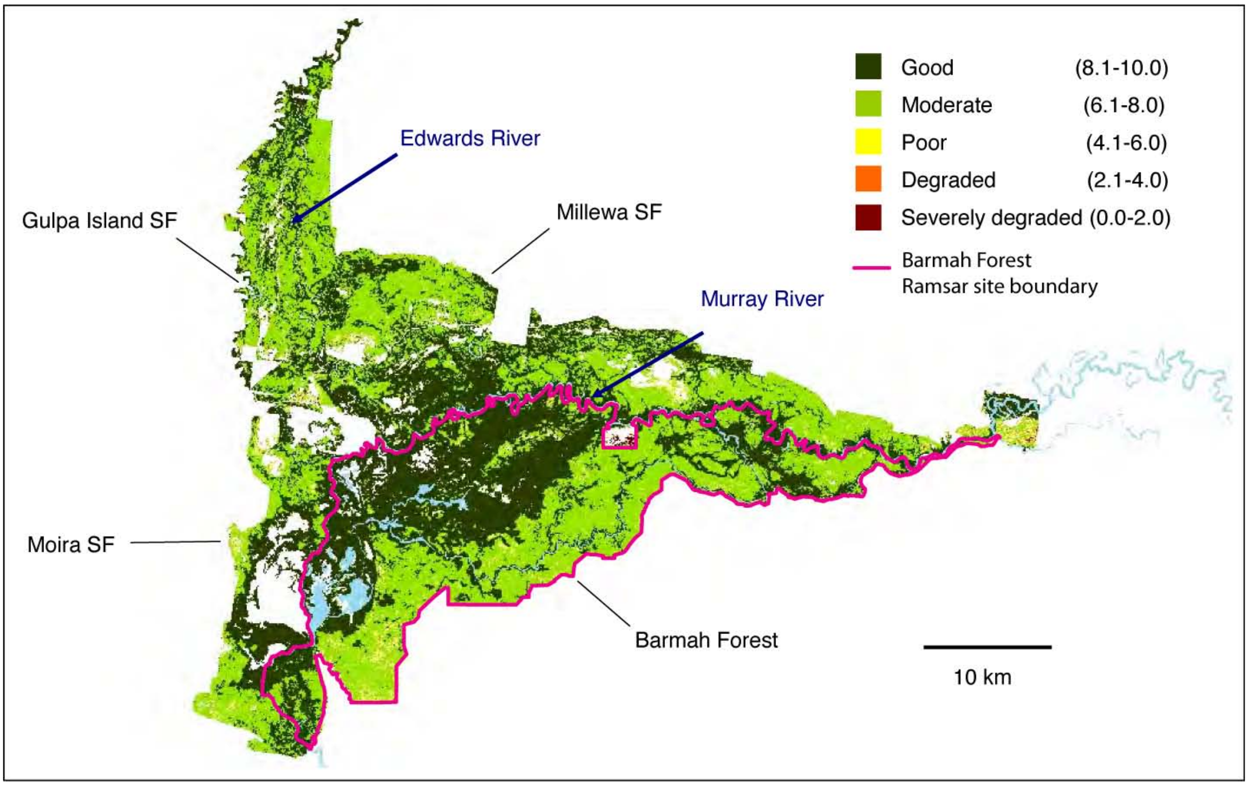

Figure 20: Canopy condition in the Barmah Forest in 2003 (adapted from Cunningham et al. 2009).

In addition to extent and condition of the trees in the site, forest structure and structural diversity is an important characteristic (Horner et al. 2010). This includes aspects such as tree density, age classes, size ranges and the presence of features such as boughs and tree hollows. The State-wide Forest Resource Inventory has mapped extents of age classes of trees within the Ramsar site benchmarked to 2002. This indicates that approximately 65 percent of trees could be classified as mature (60 – 150 years old), 28 percent as mixed age with smaller amounts of regrowth and senescent and late mature trees (DSE 2007; Figure 21).

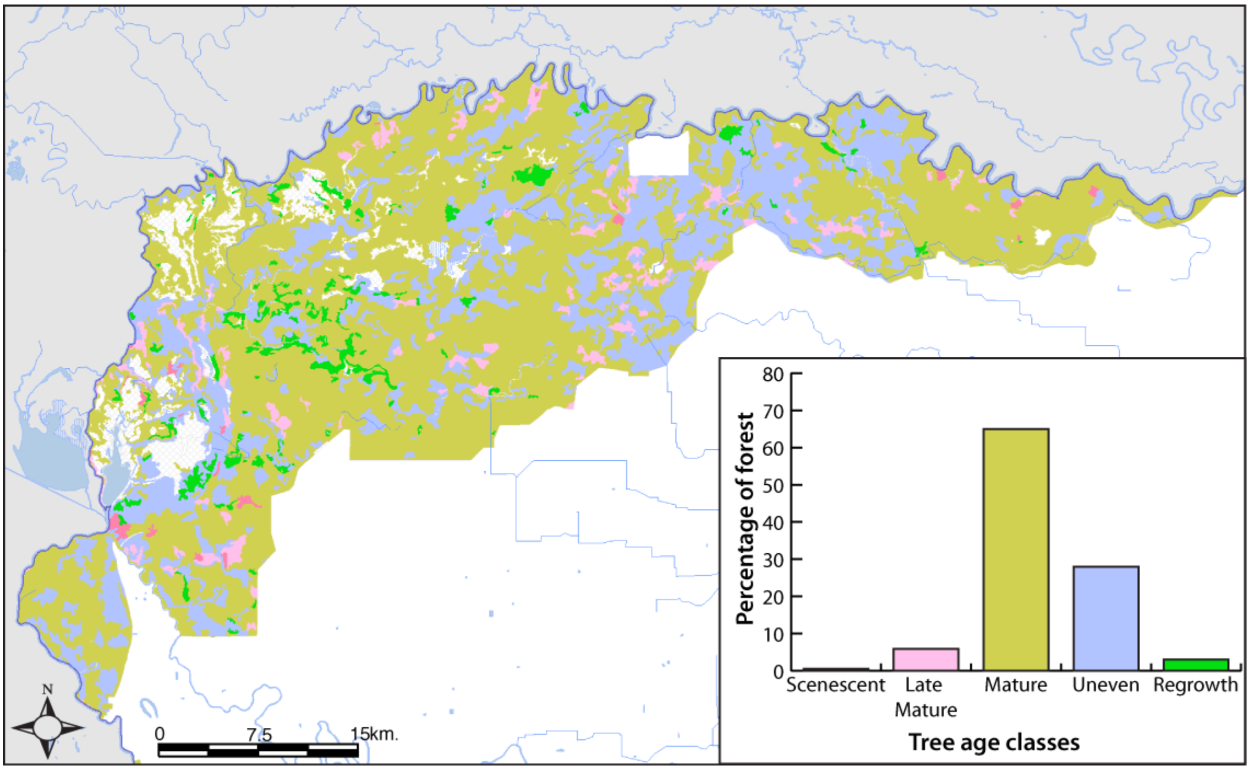

Figure 21: Tree age classes in the Barmah Forest Ramsar site in 2002 (data provided by DSE).

The number of hollow bearing trees and tree hollows within the forest has been modelled and an average of 15 hollow bearing trees per hectare and 100 hollows per hectare determined (Thomson et al. undated). However, there is a relatively high degree of variability and changes over time are undetectable in comparison (Figure 22).

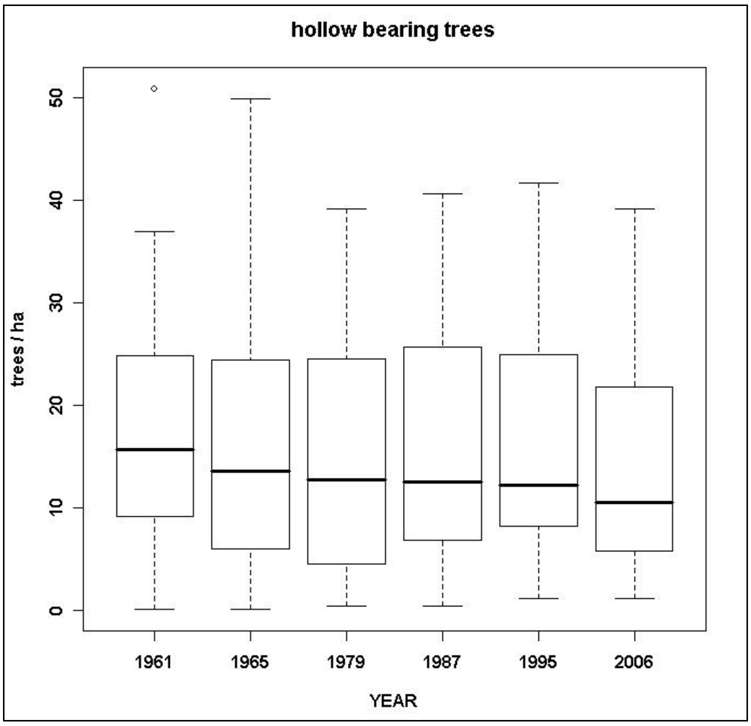

Figure 22: Modelled number of hollow bearing trees in Barmah Forest (Thomson et al. undated).

An important component of the river red gum forests and woodlands is not just the living vegetation, but also the organic matter contributed by the forest in the form of woody debris and litter. Fallen timber loads within the Ramsar site have been estimated at 24 tonnes per hectare (Mac Nally and Parkinson 2005). However, organic matter accumulations are strongly influenced by the period between floods with estimates of leaf, twig and bark litter in recently flooded areas up to five times less than those on floodplains that have not been inundated for over three years (Gigney et al. 2006; Table 12).

Table 12: Estimates of floodplain litter from within the Ramsar site (Gigney et al. 2006).

Litter type	Previously flooded (kilograms per hectare)	Previously unflooded (kilograms per hectare)
Leaf	364	1155
Bark	143	663
Twig	284	783

Floodplain marshes

Low-lying portions of the Barmah Forest Ramsar site feature a variety of treeless wetland types, including moira grass plains, giant rush (*Juncus ingens*) beds, common reed (*Phragmites australis*) beds, moist grasslands and aquatic herblands. These wetlands, referred to collectively as floodplain marshes, are associated with a variety of geomorphic settings including intermittent drainage lines, flood-runners, oxbow lagoons and floodplain depressions. Within the Ramsar site they are most prevalent around Barmah Lake, extending north to Boals Deadwood and in the area to the east near Tongalong Creek (Figure 19).

The extent and vegetation composition of these wetlands is dynamic, varying seasonally with flood cycles. A single wetland may support terrestrial herbs and grasses, aquatic herbs and macroalgae or reed beds over a single flood cycle. Examinations of species richness and abundance of macrophytes in floodplain marshes within Barmah Forest from 1998 to 2000 indicated significant differences in species richness and abundance between wetland sites and over time (Reid and Quinn 2004).

Around the time of listing, the extent of two floodplain marsh vegetation communities was mapped as approximately 500 hectares of giant rush and 1500 hectares of moira grass (Chesterfield et al. 1984). Contemporary mapping indicates a range of wetland EVCs within the site with a total extent of approximately 2500 hectares (Table 13).

Table 13: Wetland EVCs within the Barmah Forest Ramsar site (data supplied by DSE).

EVC	Description	Typical species	Extent (hectares)
Aquatic Herbland	Semi-permanent to seasonal wetland vegetation, treeless (or nearly so), dominated by herbaceous aquatic species (typically with at least rootstocks tolerant of dry periods).	Clove-strip (*Ludwigia peploides*); water-milfoil (*Myriophyllum spp.*); marshwort (*Nymphoides spp.*); river buttercup (*Ranunculus inundatus*); water ribbons (*Triglochin procera*); running marsh-flower (*Villarsia reniformis*).	145
Rushy Riverine Swamp	Collective label for the various zones of vegetation associated with semi-permanent wetlands with (turf/aquatic) grassy species co-dominating in mosaic or association with components of tall rushland and aquatic herbs.	Swamp wallaby grass; giant rush; water-milfoil; moira grass; matted starwort (*Stellaria caespitose*).	40
Floodplain Grassy Wetland	Wetland dominated by floating aquatic grasses (which persist to some extent as turf during drier periods), occurring in the most flood-prone riverine areas. Typically treeless, but sometimes with thickets of saplings or scattered more mature specimens of river red gum.	Swamp wallaby grass, native couch (*Cynodon dactylo*n), common spike-sedge, giant rush, water milfoil, creeping knotweed (*Persicaria prostrata*), moira grass, matted starwort.	470
Spike-sedge wetland	Low sedgy vegetation of seasonal or intermittent wetlands, dominated by spike-sedges and usually species-poor. Typically treeless, but sparse eucalypts (mostly river red gum) can be present in marginal sites.	Common spike sedge (*Eleocharis acuta*) monospecific or with common blown grass (*Lachnagrostis filiformis*) with opportunistic aquatic species.	105
Tall marsh	Wetland dominated by tall emergent graminoids, typically in thick species-poor swards. Rushland, sedgeland or reedbed.	Club sedge (*Bolboschoenus* spp.); giant rush, common reed, river club-sedge (*Schoenoplectus tabernaemontani*), bulrush (*Typha* spp.).	690
Open water	No vegetation.		200
Wetland complexes and mosaics	A mixture of the above together with areas of mixed forest and floodplain marsh communities.		850

3.3.3 Fish

There are 22 species of native fish that are predicted to occur within the streams and rivers of the Ramsar site (Davies et al. 2008). However, of these only 17 native species have been recorded recently and are expected to have occurred at the site at the time of listing (Davies et al. 2008; King et al. 2007; Appendix D). Three of the native species are classified as threatened either under the EPBC Act or the IUCN Red List (see Table 5).

Quantitative data exists for the Barmah-Millewa TLM Icon Site, which includes sampling locations in the Barmah Forest Ramsar site. However results are reported for a system as a whole and can only be considered indicative of populations in the Ramsar site.

A total of 15 species were recorded in the Barmah-Millewa TLM Icon Site from 2003 to 2006. This included 10 native and five introduced species (Table 14). Australian smelt (*Retropinna semoni*) and carp gudgeons (*Hypseleotris* spp.) were the most abundant species, with the former accounting for between 30 and 70 percent of the total catch. Variability between years was higher for some species than others and possibly linked to temperature and inundation patterns (King et al. 2007). There was a consistently high abundance of introduced species that comprised between 10 and 36 percent of the total abundance.

Table 14: Total abundance of fish from surveys in the Barmah-Millewa Forest (King et al. 2007).

Common name	Scientific name	2003/4	2004/5	2005/6
Native				
Australian smelt	*Retropinna semoni*	11 348	3931	8731
Carp gudgeons	*Hypseleotris* spp.	2550	4053	3352
Flat-headed gudgeon	*Philypnodon grandiceps*	94	213	149
Unspecked hardyhead	*Craterocephalus stercusmuscarum*	322	498	378
Murray cod	*Maccullochella peelii*	29	56	107
Trout cod	*Maccullochella macquariensis*	0	1	4
Golden perch	*Macquaria ambigua*	1	2	110
Silver perch	*Bidyanus bidyanus*	40	2	195
Southern pygmy perch	*Nannoperca australis*	1	17	50
Murray-Darling rainbowfish	*Melanotaenia fluviatilis*	6	1	11
Introduced				
Carp	*Cyprinus carpio*	1216	1519	1098
Goldfish	*Carassius auratus*	24	179	122
Redfin	*Perca fluviatilis*	94	157	74
Eastern gambusia	*Gambusia holbrooki*	234	2971	2512
Oriental weatherloach	*Misgurnus anguillicaudatus*	11	99	73

These results are consistent with those of the Sustainable Rivers Audit, which sampled streams and rivers both in and adjacent to the Ramsar site (Davies et al. 2008). Ten native and four introduced species were recorded in spring 2005. Australian smelt were the most abundant accounting for almost 50 percent of the catch. In total, native species represented 92 percent of total abundance, but only 23 percent of the biomass. Large bodied, alien species (such as carp), although lower in number, accounted for over 70 percent of the total biomass.

The fish communities of wetlands and lakes within the Barmah Forest Ramsar site were also monitored from 2007 to 2009 (Rourke and Tonkin 2009; Table 15). This included four creek sites (Tongalong, Budgee, Tullah and Gulf Creeks) and three wetland sites (Barmah Lake, Hut Lake and Flat Swamp). Monitoring during this period was on a smaller scale than that of the 2003 to 2005 surveys both in terms of sites as well as sampling effort and techniques used. As such, it is not possible to make quantitative comparisons between the two. The data of Rourke and Tonkin (2009) provide information on fish abundance and community composition from within the Ramsar site and as such could be useful in setting a baseline against which change can be assessed. However, the three sampling years were all extremely dry, with a number of sites unable to be sampled due to low water levels or completely dry waterbodies. As such, it is unlikely to reflect conditions around the time of listing in 1982 (which was immediately following a large flood in 1981). As more information is collected to cover the variability in inundation patterns, a more suitable baseline may be able to be established. Until this time, fish community composition and abundance within the Barmah Forest Ramsar site remains a knowledge gap.

Table 15: Abundance of fish within the Barmah Forest Ramsar site (Rourke and Tonkin 2009).

Common name	2007	2008	2009
Australian smelt	109	40	148
Carp gudgeons	523	47	318
Dwarf flat-headed gudgeon			
Flat-headed gudgeon	5		
Unspecked hardyhead	11	1	62
Murray cod		2	3
Golden perch	2	3	38
Silver perch			1
Southern pygmy perch	4	7	
Murray-Darling rainbowfish		1	6

3.3.4 Wetland birds

A total of 60 species of wetland bird have been recorded within the site (Table 16, Appendix B). The list includes seven species that are listed under international migratory bird agreements (CAMBA, JAMBA or ROKAMBA), although most of these species (for example, eastern great egret, glossy ibis, cattle egret and the white-bellied sea eagle) are considered resident in Australia; that is, not known to undertake international migrations (R. Jaensch personal communication). An additional 24 Australian species that are listed as migratory or marine under the EPBC Act have been recorded at the site. The list includes two species that are considered as nationally and/or internationally threatened (superb parrot and Australasian bittern).

The size and dynamics of the bird populations at the Ramsar site are not well documented. Attempts to quantify abundances are limited by the large size and relative inaccessibility of the wetlands (in terms of difficulty of access during floods) and the dominance by heavily forested wetlands, which reduce visibility from the air. As mentioned above, there are only two records of very large numbers of waterbirds from within the site; Chesterfield et al. (1984) published an anecdotal report of 100 000 in the 1974 floods and there is a record of 55 000 waterbirds (28 000 adults and 27 000 chicks) from 2005/6 (MDBC 2007). There are also counts of over 8500 birds in February 1979 (Chesterfield et al. 1984) and 6000 in October 1983 and 1992 (DSE unpublished). However, a lack of systematic surveys precludes a quantitative characterisation of waterbird abundance and species richness.

Thirty-one species of wetland birds have been recorded breeding within the Barmah Forest Ramsar site, including at least 15 colonial nesting species (DSE unpublished, Chesterfield et al. 1984). However, nesting records for many species are not well documented and there are limited quantitative data, particularly for non-colonial nesting species such as ducks, cranes, crakes, rails, water hens and coots.

The distribution and abundance of nesting waterbirds varies both spatially and temporally in response to flooding. The greatest concentrations of nesting species occur following spring floods in Barmah Lake, War Plain and Boals Deadwood (Barmah Millewa Forum 2001). Breeding records for the site are summarised in Table 17. It should be noted, however, that an absence of breeding/nesting records does not necessarily mean that waterbird breeding did not occur within the site as this may be a product of low survey effort. For example, although no records for colonial waterbird breeding could be found for the flood years of 1991, 1992 and 1996, breeding was recorded in the adjacent Millewa Forests in all of these years (Leslie 2001) and is likely to have occurred within the Barmah Forest Ramsar site.

Table 16: Number of wetland birds recorded within the Barmah Forest Ramsar site (DSE unpublished). See Appendix B for full list of species.

Bird group	Typical feeding requirements	Number of species
Ducks and allies	Shallow or deeper open water foragers. Vegetarian (for example Black Swan) or omnivorous with diet including leaves, seeds and invertebrates.	13
Grebes	Deeper open waters feeding mainly on fish.	3
Pelicans, cormorants, darters	Deeper open waters feeding mainly on fish.	6
Heron, ibis, spoonbills	Shallow water or mudflats. Feeding mainly on animals (fish and invertebrates).	14
Hawks, eagles	Shallow or deeper open water on fish and occasionally waterbirds and carrion.	2
Cranes, crakes, rails, water hens, coots	Coots in open water; others in shallow water within cover of dense emergent vegetation such as sedge. Some species vegetarian, others mainly take invertebrates, some are omnivores.	8
Shorebirds	Shallow water, bare mud and salt marsh. Feeding mainly on animals (invertebrates and some fish).	7
Gulls, terns	Terns, over open water feeding on fish and invertebrates; gulls, opportunistic feeders over a wide range of habitats.	2
Other	Non waterbirds that are reliant on wetlands for breeding or feeding (e.g. superb parrot, clamorous reed warbler).	5
Total		**60**

Table 17: Recorded occurrences of waterbird breeding in the Barmah Forest Ramsar site (Chesterfield et al. 1984; Barmah Millewa Forum 2001; O'Connor and Ward 2003; MDBC 2007; DSE unpublished).

Species	1964	1967	1968	1969	1970	1973	1974	1978	1979	1981	1990	1992	1999	2000/1	2002/3	2005/6
Australian white ibis						X	X	X	X	X				X	X	X
Eastern great egret		X	X	X												X
Great cormorant	X	X	X	X			X							X		X
Intermediate egret		X		X												X
Little black cormorant		X		X			X		X					X	X	
Little egret		X		X												X
Little pied cormorant	X	X	X	X		X	X	X	X	X				X	X	X
Nankeen night-heron		X	X	X						X				X		X
Pied cormorant				X												
Royal spoonbill					X											
Straw-necked Ibis						X	X	X	X	X				X	X	X
Whiskered tern	X		X					X								X
White-necked heron					X		X		X	X				X		
Yellow-billed spoonbill					X				X	X						X
Other waterbirds									X	X	X	X	X	X	X	X

Barmah Forest is one of only a handful of places that supports breeding of the nationally threatened superb parrot (*Polytelis swainsonii*). A single nest site was discovered in a 1985 survey and subsequent surveys in the early 1990s confirmed a total of 31 nests within the Ramsar site (Webster and Ahern 1992). There are a total of 10 known colonies within the Ramsar site, which occur in two general locations: Bunyip Hole, Tongalong Creek and Mannion's Yards in the east of the site; and Doctors Point, Grinters Track, Waiting Plain Runner, Sapling Landing Runner, Dougs Crossing, Bucks Crossing and Bourke St in the centre of the site (Figure 23). In the 1990s the breeding population was estimated at between 65 and 105 pairs within the Barmah Forest Ramsar site (Webster 2007).

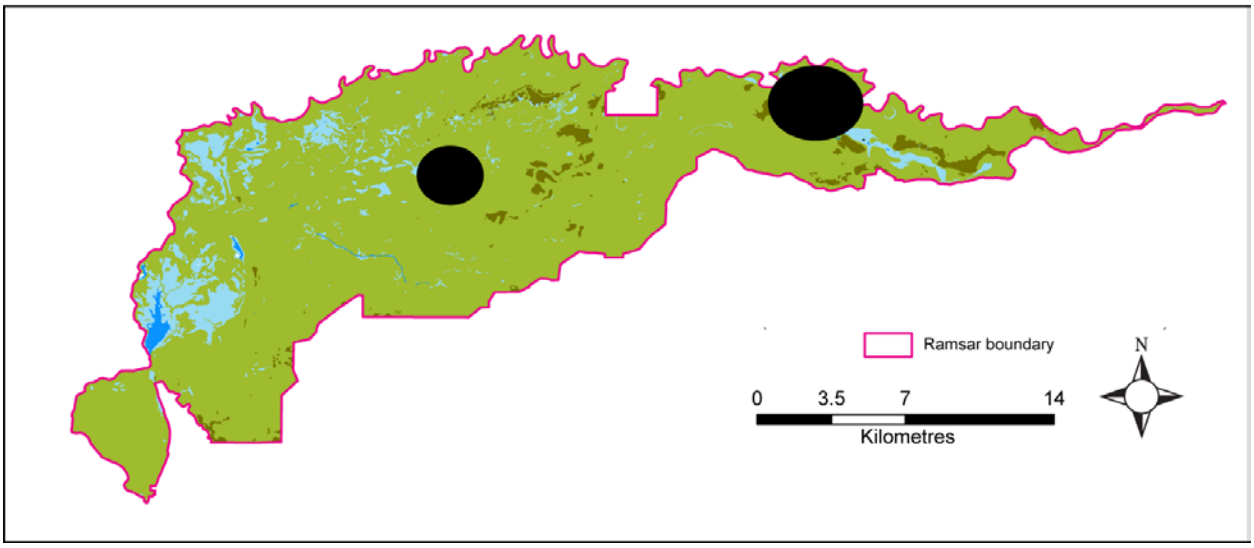

Figure 23: Approximate locations of superb parrot nesting colonies in Barmah Forest Ramsar site (data from Webster 1988). Note symbols indicate locations only and are not indicative of quantitative data.

4 Ecosystem services

4.1 Overview of benefits and services

Ecosystem benefits and services are defined under the Millennium Ecosystem Assessment definition of ecosystem services as "the benefits that people receive from ecosystems (Ramsar Convention 2005, Resolution IX.1 Annex A). This includes benefits that directly affect people such as the provision of food or water resources as well as indirect ecological benefits. The Millennium Ecosystem Assessment (Millennium Ecosystem Assessment 2005) defines four main categories of ecosystem services:

1. **Provisioning services** – the products obtained from the ecosystem such as food, fuel and fresh water;
2. **Regulating services** – the benefits obtained from the regulation of ecosystem processes such as climate regulation, water regulation and natural hazard regulation;
3. **Cultural services** – the benefits people obtain through spiritual enrichment, recreation, education and aesthetics; and
4. **Supporting services** – the services necessary for the production of all other ecosystem services such as water cycling, nutrient cycling and habitat for biota. These services will generally have an indirect benefit to humans or a direct benefit over a long period of time.

The ecosystem benefits and services of the Barmah Forest Ramsar site at the time of listing are outlined in Table 18.

4.2 Identifying critical ecosystem services and benefits

The critical ecologically based ecosystem services and benefits of a Ramsar site have been identified using the same criteria as was used for selecting critical components and processes; i.e. "As a minimum, select for analysis and description those components, subcomponents, processes, benefits and services (DEWA 2008):

1. that are important determinants of the site's unique character;
2. that are important for supporting the Ramsar criteria under which the site was listed;
3. for which change is reasonably likely to occur over short or medium time scales (less than 100 years); and/or
4. that will cause significant negative consequences if change occurs".

Using these criteria it was considered that all of the supporting services (that is, those that are ecologically based) could be considered "critical". While the site was undoubtedly beneficial in terms of timber production, cultural services and flood control, these were not considered "critical" services because a reduction in any of these services would not necessarily indicate a change in ecological character.

Therefore the critical ecosystem benefits and services of the Barmah Forest Ramsar site are:

- supports a diversity of wetland types;
- supports biodiversity;
- provides physical habitat for waterbird feeding and breeding;
- supports threatened wetland species;
- maintains ecological connectivity for fish spawning and recruitment; and
- organic carbon cycling.

Table 18: Ecosystem services and benefits provided by the Barmah Forest Ramsar site (those considered critical are shown shaded).

Category	Description
Provisioning services	
Wetland products (timber)	At the time of listing, the site was designated State Forest that was managed predominantly for timber production.
Wetland products (fodder)	At the time of listing, grazing was undertaken through much of the site.
Wetland products (firewood)	The site is locally important for firewood collection. Public access is granted for collection of fallen timber only and for personal use.
Cultural services	
Recreation and tourism	The general public have mostly unrestricted use of the forests and rivers for recreational pursuits through a well-maintained road network to and within the forests. Common activities include recreational fishing, bird watching and bushwalking.
Spiritual and inspirational	The Yorta Yorta people have a long association with the forest. Scarred trees, mounds, stone artefact scatters, middens and burial sites can be found in the park. Declining health of populations broad-shelled turtle is of particular concern for Yorta Yorta Nation as it is an animal totem connected to their creation stories. The Yorta Yorta people have long-held aspirations to be involved in caring for country and have an active role in the management of Barmah National Park. Traditional owner knowledge assists with management of the land and recognises the unique relationship of the traditional owners to the land.
Science and education	The site contains interpretative ecotourism and education sites within the site. National focus of research, environmental management and education through The Living Murray program (MDBC, 2006).
Regulating services	
Carbon sequestration	Although this aspect has not been quantified, the forests and their floodplain soils would account for a significant sink of organic carbon.
Flood control	Floodplain vegetation reduces floodwater impacts by reducing velocity of peak flows and disperses flow energy across a stable, depositional environment. The site protects agricultural lands downstream from floods (Dexter 1979). The floodplain and effluent streams allow for a slow recession of floodwaters, which is essential for native biota but also maintains river flows at manageable levels over a longer period.
Supporting services	
Diversity of wetland types	The site supports part of the largest remaining river red gum forest and provides a mosaic of vegetated wetland habitats.
Biodiversity	The site supports the regionally significant moira grass vegetation community and a significant number of plant and animal species.
Physical habitat	Barmah Forest provides habitat for feeding and breeding of wetland birds.
Threatened species	The Ramsar site supports seven species listed under the EPBC Act and/or the IUCN Red List.
Ecological connectivity	The site provides important migratory routes between riverine, wetland and floodplain habitats for fish spawning and recruitment.
Organic carbon cycling	As part of a major floodplain system, the site is important for the cycling of nutrients, particularly carbon both on the floodplain and as a source of organic carbon to receiving waterways.

4.3 Critical services

4.3.1 Supports a diversity of wetland types

As described in Section 2.3, the Barmah Forest Ramsar site contains a range of wetland types, some of which can be considered significant in a bioregional context. The major wetland types and associated habitats that are considered critical to the ecological character of the site are:

- Freshwater tree-dominated wetlands – river red gum forest and woodland;
- Intermittent freshwater marshes – freshwater marshes, open water; and
- Permanent and intermittent rivers and streams– permanent pools, instream habitats.

This diversity of habitat is brought about by the interactions between geomorphology, hydrology and vegetation (Figure 24). Water regime is the single biggest determinant of wetland vegetation, with different groups of species having different morphological adaptations to patterns of inundation (Roberts and Marston 2000). Most commonly, it is adaptations to low oxygen in the soil following inundation that determines a plant species optimum water regime (Brock and Cassanova 1997). The water regime requirements for different wetland types are provided in Table 19.

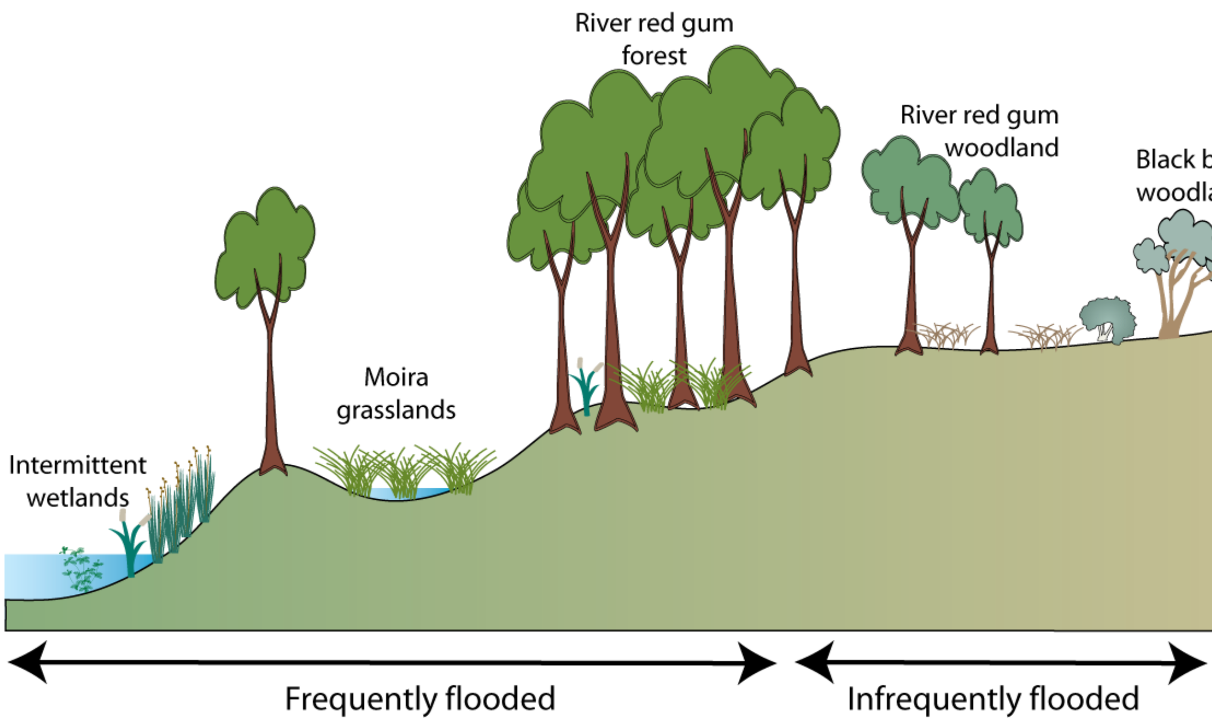

Figure 24: Vegetation associations, geomorphic setting and flood regime (adapted from MDBC 2007).

Table 19: Water requirements of select vegetation communities within Barmah Forest (DSE 2008).

Vegetation	Frequency	Duration	Timing
Giant rush	Seven to 10 years in 10	Nine to 12 months	May to January
Moira grass	Ten years in 10	Five to seven months	July to December
River red gum forest	Seven to ten years in 10	One to 18 months	August to December
River red gum woodland	Three years in 10	One to 18 months	August to December
Black box woodland	One year in 10	One month (range of one to four months)	August March

Freshwater tree dominated wetlands

River red gum forested wetlands dominate the site and natural regeneration of river red gum is largely dependent on the natural flooding cycles of river systems, and most strongly on an intermittent late winter/early spring flooding cycle. Historically, flooding across the river red gum forests lasted approximately three months and occurred seven to eight times per decade (MDBC 2007).

River red gum produces abundant quantities of seed, which is released mostly during spring and summer. Greater seed fall in spring may have adaptive significance as under the natural flow regime floods would usually recede during this period (Dexter 1978). Young plants appear over extensive areas after floods and can initially form dense stands of saplings, which gradually thin out as they grow. Maturing stands form forests of straight-trunked trees in areas with reliable floodwater. Prolonged inundation kills seedlings, which is important for maintaining the distribution of treeless communities (marshes) at the site (Cunningham et al. 1981).

Flood timing affects germination success. Flood recession in spring-early summer is optimal for regeneration while winter floods with winter recession are unfavourable. Spring-summer floods followed by summer recession provide suitable germination conditions but subsequent heat and water stress can cause massive seedling mortality. Germination can happen without flooding if the winter is wet. If seedlings survive frost, but conditions continue to be dry, moisture stress in the following summer is likely (Roberts and Marston 2000).

River red gum seedlings have a number of morphological adaptations that enable them to cope with inundation. However, complete immersion, unless brief, is likely to kill seedlings; lower leaves of small saplings die if submerged for long periods (Roberts and Marston 2000). Seedlings increase tolerance to flooding with age. Two-month old seedlings can survive waterlogging for one month (Roberts and Marston 2000), while seedlings 50 to 60 centimetres tall can survive extended flooding of 4-6 months and complete immersion for a few weeks by shedding leaves (Dexter 1978).

It must be noted that at the time of listing, the site was managed as a State Forest with over 70 percent of the site was managed predominantly for timber harvesting (DCE 1992). This management included stand thinning, select tree harvesting and (rarely) active regeneration and direct seeding (Di Stefano 2001). There is evidence from the site that early thinning of high density stands (greater than 1000 trees per hectare) to 600 to 800 stems per hectare, produces complexity of habitat and a larger number of hollow bearing trees, given time to develop (Horner et al. 2010). Therefore it is likely that forest management has played an important role in shaping the community composition and structure of the forests within the Ramsar site.

Intermittent freshwater marshes

In low lying areas where inundation is more frequent and flood durations are longer, water-logging of soil is too prolonged to sustain river red gum forest, and aquatic plant communities, which have greater tolerances for anoxic soils occur. Plant community composition and extent of these wetlands varies temporally and spatially in response to patterns of inundation and drying. Brock and Cassanova (1997) classified plants into functional groups based on water regime and adaption to flooding and this has been adapted to the flora of freshwater marshes in the site Table 20.

Intermittent rivers and streams

Barmah Forest features an extensive and complex network of instream habitats. They are all hydrologically connected to the Murray River and effluent streams, such as Gulf Creek and Tullah Creek systems and a network of smaller, unnamed effluent streams and flood runners. The networks of smaller channels are important for transmitting floodwaters across the floodplain and inundating other habitat types (MDBA 2010). In-stream habitats support the aquatic and semi-aquatic plant species listed in Table 20. They play an important role maintaining propagules of these species during dry phases and then transmitting them onto the floodplain upon re-wetting (Abel et al. 2006).

Table 20: Plant functional groups and examples from Barmah Forest (Abel et al. 2006).

Functional Group	Description	Examples from Barmah Forest
Submerged	Species which germinate, grow and reproduce underwater. Do not tolerate drying.	*Azolla* spp.*;* stoneworts
Amphibious responders - floating	Tolerate flooding and drying: truly amphibious plants that change aspects of their morphology under different water conditions. This group responds by developing floating leaves.	Moira grass (*Pseudoraphis spinescens*)*; Ludwigia peploides;* water ribbons (*Triglochin procerum*)
Amphibious responders - plastic	Tolerate flooding and drying: truly amphibious plants that change aspects of their morphology under different water conditions. This group responds in a range of ways other than by developing floating leaves, e.g. growing laterally along the mud, putting down roots at nodes when stranded and growing vertically to extend the leaves above the water.	Swamp wallaby grass (*Amphibromus fluitans*); water milfoil (*Myriophyllum* spp.)
Amphibious tolerators -low growing	Tolerate flooding and drying; not truly amphibious and have the same germination, growth and reproduction patterns in a wide range of water conditions. These plants tolerate by being able to survive underwater for some period.	Creeping knotweed (*Persicaria prostrata*); starwort (*Stellaria* spp.)
Amphibious tolerators - emergent	Tolerate flooding and drying; not truly amphibious and have the same germination, growth and reproduction patterns in a wide range of water conditions. These plants tolerate flooding by having an upright growth form that keeps the photosynthetic parts above water at all times.	common spike-sedge (*Eleocharis acuta*); Rushes (*Juncus* spp.); *Typha* spp.
Terrestrial - damp	Do not tolerate flooding and require good soil moisture at all times.	Brown-back wallaby-grass (*Austrodanthonia duttoniana*)
Terrestrial - dry	Do not tolerate flooding and can survive drying.	Silver wattle (*Acacia dealbata*)

4.3.2 Supports biodiversity

The Barmah Forest Ramsar site supports a large number of species both as resident species and during different lifecycle stages for nomadic and migratory species. This service is brought about by the combination of geomorphology and hydrology resulting in a diversity of wetland types and habitats (as described in section 3.3.2 above).

In addition to the species richness of the site, the biodiversity values of Barmah Forest are enhanced by the presence of the largest extent of moira grass plains in the Murray-Darling Basin. At the time of listing, moira grass extended over approximately five percent of the site (1500 hectares; Chesterfield et al. 1984). A description of the components and processes important for maintaining moira grasslands within the site was described by DSE 2008; Table 21).

Table 21: Components and processes important for maintaining moira grasslands within the Ramsar site (DSE 2008).

Component or process	How the component or process maintains the service
Topography (geomorphic setting)	The topography of the floodplain determines potential water depth which influences moira grass distribution. Moira grass requires a water depth of at least 0.5 metres and tolerates depth of water up to two metres. A depth of at least 0.5 metres is required to kill river red gum seedlings that have established in areas dominated by moira grass and to prevent premature nodal rooting of moira grass in the substrate.
Sedimentation	Sedimentation has the potential to decrease depth, favouring river red gum establishment in areas dominated by moira grass.
Hydrology	The seasonality and duration of floods are important in determining moira grass distribution. Prolonged flooding into summer can favour the growth of upright milfoil, which tends to precipitate sediment from floodwaters at a higher rate than moira grass because of its greater hydraulic roughness. Optimum hydrology for moira grass is annual inundation for five to seven months at a depth of 0.5 to 2.0 metres during winter to spring.
Competition	River red gum and giant rush are considered to be competitors to moira grass, encroaching into the moria grass plains when water regimes are less than optimum for moira grass.

4.3.3 Provides physical habitat for wetland bird breeding and feeding

Barmah Forest provides a range of habitats that support wetland birds in terms of feeding and breeding. Sixty species of wetland birds have been recorded at the site and this represents a wide variety of species that rely on a range of different habitats. In many instances, birds that breed within the site utilise different habitats for foraging, roosting and breeding and a network of different habitat types is required to meet all of their needs (Figure 25).

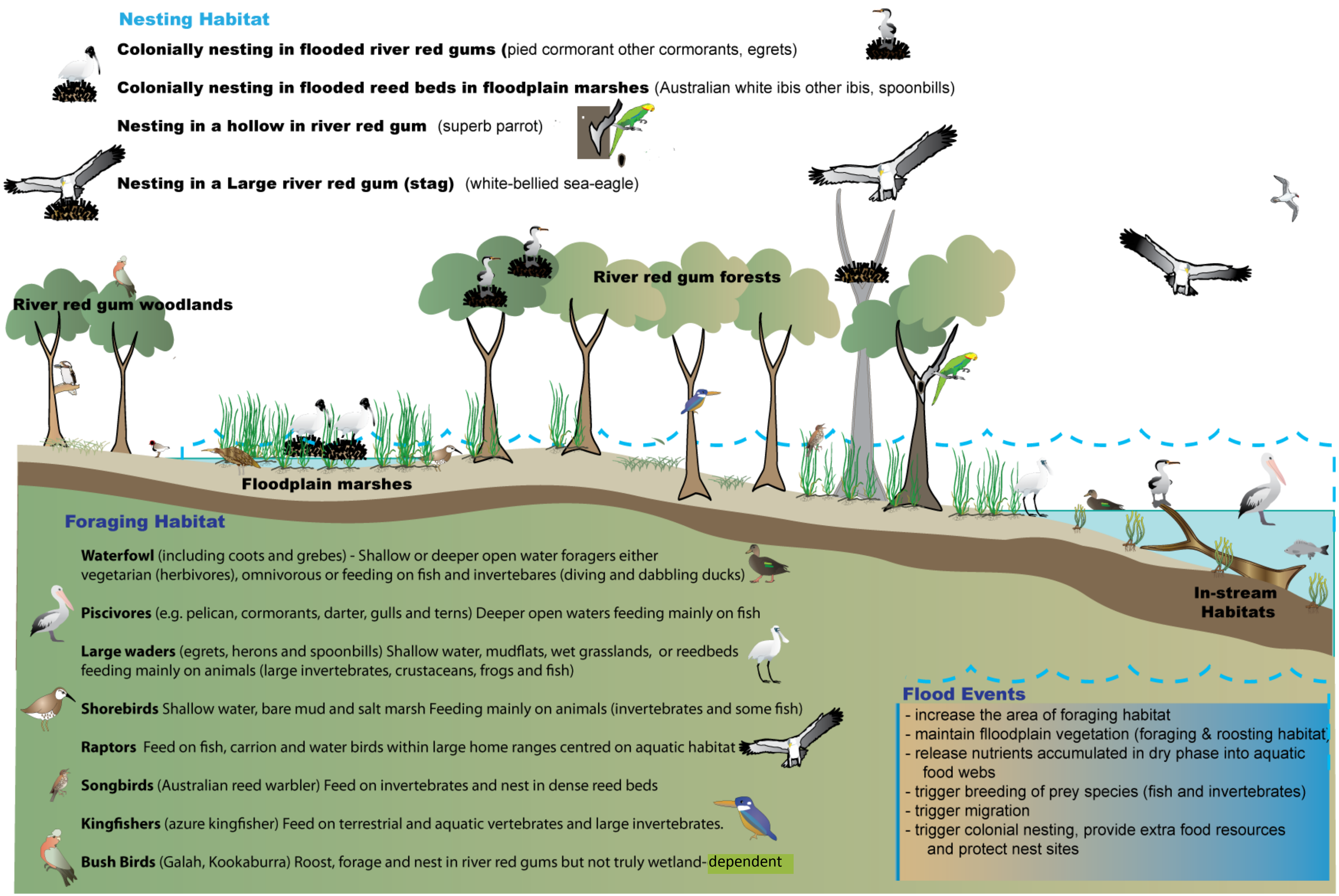

Figure 25: Conceptual diagram illustrating the variety of habitats for wetland birds within the Ramsar site.

Feeding

The service of providing habitat for wetland bird feeding is considered in terms of broad feeding/habitat guilds. Of note is the variation in feeding and foraging habitats in response to wetland inundation. This is illustrated by the proportion of total wetland bird abundance represented by each of the functional feeding groups (after Kingsford and Porter 2009) in the Barmah-Millewa TLM Icon Site following floodplain inundation in 2000 and during dry conditions in 2007 and 2008 (Figure 26). When floodplains and floodplain wetlands are inundated, there is a greater diversity of wetland birds in the system (over 35 species recorded in 2000/2001; Barmah Millewa Forum 2001), with all functional feeding groups generally dominated by large wading species such as egrets and herons. During drier times, species richness is lower (between five and 14 species in 2007 and 2008; Kingsford and Porter 2009) and the site is dominated by piscivores that are located along permanent streams and waterholes, with a complete absence of herbivores.

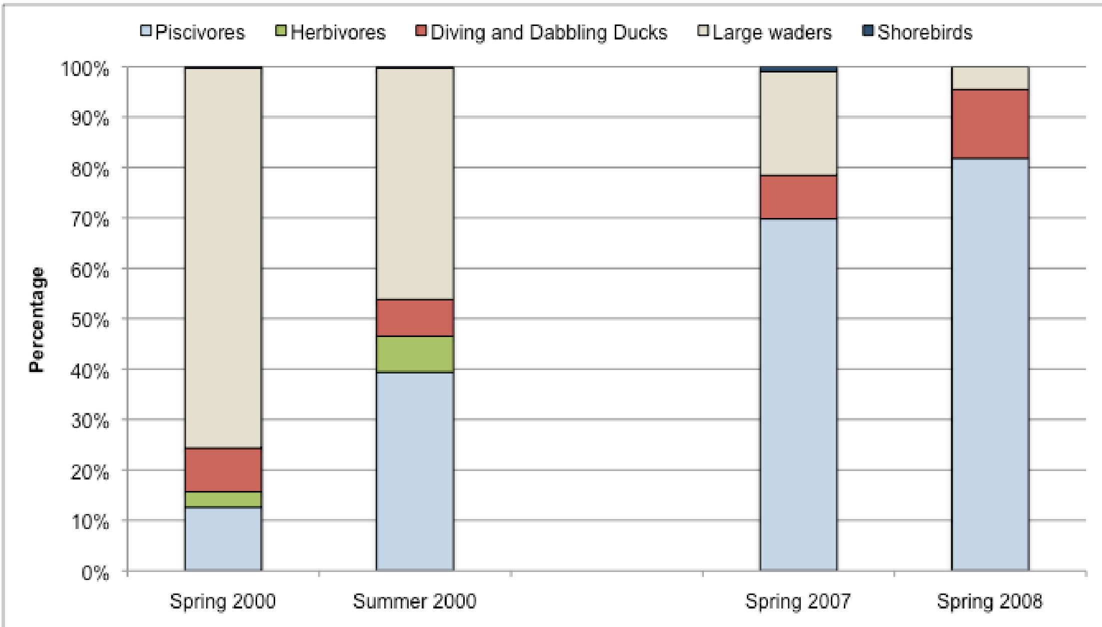

Figure 26: Proportion of birds from different feeding guilds in Barmah-Millewa Forest in 2000/2001 (Barmah-Millewa Forum 2001) and 2007 and 2008 (Kingsford and Porter 2009).

<u>Piscivores</u>
There are a number of wetland birds within the Ramsar site whose diet is wholly or mostly comprised of fish. These are the terns, cormorants and darters as well as the white-bellied sea eagle. A number of these species require relatively deep water (greater than one metre) in which to feed and plunge. Pursuit divers such as terns require open water expanses. Within the Ramsar site, these are limited to channels and instream pools as well as the larger floodplain depressions such as Barmah Lake, Boals Deadwood and Reedy Swamp. The general habitat requirements for a number of piscivorous waterbirds that have been recorded within the Ramsar site are provided in Table 22.

Table 22: General diet and feeding habitat requirements of a number of piscivorous wetland birds in the Barmah Forest Ramsar site (Marchant and Higgins 1990).

Species	Habitat characteristics
Great cormorant (*Phalacrocorax carbo*)	Diet mainly of fish, but supplemented with crustaceans and frogs. Feeds by capturing prey in shallow underwater dives, which often last for more than a minute.
Pied cormorant (*Phalacrocorax varius*)	Diet consists mainly of small to medium size fish. Feed by pursuit diving via deep underwater dives.
White-bellied sea eagle (*Haliaeetus leucogaster*)	Feed mainly on fish, but also other birds and mammals; will also take prey from other birds and feed on carrion such as dead sheep. Strike predator, requiring some open ground (or water) to capture prey. Takes prey from land or under the surface of the water.

Waterfowl and associated waterbirds

This group includes not just ducks, swans and geese but also grebes, coots and waterhens. There is a range of feeding strategies and foraging and roosting habitats for this group of waterbirds, some of which are described in Table 23. Under the functional feeding groups provided by Kingsford and Porter (2009), this group is divided into herbivores (which includes black swans and Eurasian coots) and ducks (which includes the diving and dabbling ducks and grebes).

Table 23: General diet and feeding habitat requirements of selected species of waterfowl within the Ramsar site (information from Marchant and Higgins 1990).

Species	Habitat characteristics
Eurasian coot (*Fulica atra*)	Prefers vegetated lagoons and swamps. Diet – almost entirely vegetable matter (seeds and plant material). Foraging – food is mainly obtained during underwater dives, lasting up to 15 seconds and ranging down to seven metres in depth. Birds also graze on the land and on the surface of the water.
Australasian shoveler (*Anas rhynchotis*)	Prefer deep, large permanent waterbodies. Roost on open water. Diet – plants and animals (molluscs and insect larvae). Foraging – filter feeder dabbling in mud or in surface water.
Australian shelduck (*Tadorna tadornoides*)	Wide range of habitats but prefer shallow wetlands. Diet – vegetation and invertebrates. Foraging – opportunistic grazing, dabbling, etc.
Chestnut teal (*Anas castanea*)	Prefer saline wetlands. Diet – seeds and insects. Foraging – dabbling at the water's edge or in bottom waters.
Black swan (*Cygnus atratus*)	Inland and estuarine shallow waters where floating, submerged or emergent vegetation is plentiful. Roost – mostly over water, but occasionally on shore. Diet – herbivorous feeding on the shoots and leaves of aquatic plants including filamentous algae and seagrass. Foraging – grazers.

Waders

This group includes species in the two families, Ardeidae and Threskiornithidae (herons, egrets, spoonbills and ibis), which are classified as "large waders" by Kingsford and Porter (2009) as well as the shorebirds. Wading species feed in shallow water (usually less than 15 centimetres) and within the Ramsar site, this group is dominated by large waders. Shorebirds comprise a very small proportion of the wetland bird community. Foraging and feeding strategies of some of the wading species of birds found within the Ramsar site are provided in Table 24.

Table 24: General diet and feeding habitat requirements of selected species of waders within the Ramsar site (information from Marchant and Higgins 1990)

Species	Habitat characteristics
Straw-necked ibis (*Threskiornis spinicollis*)	Favours inland, freshwater or brackish wetlands. Feeds mainly on terrestrial invertebrates, but also frogs, small reptiles and mammals. It forages by probing in the mud or taking prey from the surface of shallow water.
Yellow-billed spoonbill (*Platalea flavipes*)	Prefers inland, freshwater wetlands with shallow margins. Diet – predominantly invertebrates. Foraging – in shallow mud using the vibration detectors in its bill to detect movement of prey in the mud.
White-faced heron (*Egretta novaehollandiae*)	Very diverse array of habitats from arid inland to temperate coasts. Feeds on a diversity of prey including aquatic insects, molluscs, crustaceans, frogs and fish. Foraging – variety of techniques, wading and disturbing prey, ambush hunting and probing crevices and mud.
Black-winged stilt (*Himantopus himantopus*)	Prefer inland freshwater and saline marshes. Diet – feed mainly on aquatic insects, but also crustaceans and molluscs. Foraging – wade in shallow water and seize prey at or near the surface, but occasionally taking sub-surface prey.

Breeding

The Barmah Forest Ramsar site is significant for supporting the breeding of wetland birds, particularly colonial nesting waterbirds such as ibis, herons and cormorants. In order to breed, waterbirds require appropriate sites for their nests. Nesting requirements vary between groups of species. The critical habitat resources at the site include mature river red gums in the vicinity of open water and stands of *Juncus* or other emergent macrophytes in marshes (Barmah Millewa Forum 2001; O'Connor and Ward 2003). The greatest concentrations of important waterbird breeding colonies at the site are in Barmah Lake, Boals Deadwood and Reedy Swamp.

Waterbirds breed in response to flooding in relation to nesting habitat as well as available food resources. There is evidence to suggest that waterbird breeding occurs when food resources are at a maximum (Kingsford and Norman 2002). Depending on the season and diet of the species, this can lag behind the commencement of inundation for periods of four weeks to seven months. Once breeding has commenced, many Australian waterbirds require surface water to remain in and around nesting sites until offspring are independent feeders (Jaensch 2002). Drying prior to this can lead to abandonment of nests and young by parents or insufficient food resources for successful fledging. It is suggested that inundation for a minimum of four months would be required to allow for courting/mating, nest site selection and building, incubation and raising of young to independence (Jaensch 2002).

The site predominantly supports birds that nest in trees or shrubs and preferred nesting sites for most species recorded breeding in substantial numbers are similar. The habitat requirements, including length of inundation for a selection of these species are provided in Table 25.

Table 25: Nesting habitat and inundation requirements for some species of wetland bird previously recorded breeding in the Ramsar site ([1]DSE unpublished; [2]Briggs 1990; [3]Jaensch 2002).

Species[1]	Stimuli for breeding[2]	Nesting Habitat[3]	Inundation requirements[3]
Little pied cormorant	Flooding / seasonal	In forks and branches of trees (*Eucalyptus*) and tall shrubs in or over water; sometimes over dry land or on artificial structures.	Minimum depth of 30 to 50 centimetres for sufficient time to prevent nest site becoming dry before nestlings leave nest and reach maturity – three to four months.
White-necked heron	Flooding / seasonal	Low near-horizontal branch of tree in or overhanging water. Trees (such as river red gum) fringing river channels, waterholes, lakes and ponds; wooded swamps (such as black box).	Minimum depth of 30 to 50 centimetres for sufficient time to prevent nest site becoming dry before nestlings leave nest and reach maturity – three months.
Eastern great egret	Flooding / seasonal	Wooded swamp (such as *Eucalyptus*); high in river red gum tree or tall shrub standing in water, often at a higher site than associated species; sometimes high in trees on dry land.	Minimum depth of 30 to 50 centimetres for sufficient time to prevent nest site becoming dry before nestlings leave nest and reach maturity – three to four months.
Intermediate egret	Flooding / seasonal	Wooded swamp (such as *Eucalyptus*); high (up to 15 metres above water) in a river red gum tree or tall shrub standing in water.	Minimum depth of 30 to 50 centimetres for sufficient time to prevent nest site becoming dry before nestlings leave nest and reach maturity – three to four months.
Nankeen night heron	Flooding	Wooded swamp (such as *Eucalyptus*); in a tree or tall shrub standing in water, at variable height; often in a discrete zone (encircling a group of breeding egrets); sometimes high in trees on dry land.	Minimum depth of 30 to 50 centimetres for sufficient time to prevent nest site becoming dry before nestlings leave nest and reach maturity – two to three months.
Australian white ibis	Flooding / seasonal	Typically use platforms of Giant rush and Common reed; occasionally also wooded swamp (such as. *Eucalyptus*), exotic wetland and dryland tree copses, bare islands and artificial structures.	Minimum depth of 30 to 50 centimetres for sufficient time to prevent nest site becoming dry before nestlings leave nest and reach maturity – ten weeks to three months (not relevant to nests on dry land).
Royal spoonbill	Flooding / seasonal	Typically use platforms of Giant rush and Common reed among the main ibis colonies; occasionally also wooded swamps. Requires inundation until young fledge.	Minimum depth of 30 to 50 centimetres for sufficient time to prevent nest site becoming dry before nestlings leave nest and reach maturity – ten weeks to three months (not relevant to nests on dry land).
Black swan	Flooding / seasonal	Nest mound built in open water, on an island, or in swamp vegetation.	Minimum water depth of 30 – 50 cm until cygnets are independent. First flight 20 – 25 weeks.

4.3.4 Supports threatened species

Seven threatened species are considered critical to the ecological character of the Barmah Forest Ramsar site (see Section 3.1). The habitat requirements and important habitats within the site for each of these are described briefly below.

Australasian bittern (*Botaurus poiciloptilus*)
The Australasian bittern is a shy and cryptic wading species of wetland bird that prefers permanent, densely vegetated freshwater wetlands (Garnett 1992). It forages mainly at night in shallow water up to 30 centimetres deep and feeds on frogs, fish and invertebrates as well as occasionally plant material (Marchant and Higgins 1990).

Permanent and intermittent freshwater marshes with emergent vegetation provide habitat for this species within the Ramsar site. The Australasian bittern has been recorded at Boal's Deadwood, Pig Hole and Tram Swamp (DSE unpublished) and there is anecdotal evidence of breeding based on calls (Richard Loyn, ARI, personal communication). However, given the cryptic nature of this species coupled with a low survey effort for non-colonial nesting waterbirds, it is likely that the small number of records do not reflect the utilisation of the site by this species.

Superb parrot (*Polytelis swainsonii*)
The superb parrot generally inhabits box-gum, box-cypress pine and boree woodlands and river red gum forest. It nests in hollows in small colonies in mature river red gum, often with more than one nest in a single tree. It forages up to 10 kilometres from nesting sites, primarily in grassy box woodland, feeding mainly on grass seed and herbaceous plants, fruits, berries, nectar, buds, flowers, insects and grain (DSE 2003a).

Within the Ramsar site it has been recorded breeding in mature river red gums at a number of locations including Bunyip Hole, Tongalong Creek and Doctors Point (Webster 2007; see Figure 22).

Murray cod (*Maccullochella peelii*), trout cod (*Maccullochella macquariensis*) and silver perch (*Bidyanus bidyanus*)
These three large-bodied native fish utilise predominantly flowing environments within the site. Murray cod and trout cod prefer deep holes in rivers, with instream cover such as rocks, snags and undercut banks, while silver perch are found mostly in lowland, turbid and slow-flowing rivers (Lintermans 2007). Both Murray cod and silver perch have been recorded in a number of creeks within the forest such as Tongalong Creek (Rouke and Tonkin 2009), Gulf Creek, Black Engine Creek and Budgee Creek (Jones 2006). Trout cod are more rare within the Ramsar site, but have been recorded in Gulf Creek (Jones 2006) and Tongalong Creek (King et al. 2007) from within the site.

In addition, Barmah Forest provides temporary habitat for all three species when floods link the normal riverine habitat of these fish species with the floodplain. The provision of quality habitat for these species depends on a productive floodplain ecosystem. Murray cod and trout cod hunt on large aquatic prey such as small fish and large invertebrates, whereas silver perch consume both large aquatic prey and plant material (Ecological Associates 2003).

Mueller daisy (*Brachyscome muelleroides*)
The Mueller daisy is a small annual herb restricted to the mid-Murray and Murrumbidgee Rivers region in New South Wales South and Victoria. The species occurs in seasonally wet depressions in the landscape such as shallow depressions and around the margins of swamps, lagoons and claypans. It is thought that sufficient autumn rainfall that results in localised soil waterlogging, or periodic flooding, is required to initiate seed germination and plant growth (Lucas 2010).

It has been recorded in six locations within the Ramsar site (Grinters Ridge, Tram Swamp, Hammys Plain, Ulupna Island, Forcing Yards and Sandy Crossing). Up to 750 plants have been recorded in a single location and it is possible that it occurs over a large area at a number of locations within the Ramsar site (Lucas 2010).

Swamp wallaby-grass (*Amphibromus fluitans*)
Swamp wallaby-grass is a slender, up to one metre tall aquatic or semi-aquatic native grass. It inhabits intermittent wetlands and the littoral zone of permanent wetland systems, as well as occurring as the understorey in river red gum forests following inundation (Australian Ecosystems 2009). The species is a sword-forming grass species that spreads by adventitious stems growing along the ground or through water. It can survive prolonged periods without inundation as a low-growing turf, but is primarily a grass of aquatic environments and grows most vigorously when flooded by shallow water (Australian Ecosystems 2009). Although there are a large number of records for this species from within the site (DSE unpublished) there is little recorded information on distribution, location and extent.

4.3.5 Maintains ecological connectivity for spawning and recruitment of native fish

Understanding native fish use of flooded wetland habitats is in its infancy in Australia and the use and significance of different habitats in the Barmah Forest Ramsar site by native fish remains a knowledge gap. However, recent investigations in Barmah Forest have provided evidence of lateral movement of native fish during floods (Lyon et al. 2010) and the importance of floodplain wetlands for successful recruitment of many native fish species (King et al. 2007). Juvenile and larval native fish species have been recorded in wetland, lake and creek habitats within the site (King et al. 2007) and even fish that are known to spawn in river channels (such as Murray cod) are thought to utilise inundated floodplain and creek systems to feed (King et al. 2009; Lyon et al. 2010).

Native fish have been recorded moving large distances along the Murray River from the Ramsar site (up to 1000 kilometres upstream and 900 kilometres downstream), which is indicative of pre- and post-spawning behaviour (McKinnon 1997). The Barmah Forest Ramsar site (together with adjacent sites such as Millewa, Koondrook Perricoota and Gunbower) provides a network of habitats for fish during these long migrations. Floodplain inundation, with its associated boom in productivity, provides both physical habitat and food resources that are important in maintaining regional native fish populations (King et al. 2009). The migration and spawning habitat requirements for some of the native fish species that are known to occur in the site are provided in Table 26.

Table 26: Migration and spawning habitats for some fish species known to occur in the Ramsar site ([1]CRCFE 2003; [2]Lintermans 2007).

Species	Habitat group[1]	Migration and spawning habitats[2]
Australian smelt (*Retropinna semoni*)	Wetland specialist (spawn and recruit in floodplain wetlands and lakes, anabranches and billabongs during in-channel flows)	Known to undertake upstream migrations in adult and juvenile stages, with fish as small as 21 millimetres recorded migrating. Spawning occurs when water temperatures reach about 11 to 15 degrees Celsius (spring and late summer in region of the Ramsar site). Juveniles may migrate out of floodplains and wetlands on receding floodwaters.
Bony herring (*Nematalosa erebi*)	Wetland specialist (spawn and recruit in floodplain wetlands and lakes, anabranches and billabongs during in-channel flows)	Daytime upstream movements have been recorded for juveniles and adults in the Murray River, and individuals as small as 22 millimetres have been recorded migrating. Males mature at one to two years and females at two years. Eggs are released in the still waters of shallow, wetlands in October-February.

Species	Habitat group[1]	Migration and spawning habitats[2]
Murray-Darling rainbowfish, (*Melanotaenia fluviatilisi)*	Low Flow specialist (only spawn during low flow).	Breeding is seasonal, generally spring-summer when water temperature exceeds 20 degrees Celsius, in slow moving water or wetland habitats. Individuals as small as 21 millimetres have been recorded migrating upstream, most commonly in the afternoon and dusk.
Freshwater catfish (*Tandanus tandanus*)	Freshwater catfish (spawn in coarse sediment beds (usually sand or gravel) during any flow conditions).	Spawning occurs in spring and summer when water temperatures are 20 to 24 degrees Celsius. The nest is a circular to oval depression, 0.6 to 2.0 metres in diameter, constructed from pebbles and gravel, with coarser material in the centre. While young catfish may form loose schools and undertake movements to colonise new habitats, adults tend to be solitary when they are not breeding (Cadwallader and Backhouse 1983). Adult freshwater catfish are apparently non-migratory, remaining in the same section of river for most of their lives (Davis 1977).
Golden perch (*Macquaria ambiguai)*	Flood spawners: (Spawn and recruit following flow rises. Major spawning occurs during periods of floodplain inundation).	Adult and immature fish are migratory and extensive upstream movements of more than 1000 kilometres have been recorded for some adult fish. Outside the breeding season, individuals occupy home ranges of about 100 metres for weeks or months before relocating to another site where a new home range is established. Upstream movements by both immature and adult fish are stimulated by small rises in streamflow and most movement in the Murray occurs between October and April. Some fish may move downstream to spawn.
Murray cod (*Maccullochella peeli)*	Main channel specialists: (spawn and recruit under high or low flow in the main channel. Woody debris important habitat attribute).	Murray cod make an upstream migration of up to 120 kilometres to spawn in late winter/early spring when river levels are high. After spawning the fish move downstream again, returning to the same area they occupied before the migration, usually to exactly the same snag. Spawning occurs in spring and early summer when water temperatures exceed about 15 degrees Celsius. Eggs are usually deposited onto a hard surface such as logs, rocks or clay banks. The male guards the eggs during incubation. After hatching, larvae drift downstream for five to seven days, particularly by night in spring and summer.

4.3.6 Organic carbon cycling

River red gum forests are important in the cycling of organic carbon in lowland river systems in Australia (Robertson et al. 1999). Organic carbon is a major nutrient in freshwater systems and an important primary source of food in aquatic food webs. In forested catchments, the major terrestrial inputs of carbon to rivers are (Bunn et al. 2007):

- Coarse woody debris – logs and branches from riparian and floodplain vegetation;
- Particulate organic matter – litter inputs directly from riparian trees or washed from other areas of the floodplain; and
- Dissolved organic carbon – released from wetlands and floodplains and carried to the river on return flows.

Although there are no measures from within the Ramsar site itself, investigations on similar, river red gum forested floodplains in south-eastern Australia provide some understanding of the relative contributions of each of these sources and their role in maintaining not only the character of the Ramsar site, but in supporting surrounding river systems.

Coarse woody debris

Studies from within Barmah Forest Ramsar site indicate wood production in the river red gum forest varies between 89 and 360 grams of carbon per square metre per year, with higher rates of productivity on more frequently flooded portions of the floodplain (Bacon et al. 1993). Wood decomposes slowly with a half-life of approximately 140 years and as such the role of coarse woody debris may be more important as structural habitat for biofilms in terms of carbon production than as a direct release of organic carbon to receiving waters (Robertson et al. 1999).

Particulate organic carbon

Production of litter in river red gum forests is also variable, both seasonally and in response to frequency of inundation. Quantitative measures of leaf litter production from the adjacent Millewa Forest were between 89 and 230 grams of carbon per square metre per year (Robertson et al. 1999). Litter is more mobile than coarse woody debris and has a half-life of approximately one year in dry conditions or 50 days if inundated (Robertson et al. 1999).

Dissolved organic carbon

In addition to coarse woody debris and particulate organic matter, which must be broken down within the river / wetland to dissolved organic carbon in order to enter the food web; dissolved organic carbon can be directly transported from the forest to receiving waters. Inundation of the floodplain leads to mineralisation of organic carbon in litter and sediments. The result is often called “blackwater” due to the dark tannin stained colour of the water (Howitt et al. 2005). The period of time since the last flood, together with seasonal factors such as temperature influence the amount of carbon released (Howitt et al. 2005).

In addition to acting as a source of carbon to receiving aquatic ecosystems, floodplains also act as a store of organic carbon. In particular sediments containing particulate organic carbon may be deposited on the floodplain during inundation events. The fate of this carbon, however, is not well understood (Robertson et al. 1999).

4.4 Conceptual models

The critical components, processes and services, which combine to form the ecological character of the Barmah Forest Ramsar site, each feature complex interrelationships. Cycles of wetting and drying are fundamental to these floodplain ecosystems, affecting the physical, chemical and biological processes and functions. The duration, seasonality, frequency and intensity of wetting and drying determines the type of biota that occurs on the floodplain and wetting and drying can provide important cues for flora and fauna in reproductive cycles. Simple conceptual models of wet (Figure 27) and dry phases (Figure 28) illustrate some of the interactions between critical components, processes and services that are described for each phase below.

4.1 Wet phase (filling and inundated state)

The arrival of floodwaters brings about the following physical and chemical changes within the floodplain (Boon 2006):

- Dry and aerated sediments quickly become waterlogged and devoid of oxygen;
- Mineralisation and release of nutrients and carbon from the sediments and floodplain litter; and
- Depending on the water quality of source water, velocity of flooding and sediment type, the floodwaters may be highly turbid (particularly in channels where velocity is greatest) and sediments may be deposited on the low relief floodplain surface.

Biological processes that occur upon wetting include (Boulton and Brock 1999):

- Microorganisms (bacteria and algae) process mineralised nutrients and a “boom” of productivity commences;
- Egg and seed banks hatch/germinate;
- Plant propagules are brought in with the floodwaters from upstream environments;
- Fish and invertebrates arrive on the floodplain with the floodwaters;
- Aquatic plant growth is stimulated;
- Flowering in a number of species such as lignum is stimulated (Roberts and Marston 2000); and
- The release of nutrients and subsequent “boom” in productivity act as cues to initiate breeding of waterbirds, frogs, fish and turtles.

When inundated the following ecological processes can be expected (Boulton and Brock 1999):

- Productivity boom may be maintained for some time (depending on conditions of light, temperature and nutrients released into the water column;
- Submerged aquatic plants grow and flower, while amphibious aquatic plants exist in their aquatic form;
- Aquatic invertebrates occur in both larval (aquatic) stages as well as some emerging into mature aerial forms;
- Productivity boom provides important food resources for waterbirds, fish, frogs, turtles as well as insectivorous and nectivorous terrestrial species;
- Nesting of waterbirds in a variety of inundated habitats including inundated trees (e.g. egrets, ibis, cormorants); shrubs (e.g. coots, swamphens); and sedges and rushes (e.g. magpie geese; Australasian bittern);
- Frogs breeding in shallow water and inundated vegetation, tadpoles mature and grow;
- Turtles nesting on sandy island habitats, eggs hatch and juveniles feed and grow; and
- Fish breeding in inundated vegetation and woody debris; larval and juvenile forms within water column.

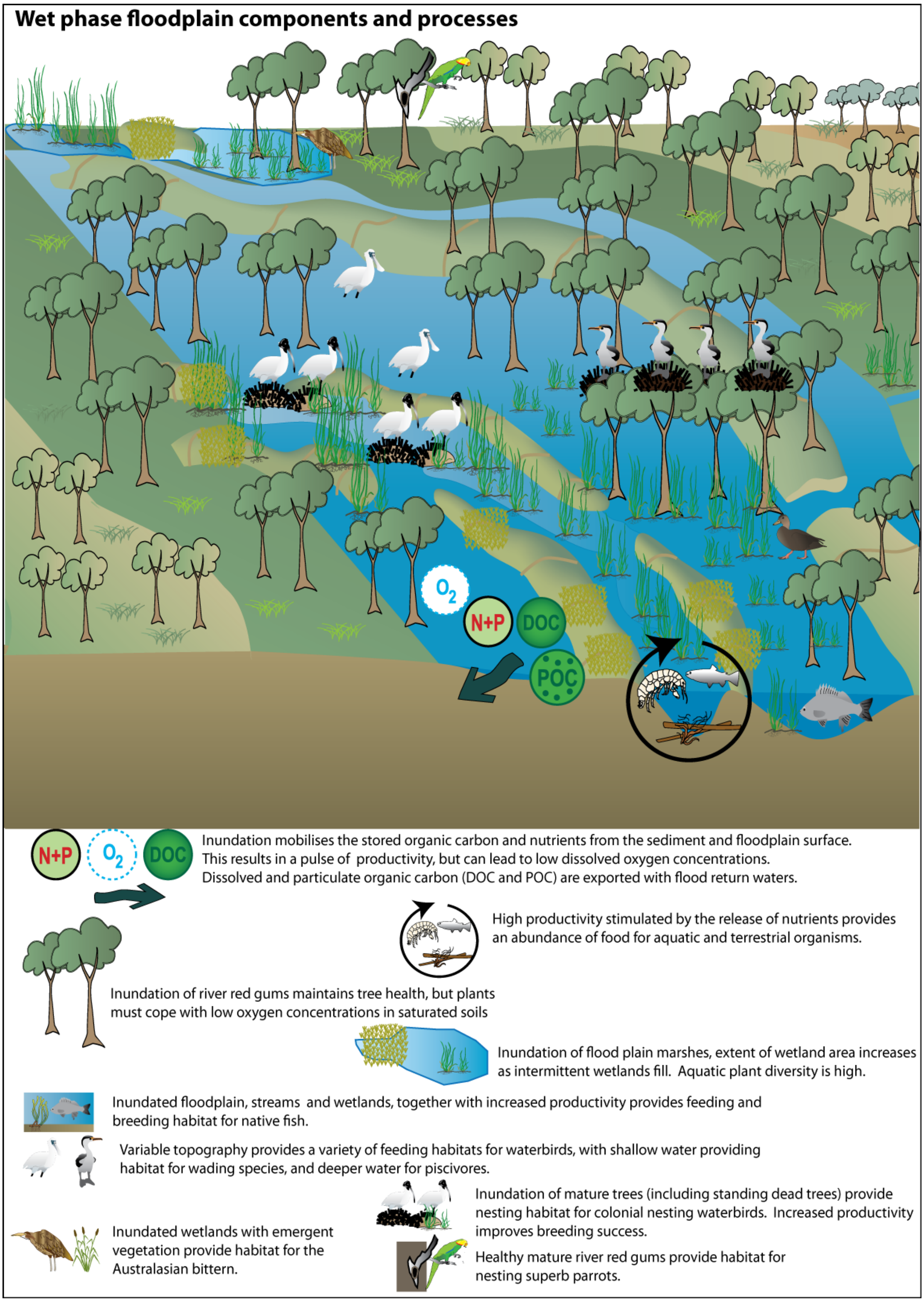

Figure 27: Simple conceptual model illustrating some of the interactions between critical components, processes and services in the Barmah Forest Ramsar site during times of floodplain inundation (wet phase).

4.2 Dry phase (drying and dry state)

The recession of floodwaters and subsequent drying of the soil results in the following ecological processes (Boulton and Brock 1999):

- As waters recede nutrients and salts become concentrated in floodplain wetlands as they dry by evaporation;
- Nutrients and organic carbon become stored in the sediment;
- Aquatic plants set seed to be stored dormant in the sediment for subsequent floods;
- Floodplain plants such as river red gum germinate and seedling emerge on the damp soil;
- Waterbirds fledge and disperse;
- Turtles migrate to nearby wet refuges, some aestivate;
- Fish return with receding waters to the river or remain in permanent channels.

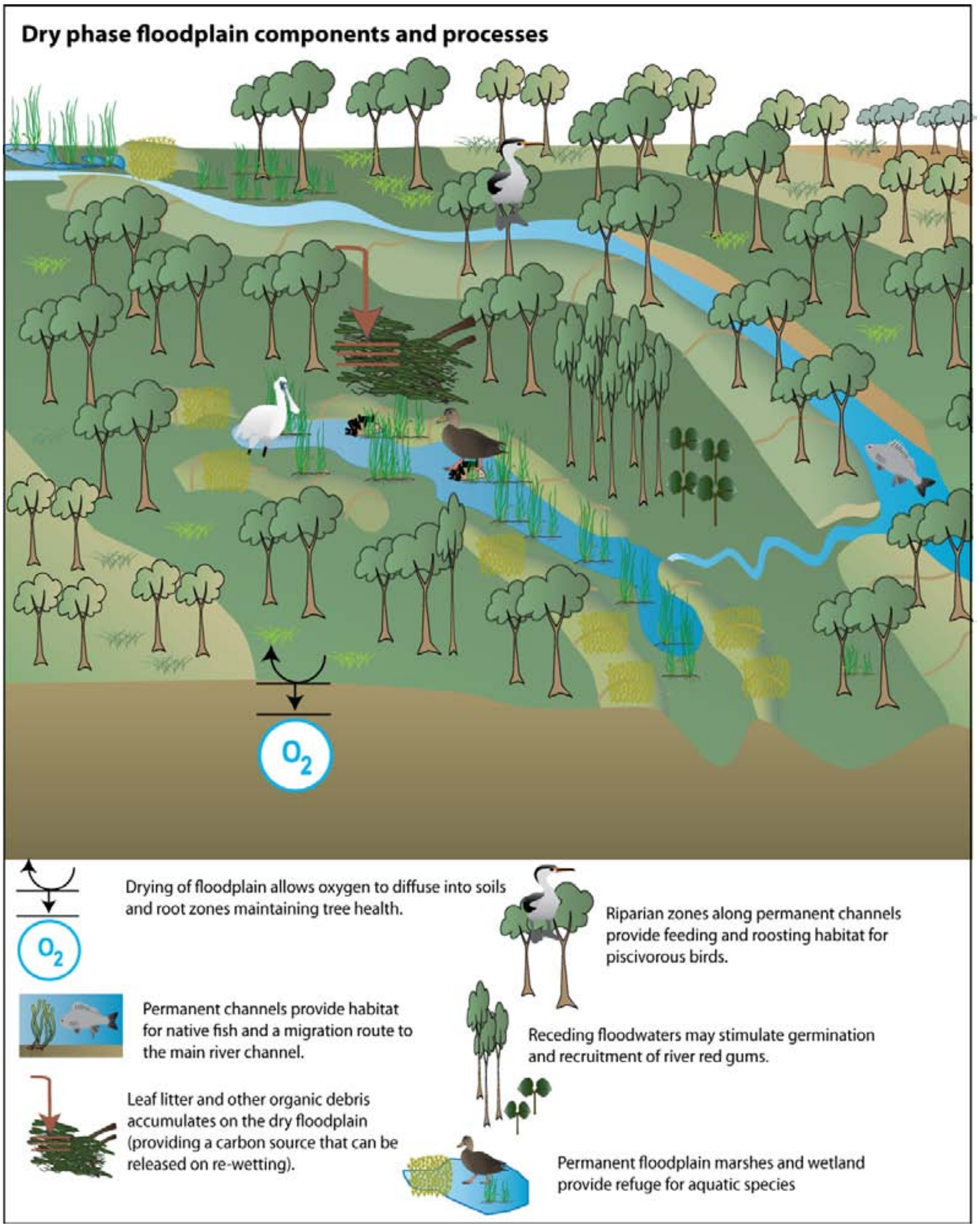

Figure 28: Simple conceptual model illustrating some of the interactions between critical components, processes and services in the Barmah Forest Ramsar site between floods (dry phase).

5. Limits of acceptable change

5.1 Process for setting Limits of Acceptable Change (LACs)

LACs are defined by Phillips (2006) as:

"…the variation that is considered acceptable in a particular measure or feature of the ecological character of the wetland. This may include population measures, hectares covered by a particular wetland type, the range of certain water quality parameter, etc. The inference is that if the particular measure or parameter moves outside the 'limits of acceptable change' this may indicate a change in ecological character that could lead to a reduction or loss of the values for which the site was Ramsar listed. In most cases, change is considered in a negative context, leading to a reduction in the values for which a site was listed".

LACs and the natural variability in the parameters for which limits are set are inextricably linked. Phillips (2006) suggested that LACs should be beyond the levels of natural variation. Setting limits in consideration with natural variability is an important but complex concept. Wetlands are complex systems and there is both spatial and temporal variability associated with all components and processes. Defining this variability so that trends away from "natural" variation can be reliably detected is not straightforward.

Hale and Butcher (2008) considered that it is not sufficient to simply define the extreme measures of a given parameter and to set LACs beyond those limits. What is required is a method of detecting change in pattern and setting limits that indicate a distinct shift from natural variability (be that positive or negative). This may mean accounting for changes in the frequency and magnitude of extreme events, changes in the temporal or seasonal patterns and changes in spatial variability as well as changes in the mean or median conditions.

The LACs described here represent what would be considered a possible change in ecological character at the site in absolute terms with no regard for detecting change prior to irrevocable changes in wetland ecology. Detecting change with sufficient time to instigate management actions to prevent an irrevocable change in ecological character is the role of wetland management and the management plan for a site should develop and implement a set of management triggers with this aim.

Additional Explanatory Notes for LACs

Limits of Acceptable Change are a tool by which ecological change can be measured. However, ECDs are not management plans and LACs do not constitute a management regime for the Ramsar site.

Exceeding or not meeting LACs does not necessarily indicate that there has been a change in ecological character within the meaning of the Ramsar Convention. However, exceeding or not meeting LACs may require investigation to determine whether there has been a change in ecological character.

In reading the ECD and the LACs, it should be recognised that the hydrology of many catchments in the Murray-Darling Basin is highly regulated, despite many of the wetlands forming under natural hydrological regimes that were more variable and less predictable. Many of the Ramsar wetlands of the Murray-Darling Basin were listed at a time when the rivers were highly regulated and water over allocated, with the character of these sites reflecting the prevailing conditions. When listed under the Ramsar Convention, many sites were already on a long-term trend of ecological decline.

While the best available information has been used to prepare this ECD and define LACs for the site, a comprehensive understanding of site character may not be possible as in many cases only limited information and data is available for these purposes. The LACs may not accurately represent the variability of the critical components, processes, benefits or services under the management regime and natural conditions that prevailed at the time the site was listed as a Ramsar wetland.

Users should exercise their own skill and care with respect to their use of the information in this ECD and carefully evaluate the suitability of the information for their own purposes.

LACs can be updated as new information becomes available to ensure they more accurately reflect the natural variability (or normal range for artificial sites) of critical components, processes, benefits or services of the Ramsar wetland.

5.2 LAC for the Barmah Forest Ramsar site

LACs have been set for the Barmah Forest Ramsar site based on conditions at the time of listing. However, it must be recognised that for some critical components and processes (particularly hydrology), long timeframes need to be considered to characterise variability. Where possible, site specific information has been used to statistically determine LAC. In the absence of sufficient site specific data, LACs are based on recognised standards or information in the scientific literature that is relevant to the site. In all these cases, the source of the information upon which the LACs have been determined is provided. However, it should be noted that for many of the critical components and processes there are limited quantitative data on which to set limits. In these instances, qualitative LACs have been recommended based on the precautionary principle. These will require careful review as better information is gained from future monitoring.

The Barmah Forest Ramsar site was listed under conditions of altered hydrology. A comparison of the water regime requirements of critical components such as vegetation (Table 19) with hydrology at the time of listing (Table 9) indicate that at the time of listing the hydrological regime may have been insufficient to maintain the character of the site in the long term. While LACs should be set for conditions at the time of listing, it is important to ensure that long term health of the critical components, processes and services, which depend on hydrology, is maintained. Obligations for contracting parties under the Ramsar Convention are to "protect and *enhance*" wetlands. However, LACs are not synonymous with management targets and should not be used to set ideal future benchmarks or targets. As such, LACs for hydrology have been set as conditions at the time of listing on the understanding that any further decrease or increase in the frequency and extent of floodplain inundation is likely to result in a change in character.

LACs are required for all identified critical components, processes, benefits and services (DEWHA 2008). However, due to the interrelated nature of components, processes and services a single LAC may in fact account for multiple components, process and services. For example, the LAC that addresses hydrology at Barmah Forest also covers the critical services of supporting a diversity of wetland types and physical habitat for waterbirds. If hydrology were significantly altered this would lead to a loss of the services. In order to limit repetition in the LACs for Barmah Forest, a hierarchical approach has been adopted where LACs have been set for components or processes, which in this case has also covered critical services.

The columns in Table 27 contain the following information:

Critical components, processes and services	The component, processes or service that the LAC is a measure of.
Baseline / supporting evidence	Baseline information (relevant to the time of listing) and any additional supporting evidence from the scientific literature and/or local knowledge.
Limit of Acceptable Change	The LAC.

Confidence level	The degree to which the authors ore confident that the LAC represents the point at which a change in character has occurred. Assigned as follows: High – Quantitative site specific data; good understanding linking the indicator to the ecological character of the site; LAC is objectively measureable. Medium – Some site specific data or strong evidence for similar systems elsewhere derived from the scientific literature; or informed expert opinion; LAC is objectively measureable. Low – No site specific data or reliable evidence from the scientific literature or expert opinion, LAC may not be objectively measurable and/or the importance of the indicator to the ecological character of the site is unknown.

Table 27: Limits of Acceptable Change for the Barmah Forest Ramsar site.

Critical components, processes and services	Baseline/Supporting evidence	Limit of Acceptable Change	Confidence level
Critical components and processes			
Hydrology	For establishing the LAC, the hydrology of the site can be characterised in terms of frequency and average duration for river flow thresholds that are considered important for critical components of the site. These are presented below for the time of listing (adapted from modelled 1984 level of development in Leitch 1989): • 10 400 megalitres a day (commence to flow into forest) – frequency is eight years in 10 and average duration is 100 days and longest dry period is 3.7 years; • 16 000 megalitres a day (moira grasslands) – frequency is seven years in 10, average duration is 90 days and longest dry period is 3.7 years; • 35 000 megalitres a day (overbank flow inundating approximately 60 percent of river red gum forest and 30 percent of river red gum woodland) – frequency is 11 years in 20, average duration is 63 days and longest dry period is 9.6 years; • 60 000 megalitres a day (inundation of all river red gum forest and woodland and black box woodland) – frequency is 12 years in 50, average duration is 21 days and longest dry period is 16.7 years. Ideally a LAC would be based on frequency and extent of inundation directly measured within the forest, but this is difficult to apply and more difficult to assess against. What is proposed is a LAC based on the frequency, and duration of flow events considered important for maintaining ecological character (Murray River at Yarrawonga).	*Minimum of 10 400 megalitres a day (Murray River at Yarrawonga) no less than seven years in any 10 year period, with a mean duration no less than 100 days; and a maximum interval of four years between the flow threshold.* *Minimum of 16 000 megalitres a day (Murray River at Yarrawonga) no less than seven years in any 10 year period, with a mean duration no less than 90 days; and a maximum interval of four years between the flow threshold.* *Minimum of 35 000 megalitres a day (Murray River at Yarrawonga) no less than 10 years in any 20 year period, with a mean duration no less than 60 days; and a maximum interval of 10 years between the flow threshold.* *Minimum of 60 000 megalitres a day (Murray River at Yarrawonga) no less than 12 years in any 50 year period, with a mean duration no less than 21 days; and a maximum interval of 12 years between the flow threshold.*	Medium

Critical components, processes and services	Baseline/Supporting evidence	Limit of Acceptable Change	Confidence level
	In addition, as the interval between floods is also critical for maintaining critical components, an Average Recurrence Interval based on the maximum intervals between events is also proposed. This is based on modelled conditions at the time of listing (as detailed above) with the exception of the 60 000 megalitres a day threshold, for which the 16.7 year maximum duration was considered to be too high to sustain the forests and woodlands (Jane Roberts, floodplain vegetation expert, personal communication). The LAC is assessed over time spans to account for the variability in hydrology at the site (i.e. to allow for meaningful means to be calculated for each of the specified flow thresholds within the assessment period).		
Vegetation – River red gum forests and woodland	The extent of river red gum forests and woodlands at the time of listing was (Chesterfield et al. 1984): • 21 500 hectares of river red gum forest • 2700 hectares of river red gum woodland In addition, there are benchmarks for tree condition (Cunningham et al. 2009) with 96% of the red gum forest and woodland in moderate or better condition in 2003. Although there is information on extent and condition for part of the Ramsar site, there is no indication of variability in either of these measures. In addition information on variability in these ecosystems from comparable sites could not be sourced. As such, an objective, statistically based LAC cannot be determined and a figure of 10 percent change has been selected informed by local knowledge and expert opinion of the steering committee.	*Extent of river red gum-dominated vegetation to be no less than:* • *19 350 hectares of river red gum forest* • *2400 hectares of river red gum woodland* *River red gum condition to be "moderate" (according to the method of Cunningham et al. 2009) or better for at least 80 percent of forest.*	Low
	Forest structure and structural diversity is an important characteristic of river red gum forests in terms of habitat value (Horner et al. (2010). The number of hollow bearing trees within the forest has been estimated at 15 per hectare (Thomson et al. undated). However variability is extremely high with a range from zero to over 60 trees per hectare. As such, it is not possible to set a LAC based on this information.	*Insufficient information to develop a LAC for forest structure at this point in time.*	Not applicable

Critical components, processes and services	Baseline/Supporting evidence	Limit of Acceptable Change	Confidence level
Vegetation – Floodplain marshes	Extent of floodplain marshes (Chesterfield et al. 1984): • *1500 hectares moira grass* • *500 hectares of giant rush* As with the river red gum extent above, there is no indication of variability but extent of inundation and community composition will vary considerably over wetting and drying cycles. As such, an objective, statistically based LAC cannot be determined and a figure of 10 percent change has been selected informed by local knowledge and expert opinion of the steering committee. Ideally a LAC would also be set for vegetation community composition. However, there are insufficient data at this stage upon which a LAC can be based.	*Extent of floodplain marshes to be no less than:* • *1350 hectares moira grass* • *450 hectares of giant rush*	Moderate
Vegetation – threatened species	The site supports the nationally threatened Mueller daisy (*Brachyscome muelleroides*) and swamp wallaby-grass (*Amphibromus fluitans*). There is no indication of the extent of location of these species at the time of listing and there are only ad hoc records from more recent times. The species are both perennial and as such a LAC is proposed based on presence only.	*Presence of Mueller daisy* (*Brachyscome muelleroides*) and *swamp wallaby-grass (Amphibromus fluitans) in permanent and intermittent wetlands within the site.*	Low
Native fish (species richness)	Data for native fish are limited from the Ramsar site. Quantitative data are available for the Barmah-Millewa Forest with an average abundance of native fish (2003 to 2006) of 12 000 ± 2700 (mean ± standard deviation; n=3; King et al. 2007). A total of 15 native fish species were recorded in 2002 – 2006 (King et al. 2007). The survey areas were however, not limited to the Ramsar site and this is insufficient to develop a quantitative LAC. There is a lack of underlying knowledge of variability in fish species richness and the relationship with ecological character. As such the LAC has been developed based on expert opinion (L. Beesley, DSE, personal communication May 2010) with respect to fish that are characteristic of the site and would be expected to be present.	*Presence of the following species in no less than two in five annual surveys:* • *Australian smelt (Retropinna semoni)* • *Carp gudgeons (Hypseleotris spp.)* • *Dwarf flat-headed gudgeon (Philypnodon macrostomus)* • *Flat-headed gudgeon (Philypnodon grandiceps)* • *Unspecked hardyhead (Craterocephalus stercusmuscarum fulvus)* • *Murray-Darling rainbowfish (Melanotaenia fluviatilis).*	Low
Native fish (threatened species)	Three threatened native species of fish are known from the site (Jones 2006; King et al. 2007; Davies et al. 2008). Population size, dynamics and distribution not fully understood.	*Presence of Murray cod, trout cod and silver perch in three out of five of annual surveys.*	Low

Critical components, processes and services	Baseline/Supporting evidence	Limit of Acceptable Change	Confidence level
Wetland birds (abundance)	A total of 64 species of wetland bird have been recorded from within the site. However, there is no indication of the number of species that regularly utilise the habitats within the site. There is evidence that the site "regularly" supports thousands of colonial nesting waterbirds during significant flood events with successful breeding occurring on 10 occasions between 1962 and 1981 (DSE 2008). LAC set based on the findings of Leslie (2001) and a definition of successful breeding of 80 percent of chicks fledged (Rick Webster, NPWS, personal communication).	*Successful breeding (80 percent chicks fledged) of colonial nesting waterbirds in at least five years in 10.* *Thousands of colonial nesting birds in no less than two years in 10.*	Low
Wetland birds (threatened species)	The site supports at least two threatened species of wetland bird (Australasian bittern and superb parrot, with regular records of both species (MDBC 2007) However, there are no population estimates for either species. Insufficient data from the Ramsar site to set a quantitative LAC.	*Presence of Australasian bittern when Tall Marsh is inundated.* *Presence of superb parrot and evidence of breeding annually.*	Medium High
Critical Services			
Diversity wetland types	This critical service is linked to changes in the frequency and duration of wetland wetting and drying as well as changes in extent and condition of wetland vegetation. Therefore no direct LAC has been developed and instead the critical service will be assessed indirectly through changes in the frequency and duration of specific flow events, extent and condition of river red gum forests and woodlands and extent of floodplain marshes.	*See LAC for hydrology and vegetation*	Not applicable
Biodiversity	This critical service relates not only to species richness, but also to the presence and extent of moira grasslands within the site. A LAC based on a total species census is not sensible in terms of assessment and it is likely that not all species that use the site have yet to be recorded. As such, surrogates in terms of fish, vegetation and waterbirds will be used to assess against this service.	*See LAC for wetland birds, fish and vegetation.*	Not applicable

Critical components, processes and services	**Baseline/Supporting evidence**	**Limit of Acceptable Change**	**Confidence level**
Physical habitat	This critical service is linked to changes in the frequency and duration of wetland wetting and drying as well as changes in extent and condition of wetland vegetation. In addition, wetland bird abundance can be used as a surrogate measure. Therefore no direct LAC has been developed and instead the critical service will be assessed indirectly through changes in the frequency and duration of specific flow events, extent and condition of river red gum forests and woodlands, extent of floodplain marshes and abundance of wetland birds.	*See LAC for hydrology, vegetation and wetland birds.*	Not applicable
Threatened species	This critical service is indicated by the presence of threatened species at the site. Therefore no direct LAC has been developed and instead the critical service will be assessed through presence of threatened species.	*See LAC for wetland birds, fish and vegetation*	Not applicable
Ecological connectivity	The site maintains connectivity between the river and floodplain wetlands and channels for fish spawning and recruitment. This service is maintained by hydrology and can also be indicated by the species richness and abundance of native fish. Therefore no direct LAC has been developed and instead the critical service will be assessed indirectly through changes in hydrology and native fish populations.	*See LAC for hydrology and native fish.*	Not applicable
Carbon cycling	This service is provided by the uptake of carbon by vegetation, the deposition of organic matter (coarse woody debris and litter) on the floodplain and the mobilisation of particular and dissolved organic carbon to receiving river systems with flood return waters. This service is maintained by vegetation extent, forest structure and hydrology. Therefore no direct LAC has been developed and instead the critical service will be assessed indirectly through changes in hydrology and floodplain forest extent.	*See LAC for hydrology and vegetation*	Not applicable

6. Threats to Ecological Character

Wetlands are complex systems and an understanding of components and processes and the interactions or linkages between them is necessary to describe ecological character. Similarly threats to ecological character need to be described not just in terms of their potential effects, but the interactions between them. One mechanism for exploring these relationships is the use of stressor models (Gross 2003). The use of stressor models in ecological character descriptions has been suggested by a number of authors to describe ecological character (Phillips and Muller, 2006; Hale and Butcher 2008) and to aid in the determination of limits of acceptable change (Davis and Brock 2008).

Stressors are defined as (Barrett et al. 1976):

"*physical, chemical, or biological perturbations to a system that are either (a) foreign to that system or (b) natural to the system but applied at an excessive [or deficient] level*"

In evaluating threats it is useful (in terms of management) to separate the driver or threatening activity from the stressor. In this manner, the causes of impacts to natural assets are made clear, which provides clarity for the management of natural resources by focussing management actions on tangible threatening activities. For example, soil disturbance and compaction may be identified as a threat to native vegetation in the forest. However, management actions cannot be targeted at soil disturbance without some understanding of why the disturbance is taking place. By identifying the threatening activities that could contribute to soil disturbance (e.g. feral horses, recreational vehicles), management actions can be targeted at these threatening activities and reduce the impact to the wetland.

There are a number of threats that could significantly impact on the ecological character of the site. The stressor model (Figure 29) illustrates the threats (threatening activities), stressors and resulting ecological effects on critical components, processes and services in the Barmah Forest Ramsar site.

It should be noted that at the time of listing, the site was actively managed for timber harvesting with an estimated 2.5 million cubic metres of river red gum logs harvested between 1860 and 1990 (DCE 1992). Barmah Forest was recognised as a "working forest" at the time of designation as a Wetland of International Importance with the ecological character at the time reflecting the continuing use of these forests, including timber harvesting. While forest management many have provided some benefits, "disturbance to vegetative community through cutting/clearing" is recognised as a threat to Ramsar wetlands (Wetlands International, 2008). However, the site was declared a National Park in April 2010, and timber harvesting no longer is permitted. As such it is not considered a current threat to the character of the Ramsar site and has not been included in the description below. It should be noted, however, that some of the impacts of forestry may be long lasting and that the effects to the ecological character of the site may be evident for sometime after the activity has ceased.

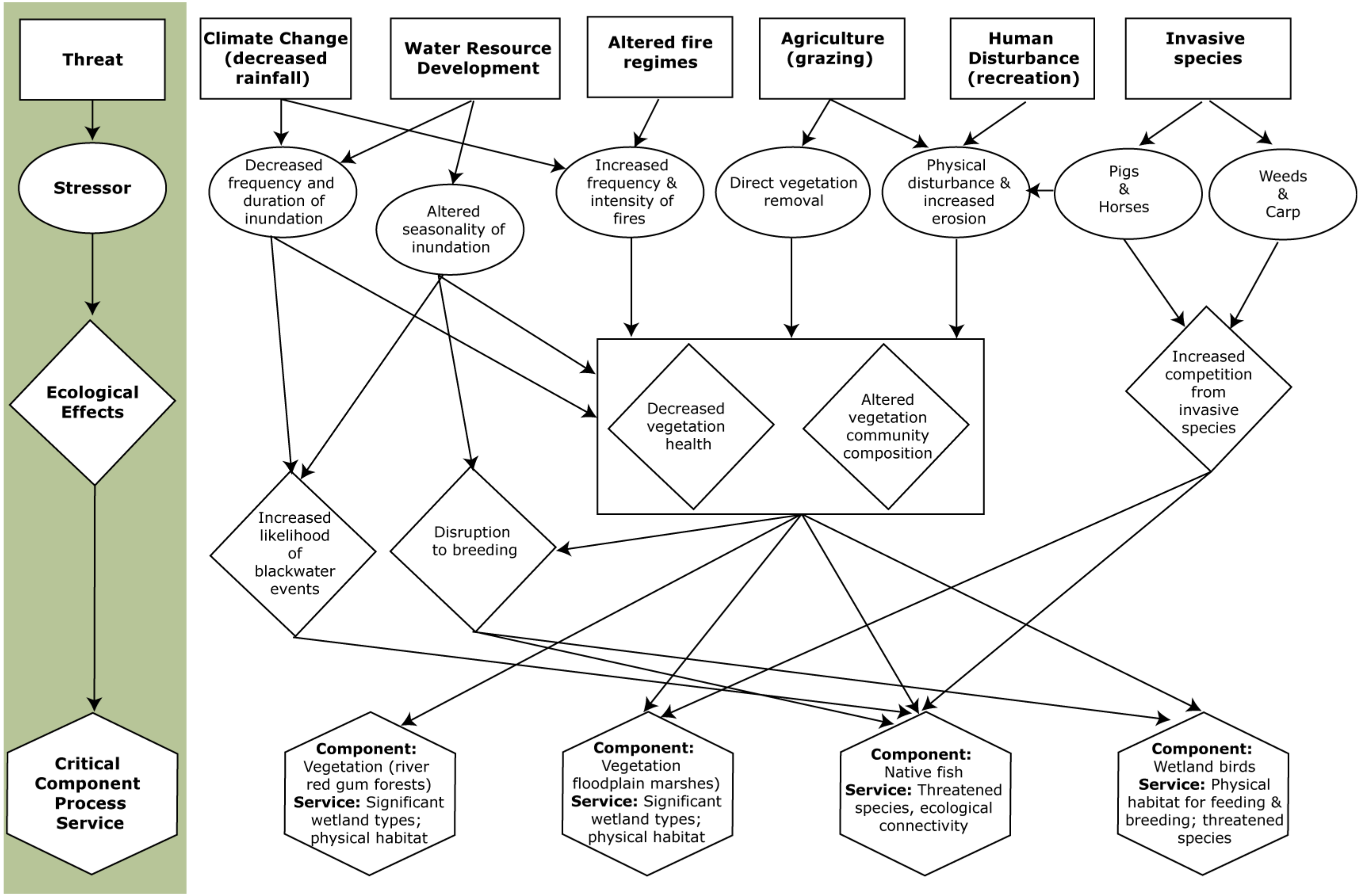

Figure 29: Stressor model of the Barmah Forest Ramsar site (after Gross 2003 and Davis and Brock 2008).

6.1 Water resource use

Water resource use in the Murray-Darling Basin involves large scale water interception, delivery and extraction which has resulted in major changes to the hydrology of the Murray River (Gippel and Blackham 2002; MDBC, 2008) and floodplain wetlands (MDBC, 2007). Adverse alterations to hydrology as a result of river regulation have been identified as the most significant threat to river and floodplain health in the Murray-Darling Basin (Thoms et al. 2000). The Hume Dam was constructed in 1934. Together with other regulatory structures, water delivery and operational rules, this has been influencing the hydrology of Barmah Forest for a number of decades and were in place at the time of listing as a Wetland of International Importance. However, allocation was not capped until 1995, a decade after listing. Altered hydrology should still be considered a threat to the ecological character of the site as the negative impacts of regulation are still developing. River red gum forests are long-lived, with records of trees 500 to 1000 years of age (Jacobs 1955). As such, past water resource management could have current and future impacts on these ecosystems through time-delayed or "lag" effects. Such effects act either directly on the systems or indirectly by reducing their resilience to other environmental factors such as drought, climate change, grazing or introduced species, or by changing the competitive interactions among different species.

Flow seasonality, magnitude and frequency have all been altered by water resource development. There has been a decline in moderate floods that inundate the areas of the floodplain that are covered in river red gum forest and woodland forest (Leitch 1989; MDBA 2010). In addition, there has been an increase in small floods in summer and autumn that cover 10 percent of the forest, particularly low lying wetland areas (Ladson and Chong 2005). Large floods that result in widespread inundation (including of Black Box communities higher on the floodplain) have been less affected (Maheshwari et al. 1995) and flood recurrences for these events remain close to natural (MDBA 2010).

The potential ecological responses to altered hydrology in the Ramsar site are wide reaching (Gippel and Blackham 2002). Particular effects to identified critical components, process and services in the Ramsar site include:

- Decreased condition of river red gums as a result of decreased frequency and duration of inundation (Bren 1988; Cunningham et al. 2009);
- Decreased extent of moira grass (*Pseudoraphis spinescens*) from replacement by *Myriophyllum propinquum* (due to increased frequency of small floods) and encroachment by river red gums (attributed to a decrease in medium floods) (Bren 1992);
- Increase in exotic flora species, due to decreased floodplain inundation frequency (Stokes et al. 2010);
- Decreased breeding numbers and successful fledging events of colonial nesting waterbirds due to a decrease in frequency and extent of moderate floods (Leslie 2001);
- Impacts to native fish populations with low flow conditions having a negative effect on the spawning and recruitment of native fish, including the reduction in the recruitment of carp gudgeons (*Hypseleotris sp.*), southern pygmy perch (*Nannoperca australis*) and golden perch (*Macquaria ambigua*); but a favourable effect on the spawning and recruitment of pest species such as common carp (*Cyprinus carpio*) (MDBC 2008); and
- Increased incidence and intensity of blackwater events due to reduced frequency of inundation, coupled with unseasonal inundation (during warmer months); resulting in very low dissolved oxygen concentrations and fish deaths.

6.2 Climate change

The CSIRO Murray-Darling Basin Sustainable Yields Project (CSIRO 2008; Chiew et al. 2008) has modelled the effect of climate change and related factors on the water resources in the Murray-Darling Basin, including predictions for the TLM Icon Sites. Models were produced for four climate scenarios: historical climate with current development, recent climate with current development, future climate with current development and future climate with future development. Under the future climate models, there was a range of potential climate estimates ranging from extreme wet to extreme dry. These different modelled scenarios resulted in a range of predictions; however, it is likely that there will be less rainfall in the Murray Catchment and increased temperatures. The median estimate is for a 10 percent decrease in average annual run-off, while extreme estimates range from a 37 percent reduction to a seven percent increase in average annual runoff (CSIRO 2008).

Almost all modelled scenarios predicted an increase in the interval between flooding of the Barmah Forest Ramsar site. This reduction in floodplain and wetland inundation is likely to exacerbate the effects of river regulation already observed at the site with an increase in stress to vegetation and fauna communities.

6.3 Altered fire regimes

Although mature river red gum trees can survive low intensity fires (MacNally and Parkinson 2005) saplings are fire-sensitive (Dexter 1978). Fires of even moderate intensity are sufficient to damage the cambium and leave the stem susceptible to secondary attack by fungal pests. As this species lacks a lignotuber, high intensity fires will generally result in significant mortality. Historically, seasonal flooding maintained grasses in a generally uncured state over the hotter summer months thereby reducing available fuels and the overall bushfire hazard. With decreased inundation, fuel loads in the understorey can increase and result in intensive fires if ignited.

6.4 Invasive species

There are over 100 species of introduced flora within the Barmah Forest Ramsar site and weed cover has been described as extensive (DSE 2003b). A number of terrestrial weeds have been competitively advantaged by the reduced frequency of inundation (Stokes et al. 2010) and there has been a spread of the invasive aquatic species arrowhead (*Sagittaria Platyphylla*) within the streams and channels of the forest in recent years (MDBA 2010). A 2008 survey reported a total area of over 34 000 square metres infested with arrowhead in the Barmah Millewa Forest (Maxwell 2008). These have displaced native flora species and reduced habitat for aquatic fauna.

Feral horses have been identified as a significant threat to the Barmah Forest ecosystem (Parks Victoria and DSE 2007). Approximately 200 feral horses are estimated to reside in the forest causing impacts to soil structure, wetland habitats and increasing the spread of weed species (Parks Victoria and DSE 2007).

The Barmah-Millewa forest has been identified as a potential recruitment zone for carp and they comprised 80 percent of the fish biomass in 1999 to 2001 (Stuart and Jones 2002). Carp compete with native fish and may contribute to water quality deterioration by increasing turbidity and bank erosion. In addition, significant numbers of other exotic fish species have been recorded within the site including eastern gambusia (*Gambusia holbrooki*), redfin (*Perca fluviatilis*) and oriental weatherloach (*Misgurnus anguillicaudatus*), which are known to cause significant impacts to native fish and other aquatic fauna such as invertebrates and frogs.

6.5 Human disturbance

Un-managed recreational activities can have a negative impact on wetland ecosystems. For example, vehicle tracks can compact the soil and impact on flora and fauna and increase access for introduced predators such as foxes. Recreational activities can also degrade habitat: e.g. digging for bardi grubs disturbs the soil, which promotes weed germination; and power boating activities which can damage river bank vegetation and contribute to soil erosion and sedimentation of rivers (VEAC 2008).

A potentially significant threat to the ecological character of the Ramsar site from public use pressures is from illegal firewood collection, particularly the practice of removing fallen timber. Fallen timber is an important habitat resource for a large number of animal species within river red gum forests. MacNally et al. (2002) estimated that more than 40 tonnes of fallen timber per hectare is required to sustain the populations of some vertebrate species such as the yellow-footed antechinus (*Antechinus flavipes*). The yellow-footed antechinus is not a wetland-dependent species but is an indicator of the value of fallen timber in river red gum forests. In addition, fallen timber is important to microorganisms, invertebrates and vertebrate species and as a carbon source and shelter substrate for fish and other aquatic organisms. Removal of significant amounts of timber can have negative effects on biodiversity and species richness as well as impacts to carbon and nutrient cycling through effects on the detrital food chain.

6.6 Summary of threats

Although a risk assessment is beyond the scope of an ECD, the DEWHA (2008) framework states that an indication of the impacts of threats to ecological character, likelihood and timing of threats should be included. The major threats considered in the previous sections have been summarised in Table 28.

Table 28: Summary of the main threats to the Barmah Forests Ramsar site.

Actual or likely threat or threatening activities	Potential impact(s) to wetland components, processes and/or service	Likelihood[1]	Timing[2]
Increased water resource development (decreased frequency and duration of inundation; altered seasonality of inundation).	Reduced health and extent of river red gum forests and floodplain marshes. Altered vegetation community composition including increase in exotic flora species. Decreased breeding and fledging success of colonial nesting waterbirds. Negative effect on the spawning and recruitment of native fish. Increased incidence and intensity of blackwater events.	Low	Current
Climate change (increased temperatures and decreased rainfall).	Exacerbate effects of water resource development and altered fire regimes.	Certain	Long-term
Altered fire regimes (increased frequency and intensity of fires).	Death of mature river red gums. Adverse changes to forest structure. Loss or degradation of habitat.	Medium	Current
Invasive species (e.g. weeds, carp, horses).	Predation or competition with native flora and fauna. Increased risk of destructive wildfire through increased understorey biomass.	Certain	Current
Human disturbance (recreation)	Loss or degradation of habitat through unauthorised firewood collection. Soil and riparian zone degradation by off road vehicles or watercraft. Increased risk of destructive wildfire.	Medium	Current

[1] Where Certain is defined as known to occur at the site or has occurred in the past; Medium is defined as not known from the site but occurs at similar sites; and Low is defined as theoretically possible, but not recorded at this or similar sites.
[2] Where Current is defined as happening at the time of writing (2010); Long-term is defined as greater than 10 years.

7. Current Ecological Character and Changes Since Designation

7.1 Changes in land use

From 1 April 2010, the Barmah Forest Ramsar site (formally comprised of State forest, State Park and Reference Areas) was reserved as national park under the Victorian *Parks and Crown Land Legislation Amendment (River Red Gum) Act 2010.* These alterations to land tenure have resulted in major land use changes including a restriction of logging activities in the area.

Permitted activities in the national park include camping within designated areas, development/enhancement of accommodation facilities within designated areas, horse riding within designated areas, the use of motor vehicles (cars and trail bikes) within designated areas and the regulated taking of firewood for personal use until June 2011 (DSE unpublished 2011).

7.2 Changes in critical components, processes and services

The assessment of changes since designation in 1982 for the Barmah Forest Ramsar site is hampered by a lack of baseline data from around the time of listing. This is particularly so for biotic critical components, processes and services. An assessment of current conditions with respect to LAC is provided in Table 29 and illustrates the problems in assessing change at this site.

There is evidence that the hydrology of the site has changed in recent years and the LAC for small and medium flood frequencies and duration has been exceeded (Table 29). However, whether this is a result of sustained change or the effects of the recent (2000 to 2010) drought is unknown. It is likely due to a combination of a number of factors that include water resource development, climate change and shorter term climatic cycles.

On the basis of available information, the LAC for frequency of successful breeding of colonial nesting waterbirds (at least five years in ten) has been exceeded. Again, it is unknown whether this is a result of sustained change or the effects of the prolonged drought from 2000 to 2010. As waterbird breeding events are closely linked to hydrology the same factors are likely to apply.

There has been a decline in tree health from 2003 to 2009 (Cunningham et al. 2009), which reflects the decreased floodplain inundation in the last decade. However, the LAC for this component has not been exceeded. The extent of moira grass has declined since the time of listing, with the encroachment of both giant rush and river red gum into grasslands. Mapping of giant rush expansion at Barmah Lake provides an indication of the magnitude of change in extent of this species (DPI 2009; Figure 30). This expansion has been at the expense of moira grass and open water habitats (Keith Ward, GBCMA, personal communication). However, the current extent of both giant rush and moira grasslands is not provided in DPI (2009) and remains a knowledge gap.

It is important to note that information provided in this ECD does not constitute an assessment of change in ecological character for this Ramsar site. A preliminary assessment will be undertaken by the Australian Government (DSEWPaC) in consultation with the Victorian Government to determine whether a formal assessment is required. This process follows the *National Guidance on Notifying Change in Ecological Character of Australian Ramsar Wetlands (Article 3.2) – Implementing the Ramsar Convention in Australia* (DSEWPaC 2009) which was developed by Australian and state/territory governments.

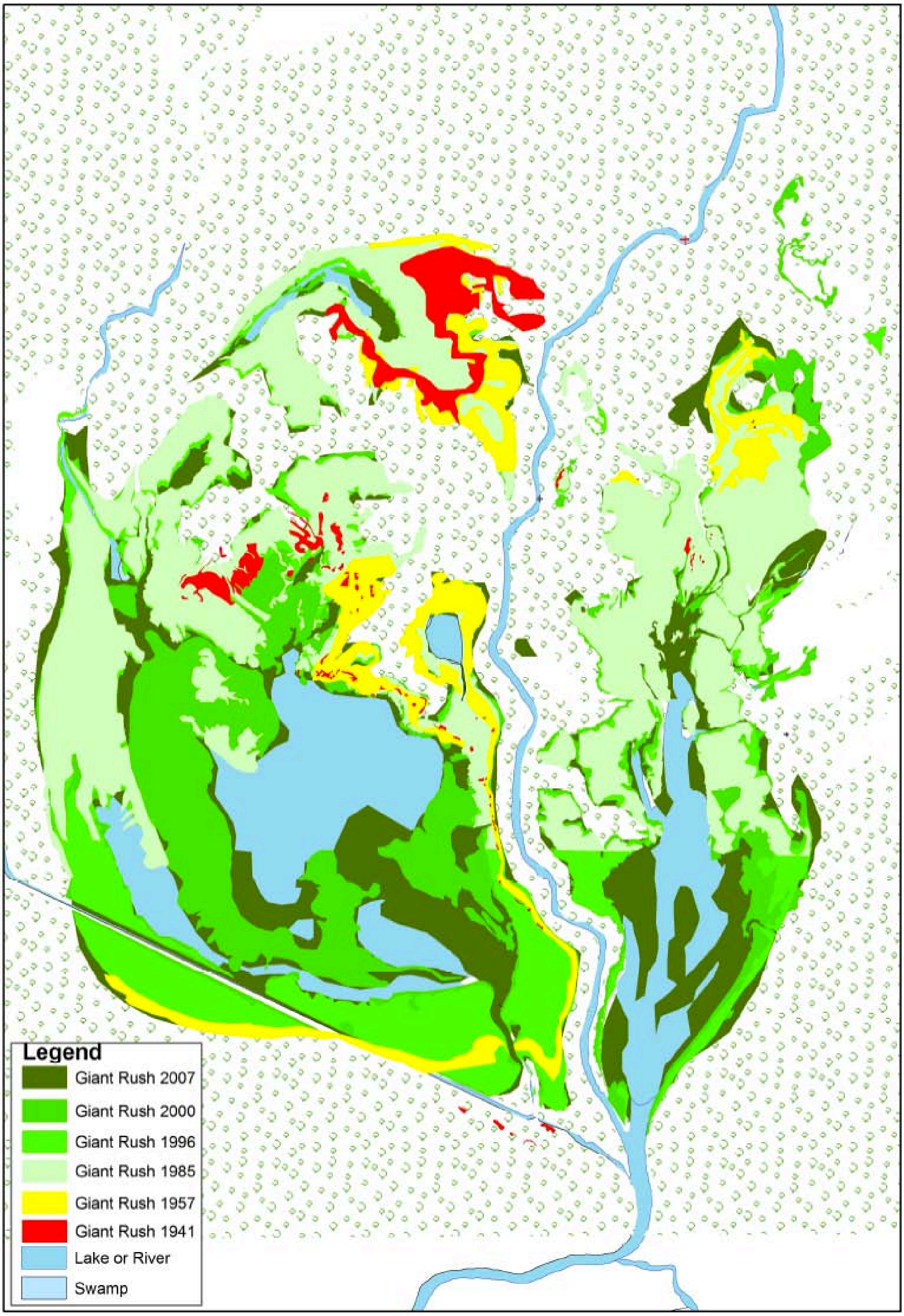

Figure 30: Spread of giant rush at Barmah Lake (DPI 2009). Of most relevance to this ECD is the change since 1985 (close to the time of listing).

Table 29: Assessment of current conditions against LAC for the Barmah Forest Ramsar site.

Component / process	Limit of Acceptable Change	Current conditions	Confidence in LAC assessment
Hydrology	*Minimum of 10 400 megalitres a day (Murray River at Yarrawonga) no less than seven years in any 10 year period, with a mean duration no less than 100 days; and a maximum interval of four years between the flow threshold.* *Minimum of 16 000 megalitres a day (Murray River at Yarrawonga) no less than seven years in any 10 year period, with a mean duration no less than 90 days; and a maximum interval of four years between the flow threshold.* *Minimum of 35 000 megalitres a day (Murray River at Yarrawonga) no less than 10 years in any 20 year period, with a mean duration no less than 60 days; and a maximum interval of 10 years between the flow threshold.* *Minimum of 60 000 megalitres a day (Murray River at Yarrawonga) no less than 12 years in any 50 year period, with a mean duration no less than 21 days; and a maximum interval of 12 years between the flow threshold.*	Based on flow data from the Murray River downstream of Yarrawonga: *10 400 megalitres per day in nine of the last 10 years, average duration of 90 days, maximum interval of 1.5 years.* **LAC for duration exceeded; however, here is little evidence to suggest there has been a change to the ecological character of the site since the time of listing. The extended period of drought from 2000 to 2010 may have impacted on the duration of flooding.** *16 000 megalitres a day in six years in past 10 years, average duration 32 days, maximum interval five years.* **LAC for frequency, duration and maximum dry interval exceeded; however, there is little evidence to suggest there has been a change to the ecological character of the site since the time of listing. The extended period of drought from 2000 to 2010 may have impacted on the frequency and duration of flooding and maximum dry interval.** *35 000 megalitres a day in seven years in past 20 years, average duration 60 days, maximum interval 10 years.* **LAC for frequency exceeded; however, there is little evidence to suggest there has been a change to the ecological character of the site since the time of listing. The extended period of drought from 2000 to 2010 may have impacted on the frequency of flooding.** *60 000 megalitres a day in 17 years in the past 50 years, average duration 27 days, maximum interval 10 years.* **LAC has not been exceeded.**	Medium

Component / process	Limit of Acceptable Change	Current conditions	Confidence in LAC assessment
Wetland vegetation	*Extent of river red gum-dominated vegetation to be no less than:* • *19 350 hectares of river red gum forest* • *2400 hectares of river red gum woodland* *River red gum condition to be "moderate" (according to the method of Cunningham et al. 2009) or better for at least 80 percent of forest.*	EVC mapping of forest extent in 2005 does not use the same categories: 18 900 hectares of river red gum forest; 2700 river red gum woodland, 2450 mixed forest and woodland. Given the differences between mapping techniques, this must be considered to be met. Cunningham et al. (2009) indicated that 95 percent of trees were in moderate or better condition. **LAC has not been exceeded.**	Medium
	Extent of floodplain marshes to be no less than: • *1350 hectares moira grass* • *450 hectares of giant rush*	There is no quantitative data for extent of moira grass and giant rush. However DPI (2009) mapping indicates that giant rush has expanded since the time of listing, at the expense of moira grass. **LAC may have been exceeded but there is insufficient evidence.**	Low
	Presence of Mueller daisy (*Brachyscome muelleroides*) and *swamp wallaby-grass (Amphibromus fluitans) in permanent and intermittent wetlands within the site.*	Mueller daisy was recorded as recently as 2004 (Lucas 2010) and swamp wallaby-grass as recently as 2005 (DSE unpublished). **LAC has not been exceeded.**	Medium
Native fish	*Presence of the following species in no less than 2 in five annual surveys:* • *Australian smelt (Retropinna semoni)* • *Carp gudgeons (Hypseleotris spp.)* • *Dwarf flat-headed gudgeon (Philypnodon macrostomus)* • *Flat-headed gudgeon (Philypnodon grandiceps)* • *Unspecked hardyhead (Craterocephalus stercusmuscarum fulvus)* • Murray-Darling rainbowfish *(Melanotaenia fluviatilis).*	Surveys in 2007 to 2009 resulted in all of these species being recorded in the Barmah Forest (Rouke and Tonkin 2009). **LAC has not been exceeded.**	High
	Presence of Murray cod, trout cod and silver perch in three out of five of annual surveys.	Surveys in 2007 to 2009 resulted in all of these species being recorded in the Barmah Forest (Rouke and Tonkin 2009). **LAC has not been exceeded.**	High

Component / process	Limit of Acceptable Change	Current conditions	Confidence in LAC assessment
Wetland birds	*Successful breeding (80 percent chicks fledged) of colonial nesting waterbirds in at least five years in 10.* *Thousands of colonial nesting birds in no less than two years in 10.*	Breeding records for colonial nesting waterbirds were presented in DSE (2008) with breeding recoded for 10 years in the 20 year period between 1961 and 1981. In more recent times, colonial waterbird breeding has been recorded in 1983, 1989, 1992, 2000/01, 2001/02 2002/03, 2005/06 and 2010/11 (DSE unpublished, O'Connor and Ward 2003, MDBC 2007, Rick Webster personal communication). In the ten-year period from January 2000 to December 2009 there were two large breeding events of colonial nesting waterbirds (in 2000/01 and 2005/06), with thousands of birds recorded on both occasions (MDBC 2007; MDBC 2008). In addition, thousands of waterbirds bred successfully in 2010/11 (Keith Ward, GBCMA, personal communication). **LAC for successful breeding in five years of ten has been exceeded; however, there is little evidence to suggest there has been a change to the ecological character of the site since the time of listing. The extended period of drought from 2000 to 2010 may have impacted on the frequency of successful waterbird breeding events.**	High
	Presence of Australasian bittern when Tall Marsh is inundated. *Presence of superb parrot and evidence of breeding annually.*	Australasian bittern was recorded in 2010/2011 and suspected of breeding (Keith Ward, GBCMA, personal communication). Superb parrot nesting recorded in 2005/06 (Webster 2007). **LAC has not been exceeded.**	High

8. Knowledge Gaps

Throughout the ECD for the Barmah Forest Ramsar site, mention has been made of knowledge gaps and data deficiencies for the site. While there is potentially a large list of research and monitoring needs for this wetland system, it is important to focus on the purpose of an ECD and identify and prioritise knowledge gaps that are important for describing and maintaining the ecological character of the wetland. Since being identified as a TLM Icon Site, increased assessment and monitoring has been undertaken within the Barmah Forest Ramsar site and the newly developed icon site monitoring program covers all identified critical CPS. There is a lack of knowledge about the condition of the site at the time of listing, but this cannot, for the most part be addressed retrospectively. As such, there are relatively few critical knowledge gaps remaining for the forest Table 30.

Table 30: Knowledge Gaps for the Barmah Forest Ramsar site.

Critical components, processes and services	Knowledge Gap	Recommended Action
Hydrology	Extent, frequency and duration of inundation for wetlands within the site benchmarked at the time of listing.	Regular flood inundation mapping.
Wetland vegetation – floodplain forests	The condition of forests at the time of listing. Forest structure at the time of listing: tree age classes, coarse woody debris loads.	Current monitoring programs under The Living Murray collect data on forest condition and proposed monitoring includes age structure. Data collected to date has been from a short period of time (post 2003) and includes mostly drought years. An understanding of the variability of forest condition under different climatic conditions will improve over time with current monitoring.
Wetland vegetation – floodplain marshes	The extent, community composition and condition of floodplain marshes at the time of listing. In particular, current extent of moira grasslands within the site is a critical knowledge gap.	Current and proposed monitoring programs conducted by MDBA and GBCMA include assessment of floodplain marsh vegetation. Results of current mapping and community composition programs will inform on key knowledge gaps such as the current extent of moira grasslands within the site.
Native fish	Species composition, use of off-stream habitats, variability across site.	Current monitoring programs conducted by MDBA and ARI include fish surveys in creek and wetland habitats within the site. Data collected to date has been from a short period of time (post 2007) and includes mostly drought years. An understanding of fish population dynamics in the site will improve over time with current monitoring.
Wetland birds	Quantitative data for waterbirds and nesting wetland birds.	Current monitoring programs conducted by MDBA and NCCMA include waterbird surveys. Continued, regular monitoring will improve understanding.
	Importance of the site for the endangered Australasian bittern	Include Barmah Forest in the Birds Australia National Bittern Surveys (BA 2011).

9. Monitoring

As a signatory to the Ramsar Convention, Australia has made a commitment to protect the ecological character of its Wetlands of International Importance. Under Part three of the EPBC Act a person must not take an action that has, will have or is likely to have a significant impact on the ecological character of a declared Ramsar wetland. While there is no explicit requirement for monitoring the site, a monitoring program is required in order to ascertain if the ecological character of the wetland site is being protected.

A comprehensive monitoring program is beyond the scope of an ECD. What is provided is an identification of monitoring needs required both to set baselines for critical components and processes and to assess against LACs. It should be noted that the focus of the monitoring recommended in an ECD is to assist with an assessment against LACs and determination of changes in ecological character. This monitoring is not designed as an early warning system whereby trends in data are assessed to detect changes in components and processes prior to a change in ecological character of the site. This should be included in the management plan for the site. The recommended monitoring to meet the obligations under the Ramsar Convention and the EPBC Act with respect to the Barmah Forest Ramsar site are provided in Table 31.

Table 31: Monitoring needs for the Barmah Forest Ramsar site

Parameter	Purpose	Indicator	Locations	Frequency	Priority
Hydrology (river flows)	Assessment against LAC	River flow	Murray River at Yarrawonga	Continuous	High
Hydrology (floodplain water regime)	Assessment against LAC	Extent of inundation	Entire site	Flood events	High
Water quality	Assessment of threat	Salinity; dissolved oxygen	Key wetlands	Flood events	Low
River red gum forests (extent)	Assessment against LAC	Extent	Entire site	Five yearly	Medium
River red gum forests (condition)	Assessment against LAC	Condition as per Cunningham et al. (2009) or similar	Entire site	Annual	High
Floodplain marshes (extent & composition)	Assessment against LAC	Extent and composition	Entire site	Annual	High
Wetland birds (colonial nesting)	Establishment of benchmarks & assessment against LAC	Species, counts, breeding activity	At identified breeding locations	Coincident with flood events	High
Wetland birds (general)	Establishment of benchmarks & assessment against LAC	Species, counts, breeding activity	At identified breeding locations	Coincident with flood events	Medium
Wetland birds (threatened species)	Establishment of benchmarks & assessment against LAC	Australasian bittern	Wetlands with emergent vegetation	Coincident with flood events	High
		Superb parrot	Known nesting locations	Annual	High
Fish (composition)	Assessment against LAC	Community composition.	Representative sample locations	Annual	Medium
Fish (abundance and spawning)	Establishment of benchmarks & assessment against LAC	Abundance and spawning activity	Representative sample locations	Annual	High

10. Communication and Education Messages

Under the Ramsar Convention a Program of Communication, Education, Participation and Awareness (CEPA) was established to help raise awareness of wetland values and functions. At the Conference of Contracting Parties in Korea in 2008, a resolution was made to continue the CEPA program in its third iteration for the next two triennia (2009 – 2015).

The vision of the Ramsar Convention's CEPA Program is: "People taking action for the wise use of wetlands." To achieve this vision, three guiding principles have been developed:

a) The CEPA Program offers tools to help people understand the values of wetlands so that they are motivated to become advocates for wetland conservation and wise use and may act to become involved in relevant policy formulation, planning and management.
b) The CEPA Program fosters the production of effective CEPA tools and expertise to engage major stakeholders' participation in the wise use of wetlands and to convey appropriate messages in order to promote the wise use principle throughout society.
c) The Ramsar Convention believes that CEPA should form a central part of implementing the Convention by each Contracting Party. Investment in CEPA will increase the number of informed advocates, actors and networks involved in wetland issues and build an informed decision-making and public constituency.

The Ramsar Convention encourages that communication, education, participation and awareness are used effectively at all levels, from local to international, to promote the value of wetlands. A comprehensive CEPA program for an individual Ramsar site is beyond the scope of an ECD.

There are a number of programs currently in place, which focus on communication, and education of wetland values in the Barmah Forest Ramsar site. Key CEPA messages for the site arising from this ECD, which should be promoted through these programs, include:

- The key role of floodplain hydrology at the site and the impacts of river regulation. The intrinsic value of the ecological character of the site and the need to maintain and conserve it. This would help promote understanding in the community of the need for environmental water allocations and the benefits they provide at Barmah.

- The role of purposeful and adaptive management of the site. The ecological character of the site is a product of a multitude of human activities and continues to be influenced by human activities both within and outside the site. It is likely that the ecological character of the site would decline if the site was not actively managed. Most notably the hydrology of the site depends on the purposeful operation of water management infrastructure to avoid adverse effects on wetland ecosystems. Fire and weed and pest animals also require direct management to avoid negative impacts. Greater public awareness of the need to actively manage the site would help to secure funding and promote understanding of the justification for management actions.

- Identification of threatened species (Australasian bittern, superb parrot, Murray cod, trout cod, silver perch, Mueller daisy and swamp-wallaby grass) and communication of their conservation value. This may help to minimise the number of threatened fish species taken.

- The Ramsar criteria that the site meets and how they contribute to the ecological character of the site and define its national and International value.

- The threats to the site, as outlined in Section 7 above, especially threats that may be monitored or managed through public awareness and behaviour (for example, recreational fishing, public use pressures, destructive wild fires).

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Appendix A: Methods

A.1 Approach

The method for compiling this ECD comprised of the following tasks:

Project Inception:
Consultant team leader Jennifer Hale met with the DSEWPaC project manager to confirm the scope of works and timelines as well as identifying relevant stakeholders that would be consulted.

Task 1: Review and compilation of available data
The consultant team undertook a review of the existing ECD for the site (DSE 2008) and new information available since the first ECD was developed in 2005.

Task 2: Stakeholder engagement and consultation
A Steering Committee was formed for the Barmah Forest Ramsar site ECD. This group was comprised of representatives of the following stakeholder groups with an interest in the ECD and management planning process:

- Leah Beesley; Department of Sustainability and Environment
- Tamara Boyd; Parks Victoria
- Lyndell Davis; Department of Sustainability, Environment, Population and Communities
- John Foster; Department of Sustainability, Environment, Population and Communities
- Janet Holmes; Department of Sustainability and Environment
- Richard Loyn; Department of Sustainability and Environment
- Shar Ramamurthy; Department of Sustainability and Environment
- Melanie Tranter; North Central Catchment Management Authority;
- Keith Ward; Goulburn-Broken Catchment Management Authority;
- Kane Weeks; Parks Victoria

Task 3: Development of a draft ECD
Consistent with the national guidance and framework (2008) the following steps were undertaken to describe the ecological character of the Barmah Forest Ramsar site:

1. Document introductory details – site details, purpose and legislation.
2. Describe the site - description in terms of: location, land tenure, Ramsar criteria, wetland types (using Ramsar classification).
3. Identify and describe the critical components, processes and services
4. Develop a conceptual model of the system - two types of models were developed for the system:
    - A series of control models that describe important aspects of the ecology of the site, including feedback loops. Aiding in the understanding of the system and its ecological functions.
    - A stressor model that highlights the threats and their effects on ecological components and processes.
5. Set Limits of Acceptable Change (LAC) – for each identified critical component, process and service.
6. Identify threats to the site – a summary of major threats was developed.
7. Describe changes to ecological character since the time of listing.
8. Summarise knowledge gaps
9. Identify site monitoring needs
10. Identify communication, education and public awareness messages.

Task 5 Finalising the ECD
The draft ECD was submitted to DSEWPaC, and a representative from DSE for review. Comments from agencies and stakeholders were incorporated to produce a revised ECD.

A.2 Consultant Team

Jennifer Hale

Jennifer has over twenty years experience in the water industry having started her career with the State Water Laboratory in Victoria. Jennifer is an aquatic ecologist with expertise in freshwater, estuarine and near-shore marine systems. She is qualified with a Bachelor of Science (Natural Resource Management) and a Masters of Business Administration. Jennifer is an aquatic ecologist with specialist fields of expertise including phytoplankton dynamics, aquatic macrophytes, sediment water interactions and nutrient dynamics. She has a broad understanding of the ecology of aquatic macrophytes, fish, waterbirds, macroinvertebrates and floodplain vegetation as well as geomorphic processes. She has a solid knowledge of the development of ecological character descriptions and has been involved in the development of ECDs for the Peel-Yalgorup, the Ord River Floodplain, Eighty-mile Beach, the Coorong and Lakes Alexandrina and Albert, Lake MacLeod, Elizabeth and Middleton Reefs, Ashmore Reef and the Coral Seas Ramsar sites.

Rhonda Butcher

Rhonda is considered an expert in wetland ecology and assessment. She has a BSc (hons) and a PhD in Wetland Ecology together with over twenty years of experience in the field of aquatic science. She has extensive experience in biological monitoring, biodiversity assessment, invertebrate ecology as well as wetland and river ecology having worked for CSIRO/Murray-Darling Freshwater Research Centre, Monash University/CRC for Freshwater Ecology, Museum of Victoria, Victorian EPA and the State Water Laboratories of Victoria. Rhonda has worked on numerous Ramsar related projects over the past eight years, including the first pilot studies into describing ecological character. She has subsequently co-authored, provided technical input, and peer reviewed a number of Ecological Character Descriptions. She project managed the preparation of Ramsar nomination documents for Piccaninnie Ponds Karst Wetlands in South Australia, which included preparation of the ECD, RIS and Ramsar Management Plan. Other Ramsar sites she has been involved with the development of ECD include Coongie Lakes, Banrock Station Wetland Complex, Coorong and Lakes Alexandrina and Albert, Lake MacLeod, Peel-Yalgorup, Eighty-mile Beach, Narran Lakes, The Dales and Hosnies Spring on Christmas Island. Rhonda is currently project managing the Ramsar Rolling Review developing a framework for reporting the status of ecological character at all 64 Ramsar sites in Australia.

Halina Kobryn

Dr Halina Kobryn has over fifteen years of experience in applications of GIS and remote sensing in environmental applications. She is a GIS and remote sensing expert, specialising in natural resource assessment. Dr Kobryn has a BSc in Physical Geography and Cartography, Graduate Diploma in Surveying and Mapping and a PhD which explored impacts of stormwater on an urban wetland and explored GIS methods for such applications. She has worked at a university as a lecturer for over 15 years and taught many subjects including GIS, remote sensing, environmental monitoring and management of aquatic systems. She has developed the first course in Australia (at a graduate level) on Environmental Monitoring. She has been involved in many research and consulting projects and her cv outlines the breadth of her expertise. She has also supervised over 20 research students (honours, Masters and PhD). She has worked in Indonesia, Malaysia (Sarawak) and East Timor on projects related to water quality and river health.

Jane Roberts

Jane Roberts is a well-respected plant ecologist, providing high-level technical expertise and broad on-ground experience in vegetation as it relates to water management, ecosystem functioning and assessment. Initially trained in wetland plant ecology, her interests and skills have expanded to include rivers and floodplains, forests and woodlands, landscape change and environmental history; she pioneered the use of oral history in river ecology in Australia. A decade as a research scientist with CSIRO in agricultural regions of western NSW engendered a fascination for lowland rivers and floodplains, a deep commitment to effective NRM and to the incorporation of sound science into management and policy. Since 2000, she has been based in Canberra where she works independently as an ecological consultant, typically as a specialist member of a team for large firms or consulting groups, where she is a valued contributor. Her clients range from government agencies, catchment authorities, research institutions to conservation organizations, and she specialises in lowland and regional areas in inland and south-eastern Australia. As well as undertaking her own projects, she sits on technical and advisory panels for projects undertaking research, complex monitoring programs and the development of state government policy or procedures.

Peter Cottingham

Peter Cottingham is a versatile and experienced facilitator and project manager, having worked in a diversity of technical and scientific environments over the past 25 years. He is currently the Principal of Peter Cottingham & Associates, undertaking a diverse range of projects for clients related to the management and rehabilitation of river and wetland systems across southeastern Australia. Prior to this, Peter was a senior Knowledge Broker with the Cooperative Research Centre for Freshwater Ecology and Leader of the River and Catchment Restoration program for the eWater CRC. Peter has led and facilitated numerous scientific panel deliberations, projects and workshops focusing on the management of river, lake and wetland across southeastern Australia. Example include key facilitation roles include projects on nutrient management in the Gippsland Lakes, the review of the MDBC Native Fish Strategy, the development of a fish information system for the MDB, wetland management priority for southeastern South Australia, and numerous scientific panels focused on environmental flow and drought management. Peter also led the development of a consistent monitoring and assessment framework from which to measure the performance of environmental flow releases. He has a proven track record in strategy and management plan development and communication at all levels of NRM organisations and across a broad range of stakeholder groups, as well as in project management and establishing and managing high-performing teams. Peter has exceptional skills as a knowledge broker and facilitator. He is very experienced in the preparation of technical and scientific reports, and in delivering presentations at conferences, seminars and workshops.

Appendix B: Waterbirds

Species listing:
Ma = Marine under the EPBC Act; Mi = Migratory under the EPBC Act; V = Vulnerable nationally or internationally; E = Endangered nationally or internationally; J = JAMBA; C= CAMBA; R = ROKAMBA, B = Bonn.

Species list compiled from DSE unpub., Birds Australia unpub. and Chesterfield et al. 1984.

Common Name	Species name	Breeding	Listing
Australasian bittern	*Botaurus poiciloptilus*	Yes	E (EPBC, IUCN)
Australasian grebe	*Tachybaptus novaehollandiae*	Yes	
Australasian shoveler	*Anas rhynchotis*		
Australian darter	*Anhinga novaehollandiae*	Yes	
Australian little bittern	*Ixobrychus dubius*		
Australian pelican	*Pelecanus conspicillatus*		Ma
Australian shelduck	*Tadorna tadornoides*	Yes	
Australian spotted crake	*Porzana fluminea*		
Australian white ibis	*Threskiornis molucca*	Yes	Ma
Australian wood duck	*Chenonetta jubata*	Yes	
Azure kingfisher	*Alcedo azurea*		
Ballion’s crake	*Porzana pusilla palustris*		Ma
Black swan	*Cygnus atratus*	Yes	
Black-fronted dotterel	*Elseyornis melanops*		
Black-tailed native-hen	*Tribonyx ventralis*		
Black-winged stilt	*Himantopus himantopus*		Ma
Blue-billed duck	*Oxyura australis*		
Brolga	*Grus rubicunda*	Yes	
Buff-banded rail	*Gallirallus philippensis*		Ma
Cattle egret	*Ardea ibis*		Ma, Mi, C, J
Clamorous reed-warbler	*Acrocephalus stentoreus*		Ma, Mi, B
Chestnut teal	*Anas castanea*		
Common greenshank	*Tringa nebularia*		Ma, Mi, B, C, J, R
Dusky moorhen	*Gallinula tenebrosa*	Yes	
Eastern great egret	*Ardea modesta*	Yes	Mi, C, J
Eurasian coot	*Fulica atra*	Yes	
Freckled duck	*Stictonetta naevosa*		
Glossy ibis	*Plegadis falcinellus*		Ma, Mi, B, C
Great cormorant	*Phalacrocorax carbo*	Yes	
Great crested grebe	*Podiceps cristatus*	Yes	
Grey teal	*Anas gracilis*	Yes	
Hardhead	*Aythya australis*	Yes	
Hoary-headed grebe	*Poliocephalus poliocephalus*	Yes	
Intermediate egret	*Ardea intermedia*	Yes	Ma
Latham's snipe	*Gallinago hardwickii*		Ma, Mi, B, C, J, R
Little black cormorant	*Phalacrocorax sulcirostris*	Yes	
Little egret	*Egretta garzetta*	Yes	Ma
Little pied cormorant	*Microcarbo melanoleucos*	Yes	
Masked lapwing	*Vanellus miles*		
Musk duck	*Biziura lobata*		Ma
Nankeen night-heron	*Nycticorax caledonicus*	Yes	Ma

Common Name	Species name	Breeding	Listing
Pacific black duck	*Anas superciliosa*	Yes	
Pied cormorant	*Phalacrocorax varius*	Yes	
Pink-eared duck	*Malacorhynchus membranaceus*		
Plumed whistling-duck	*Dendrocygna eytoni*		
Purple swamphen	*Porphyrio porphyrio*	Yes	Ma
Red-kneed dotterel	*Erythrogonys cinctus*		
Red-necked stint	*Calidris ruficollis*		Ma, Mi, B, C, J, R
Royal spoonbill	*Platalea regia*	Yes	
Sacred kingfisher	*Todiramphus sanctus*		Ma
Silver gull	*Chroicocephalus novaehollandiae*		Ma
Spotless crake	*Porzana tabuensis*		Ma
Straw-necked Ibis	*Threskiornis spinicollis*	Yes	Ma
Superb parrot	*Polytelis swainsonii*		V (EPBC, IUCN)
Swamp harrier	*Circus approximans*		Ma
Whiskered tern	*Chlidonias hybrida*	Yes	Ma
White-bellied sea eagle	*Haliaeetus leucogaster*	Yes	Ma, Mi, C
White-faced heron	*Egretta novaehollandiae*	Yes	
White-necked heron	*Ardea pacifica*	Yes	
Yellow-billed spoonbill	*Platalea flavipes*	Yes	

Appendix C: Aquatic mammals, reptiles and frogs

Aquatic mammals, reptiles and frogs species that have been recorded within the site since 1960.
Data from DSE (unpublished) and Ward (2001, 2002, 2004, 2006).

Habitat: M - Floodplain marshes; F = River red gum forest

Scientific Name	Common Name	Habitat
MAMMALS		
Hydromys chrysogaster	Water rat	M
Myotis macropus	Large-footed myotis	F
Ornithorhynchus anatinus	Platypus	M
AMPHIBIANS		
Crinia parinsignifera	Plains froglet	M
Crinia signifera	Common froglet	M
Crinea sloanei	Sloanes froglet	M
Limnodynastes fletcheri	Barking marsh frog	M
Limnodynastes dumerili	Pobblebonk	M
Limnodynastes tasmaniensis	Spotted marsh frog	M
Litoria peronii	Peron's tree frog	F
Neobatrachus sudelli	Common spadefoot	M
Pseudophryne bibronii	Brown Toadlet	M
REPTILES		
Macrochelodina expansa	Broad-shelled river turtle	M
Chelodina longicollis	Eastern long-necked tortoise	M
Emydura macquarii	Murray turtle	M
Eulamprus heatwolei	Yellow-bellied water skink	M

Appendix D: Fish predicted and recorded within the Ramsar site

Table indicates all fish species predicted to occur by Davies et al. 2008; last record / probability of occurrence is from King et al. 2007 and MDBC Native Fish Facts (http://www2.mdbc.gov.au/subs/fish-info/native_info/). Recently recorded equals a record since1998. Conservation status: E = endangered; V = vulnerable.

Common Name	**Scientific Name**	**Probability of occurrence**	**Conservation**	
			VIC	**EPBC**
Australian smelt	*Retropinna semoni*	Recently record		
Bony bream	*Nematalosa erebi*	Recently record		
Carp gudgeons	*Hypseleotris sp.*	Recently record		
Climbing galaxias	*Galaxias brevipinnis*	Recently record		
Dwarf flat-headed gudgeon	*Philypnodon macrostomus*	Not recorded in region since 1980.		
Flathead galaxias	*Galaxias rostratus*	No record – may occur		
Flathead gudgeon	*Philypnodon grandiceps*	Recent record		
Freshwater catfish	*Tandanus tandanus*	Recent record		
Golden perch	*Macquaria ambigua*	Recent record		
Macquarie perch	*Macquaria australasica*	Probably locally extinct, last record 1940s	V	E
Mountain galaxias	*Galaxias olidus*	Recent record		
Murray cod	*Maccullochella peelii*	Recent record		V
Murray hardyhead	*Craterocephalus fluviatilis*	Recent record	V	V
Murray –Darling rainbowfish	*Melanotaenia fluviatilis*	Recent record		
Purple-spotted gudgeon	*Mogurnda adspersa*	No record – likely locally extinct	E	
Olive perchlet	*Ambassis agassizii*	Probably locally extinct – last record 1960s		
River blackfish	*Gadopsis marmoratus*	Recent record		
Short-headed lamprey	*Mordacia mordax*	Recent record		
Silver perch	*Bidyanus bidyanus*	Recent record	V	
Southern pygmy perch	*Nannoperca australis*	Recent record		
Trout cod	*Maccullochella macquariensis*	Recent record	E	E
Unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	Recent record		